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Comparative study of two Soft Graph Concepts

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Abstract

In the present paper, the comparative study of theory of soft graph introduced in two different aspects by different authors is given. We derive some results by comparing tabular representation, adjacency and incidency matrix, radius and diameter, degree of a vertex with respect to soft graph etc.

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1. INTRODUCTION

Soft set theory[1] is a mathematical tool which was first proposed by D. Molodstov in 1999 which deals with uncertainities and free from the inadequacy of the parametrization tools. More operations on soft sets can be found in [2], Muhammad Irfan Ali [3] has introduced representation of graphs based on neighborhoods and soft sets. Connectedness of soft graph is discussed in [11]. Attribute reduction using multi soft sets and its applications is discussed in [6], [7] and application of normal parameter

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reduction of soft sets in decision making is given in [8]. In 2014, R. Thumbakara and B. George [12] has introduced a concept of soft graph and in 2016, Muhammad Akram and Saira Nawaz [4] has given one more definition of soft graph. In this paper we make the comparative study of the two different concept of soft graphs introduced by different authors.

2. PRELIMINARIES

Definition 2.1. Soft set[1]
Let U be an universe and E be a set of parameters. Let $P(U)$ denote the power set of U and A be a non-empty subset of E. A pair (F, A) is called a soft set over U, where F is a mapping given by $F : A \to P(U)$.
In other words, a soft set over U is a parameterized family of subsets of the universe U. For $\epsilon \in A,\ F(\epsilon)$ may be considered as the set of ϵ-elements of the soft set (F, A) or as the set of ϵ-approximate elements of the soft set.

Definition 2.2. Soft Graph[12]
Let $G = (V, E)$ be a simple connected graph, C be any non-empty subset of V and R is an arbitrary relation between elements of C and elements of V. i.e. $R \subseteq C \times V$. A set valued function $F : C \to P(U)$ can be defined as $F(x)$=$\{y \in V|xRy\}$. The pair (F, C) is called soft set over V.
Then (F, C) is said to be a soft graph of G if the subgraph induced by $F(x)$ is a connected subgraph of G for all $x \in C$.
In the rest of paper this definition of soft graph is written as soft graph-I and is denoted as (G, F, C).

There is another version of soft graph given as below.

Definition 2.3. Soft graph [12]
A 4-tuple $G^* = (G, S, T, A)$ is called a soft graph if it satisfies the following conditions,

1. $G = (V, E)$ is a simple graph.
2. A is non empty set of parameters.
3. (S, A) is a soft set over V.
4. (T, A) is soft set over E.
5. $(S(a), T(a))$ is a subgraph of $G\ \forall\ a \in A$.

The subgraph $(S(a), T(a))$ is denoted by $H(a)$ for convenience. A soft graph can also be represented by,

$$G^* = (G, S, T, A) = \{H(x), x \in A\}$$

In the rest of paper this definition of soft graph is written as Soft graph-II and is denoted as (G, S, T, A) or (G, H, A)

Definition 2.4. Tabular representation of soft graph[9]
Let $G = (V, E)$ be a simple connected graph where $V = \{v_1, v_2, ..., v_s\}$, $E = \{e_1, e_2, ..., e_j\}$. Let (F, A) be a soft graph of G for $A \subseteq V$ given by $A = \{v_{i1}, v_{i2}, ..., v_{im}\}$ and $F : A \to P(V)$. Then we can represent soft graph in tabular form as

A/V	v_1	v_2	...	v_s
v_{i1}	(v_{i1}, v_1)	(v_{i1}, v_2)	...	(v_{i1}, v_s)
v_{i2}	(v_{i2}, v_1)	(v_{i2}, v_2)	...	(v_{i2}, v_s)
...	...	...	...	...
v_{im}	(v_{im}, v_1)	(v_{im}, v_2)	...	(v_{im}, v_s)

where

$$(v_{ik}, v_r) = \begin{cases} 1, & v_r \in F(v_{ik}); \\ 0, & otherwise \end{cases}$$

for all $k = 1, 2, ...m$ and $r = 1, 2, ...s$
And

A/E	e_1	e_2	....	e_j
v_{i1}	(v_{i1}, e_1)	(v_{i1}, e_2)	...	(v_{i1}, e_j)
v_{i2}	(v_{i2}, e_1)	(v_{i2}, e_2)	...	(v_{i2}, e_j)
....	...	...	...	...
v_{im}	(v_{im}, e_1)	(v_{im}, e_2)	...	(v_{im}, e_j)

where

$$(v_{ik}, e_p) = \begin{cases} 1, & e_p \in F(v_{ik}); \\ 0, & otherwise \end{cases}$$

for all $k = 1, 2, ...m$ and $p = 1, 2, ...j$

Definition 2.5. Adjacent vertices in soft graph ([10])
Let $G = (V, E)$ be a simple connected graph such that $C \subseteq V$, a set valued function $S : C \rightarrow \mathcal{P}(V)$ is defined as $S(x)$=$\{y \in V|d(x,y) \leq 1\}$ and a set valued function $T : C \rightarrow \mathcal{P}(E)$ is defined as $T(x)$=$\{xu \in E|u \in S(x)\}$. Thus (F, C) be a soft graph of G where $F(x) = (S(x), T(x))$. Any two vertices v_i and v_j in V are said to be adjacent with respect to soft graph (F, C) if,

1. $\{v_i, v_j\} \subseteq F(v_i) \cap F(v_j)$; if $v_i, v_j \in A$ and $i \neq j$

2. $v_i \in F(v_j)$; if $v_i \notin A$ and $v_j \in A$.

If both the vertices v_i, v_j are not in C then are said to be not adjacent.

Definition 2.6. Adjacency matrix of a soft graph ([10])
Let $G = (V, E)$ be a simple connected graph, $C \subseteq V$ and (F, C) be a soft graph of G where set valued function $S : C \rightarrow \mathcal{P}(V)$ is defined as $S(x)$=$\{y \in V|d(x,y) \leq 1\}$, a set valued function $T : C \rightarrow \mathcal{P}(E)$ is defined as $T(x)$=$\{xu \in E|u \in S(x)\}$ and $F(x) = (S(x), T(x))$. Let $A = \bigcup_{v \in C} S(v) = \{v_1, v_2, ...v_n\}$. The adjacency matrix of the soft graph (F, C) is a square matrix of order $n \times n$ denoted as $\mathcal{A}(F, C) = (c_{ij})$, $(i, j)^{th}$ entry c_{ij} is given by

$$c_{ij} = \begin{cases} 1, & \text{if } v_i \text{ is adjacent to } v_j \\ 0, & \text{if } v_i \text{ is not adjacent to } v_j, \;\; i, j = 1, 2, 3, ..., n. \end{cases}$$

Definition 2.7. Incidence matrix of a soft graph ([10])
Let $G = (V, E)$ be a simple connected graph, $C \subseteq V$ and (F, C) be a soft graph of G where set valued function $S : C \rightarrow \mathcal{P}(V)$ is defined as $S(x)$=$\{y \in V|d(x,y) \leq 1\}$, a set valued function $T : C \rightarrow \mathcal{P}(E)$ is defined as $T(x)$=$\{xu \in E|u \in S(x)\}$ and $F(x) = (S(x), T(x))$. Let $A = \bigcup_{v \in C} S(v) = \{v_1, v_2, ...v_n\}$ and $B = \bigcup_{v \in C} T(v) = \{e_1, e_2, ...e_m\}$. The incidence matrix of a soft graph (F, C) is a matrix $\mathcal{I}(F, C) = (b_{ij})$ of order $n \times m$ where $(i, j)^{th}$ entry b_{ij} is given by

$$b_{ij} = \begin{cases} 1, & \text{if } e_j \in F(v_i) \\ 0, & \text{otherwise} \end{cases}$$

Definition 2.8. Radius of Soft Graph ([9])
Let $G = (V, E)$ be a simple connected graph with $V = \{v_1, v_2, ..., v_n\}$ and (F, A) be a soft graph of G where $A = \{v_{i1}, v_{i2}, ..., v_{im}\}$. Then the radius of a soft graph is defined as $r(F, A) = max\{r(F(v_{ir}))/1 \leq r \leq m)\}$ where $r(F(v_{ir}))$ is the radius of subgraph $F(v_{ir})$.

Definition 2.9. Diameter of Soft Graph([9])
Let $G = (V, E)$ be a simple connected graph with $V = \{v_1, v_2, ..., v_n\}$ and (F, A) be a soft graph of G where $A = \{v_{i1}, v_{i2}, ..., v_{im}\}$. Then the diameter of a soft graph is defined as $d(F, A) = max\{d(F(v_{ir}))/1 \leq r \leq m)\}$ where $d(F(v_{ir}))$ is the diameter of subgraph $F(v_{ir})$.

Definition 2.10. Degree of a vertex in soft graph ([9])
Let $G = (V, E)$ be a simple connected graph and (F, A) be a soft graph of G. Then degree of a vertex $v \in V$ with respect to (F, A) is defined as $max\{deg_{F(v_i)}(v), \forall v_i \in A\}$ and is denoted by $deg_{(F,A)}(v)$.

3. COMPARATIVE STUDY BETWEEN SOFT GRAPH-I AND SOFT GRAPH-II

In this section, our approach is to make comparative study of soft graph-I and soft graph-II and derive some results accordingly by verifying some properties such as tabular representation, degree of vertex, radius, diameter, adjacency and incidence matrix of soft graph etc.

Remark 3.1. If given graph is soft graph-I then it is also a soft graph-II, but if given graph is soft graph-II then it is not necessarily soft graph-I, since in soft graph-I, connectedness of subgraphs is essential but in soft graph-II, connectedness of subgraphs is not essential.

Theorem 3.2. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq k\}$ where k is any positive integer and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq k\}$ and T is defined as $T(x) = \{uv \in E : \{u, v\} \in S(x)\}$, then both soft graphs (G, F, A) and (G, S, T, A) are identical.*

Proof. Let $G = (V, E)$ be simple connected graph.
For $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq k\}$. Here every component $F(x)$ is an induced subgraph of G.
i.e. $F(x)$ induced subgraph is the graph whose vertex set is $F(x)$ and whose edge set consists of all of the edges in $G = (V, E)$ that have both endpoints in $F(x)$.
Also, (G, S, T, A) is a soft graph-II, where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq k\}$ and T is defined as $T(x) = \{uv \in E : \{u, v\} \in S(x)\}$. We write for convenience,

$$(G, S, T, A) = \{H(x), x \in A\}$$

The component $H(x)$ contains all edges of G which are available in every pair of vertices in $S(x)$.
i.e. $H(x)$ is an induced subgraph by $S(x)$ in G.
Thus,

$$F(x) = H(x), \forall\, x \in A \tag{1}$$

Hence both soft graphs (G, F, A) and (G, S, T, A) are identical. □

Theorem 3.3. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : \; u \in S(x)\}$, then (G, S, T, A) is soft subgraph of (G, F, A).*

Proof. Let $G = (V, E)$ be simple connected graph.
For $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$. Here every component $F(x)$ is an induced subgraph of G.
i.e. $F(x)$ induced subgraph is the graph whose vertex set is $F(x)$ and whose edge set consists of all of the edges in $G = (V, E)$ that have both endpoints in $F(x)$.
Also, (G, S, T, A) is a soft graph-II, where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : \; u \in S(x)\}$. Here $T(x)$ collects edges of graph G that are incident on x.
We write for convenience,

$$(G, S, T, A) = \{H(x), x \in A\}$$

Thus,

$$F(x) \subseteq H(x), \forall\, x \in A \tag{2}$$

Hence, (G, S, T, A) is soft subgraph of (G, F, A). □

Theorem 3.4. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{uv \in E : \{u, v\} \in S(x)\}$, then tabular representation of both soft graphs is same.*

Proof. Let $G = (V, E)$ be simple connected graph.
(G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ for $A \subseteq V$.
(G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{uv \in E : \{u, v\} \in S(x)\}$ for $A \subseteq V$.

Here, vertex set of $F(x)$= $S(x)$, $\forall\, x\, \in A$
i.e. vertex set of every component of both soft graphs is same.
Hence tabular representation of soft graph with respect to vertex set is same.
Likewise, edge set of every component of both soft graphs is also same since every component is a subgraph induced by vertex sets $F(x)$ and $S(x)$ where these vertex sets are same.
Thus, tabular representation of soft graph with respect to edge set also same.
Hence tabular representation of both soft graphs (G, F, A) and (G, S, T, A) is same. □

Theorem 3.5. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : u \in S(x)\}$, then tabular representation of soft graph with respect to vertex set is same but tabular representation of soft graph with respect to edge set need not be same.*

Proof. Let $G = (V, E)$ be simple connected graph.
(G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ for $A \subseteq V$.
(G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : u \in S(x)\}$ for $A \subseteq V$.
Here, vertex set of $F(x)$= $S(x)$, $\forall\, x\, \in A$
i.e. vertex set of every component of both soft graphs is same.
Hence tabular representation of soft graph with respect to vertex set is same.
But, edge set of every component of both soft graphs is not same, since $T(x)$ contains only those edges of G which are incident on x and subgraph induced by $F(x)$ contains those edges of G which are available in every pair of vertices in $S(x)$.

$$\text{i.e. } T(x) \subseteq \text{edge set of } F(x),\ \forall\, x\, \in A$$

Thus, tabular representation of soft graph with respect to edge set is need not be same. □

Theorem 3.6. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : u \in S(x)\}$, then adjacency matrix and incidence matrix of both soft graphs are not same.*

Proof. To justify this, consider the following example.
Here $G = (V, E)$ is a simple connected graph, for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$.

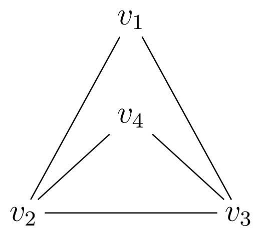

Figure 1: G

Take $A = \{v_1, v_3\}$ then, $F(v_1) = \{v_1, v_2, v_3\}$ and $F(v_3) = \{v_1, v_2, v_3, v_4\}$.

The adjacency matrix of soft graph (G, F, A) is given by,

$$\mathcal{A}(G, F, A) = \begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{array} \begin{array}{c} \begin{array}{cccc} v_1 & v_2 & v_3 & v_4 \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{pmatrix} \end{array}$$

The incidence matrix of soft graph (G, F, A) is given by,

$$\mathcal{I}(G, F, A) = \begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{array} \begin{array}{c} \begin{array}{ccccc} v_1v_2 & v_1v_3 & v_2v_3 & v_2v_4 & v_3v_4 \end{array} \\ \begin{pmatrix} 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \end{array}$$

Now, (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : u \in S(x)\}$.
Here take $A = \{v_1, v_3\}$ then, $S(v_1) = \{v_1, v_2, v_3\}$, $S(v_3) = \{v_1, v_2, v_3, v_4\}$, $T(v_1) = \{e_1, e_2, e_5\}$ and $T(v_3) = \{e_1, e_2, e_3, e_4, e_5\}$
We write for convenience,

$$(G, S, T, A) = \{H(x), x \in A\}$$

The adjacency matrix of soft graph (G, S, T, A) is given by,

$$\mathcal{A}(G,S,T,A) = \begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{array} \begin{array}{c} \begin{array}{cccc} v_1 & v_2 & v_3 & v_4 \end{array} \\ \begin{pmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \end{array}$$

The incidence matrix of soft graph (G, S, T, A) is given by,

$$\mathcal{I}(G,F,A) = \begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{array} \begin{array}{c} \begin{array}{cccc} v_1v_2 & v_1v_3 & v_2v_3 & v_3v_4 \end{array} \\ \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

Thus, adjacency matrix and incidence matrix of both soft graphs are not same. □

Theorem 3.7. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq 1\}$ and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq 1\}$ and T is defined as $T(x) = \{xu \in E : u \in S(x)\}$, then degree of $v \in V$ with respect to (G, S, T, A) is less than or equal to degree of $v \in V$ with respect to (G, F, A).*

Proof. As proved in above theorem———, (G, S, T, A) is a soft subgraph of (G, F, A). i.e.

$$H(v_i) \subseteq F(v_i), \forall\, v_i \in A \tag{3}$$

where for convenience,

$$(G, S, T, A) = \{H(x), x \in A\}$$

By definition, degree of a vertex $v \in V$ with respect to (G, F, A) is defined as $max\{deg_{F(v_i)}(v), \forall v_i \in A\}$ and is denoted by $deg_{(G,F,A)}(v)$.
Also, degree of a vertex $v \in V$ with respect to (G, S, T, A) is defined as $max\{deg_{H(v_i)}(v), \forall v_i \in A\}$ and is denoted by $deg_{(G,S,T,A)}(v)$.
Thus,

$$deg_{H(v_i)}(v) \leq deg_{F(v_i)}(v), \forall v_i \in A$$

Hence, degree of $v \in V$ with respect to (G, S, T, A) is less than or equal to degree of $v \in V$ with respect to (G, F, A).

□

Theorem 3.8. *Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq k\}$ (k is a positive integer)and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq k\}$ and T is defined as $T(x) = \{xu \in E : u \in S(x)\}$, then radius of soft graph (G, S, T, A) is less than or equal to radius of soft graph (G, F, A).*

Proof. As proved in above theorem———, (G, S, T, A) is soft subgraph (G, F, A).
i.e. $H(x) \subseteq F(x), \forall x \in A$ where $H(x) = (S(x), T(x))$ □

Theorem 3.9. *Union of two soft graph-II is soft graph-II.*

Proof. Let $G = (V, E)$ be simple connected graph.
For $A \subseteq V$, (G, S_1, T_1, A) be a soft graph-II of G,
where $S_1(x)$=$\{y \in V : xRy\}$ and $T_1(x) = \{uv \in E : \{u, v\} \in S(x)\}$ and For $B \subseteq V$ (G, S_2, T_2, B) be a soft graph-II of G,
where $S_2(x)$=$\{y \in V : xRy\}$ and $T_2(x) = \{uv \in E : \{u, v\} \in S(x)\}$
Now for convenience we write,

$$(G, S_1, T_1, A) = \{H_1(x), x \in A\}$$

and

$$(G, S_2, T_2, B) = \{H_2(x), x \in B\}$$

Union of two soft graphs is union of corresponding components of both soft graph.
But union of components of both soft graph by definition soft graph-II is a subgraph of G.
Hence, union of two soft graph-II is soft graph-II. □

Theorem 3.10. *Product of two soft graph-II is soft graph-II.*

Remark 3.11. Let $G = (V, E)$ be simple connected graph. If for $A \subseteq V$, (G, F, A) is a soft graph-I where F is defined as $F(x)$=$\{z \in V : d(x, z) \leq k\}$ (k is a positive integer) and (G, S, T, A) is a soft graph-II , where S is defined as $S(x)$=$\{y \in V : d(x, y) \leq k\}$ and T is defined as $T(x) = \{uv \in E : \{u, v\} \in S(x)\}$, then

1. Adjacency and incidence matrix of both soft graphs are identical.
2. Degree of $v \in V$ with respect to (G, F, A) is equal to degree of $v \in V$ with respect to (G, S, T, A).
3. Radius of soft graph (G, S, T, A) is equal to radius of soft graph (G, F, A).
4. Diameter of soft graph (G, S, T, A) is equal to diameter of soft graph (G, F, A).

4. CONCLUSION

Graphs are one of the prime objects of study in discrete mathematics. In this paper we have put together two different aspects of soft graphs and given the comparative study between them.

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