Metric Dimension in fuzzy (neutrsophic) Graphs-II

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Abstract

In this study, the term dimension is introduced on fuzzy (neutrsophic) graphs. The classes of these specific graphs are chosen to obtain some results based on dimension. The types of crisp notions and fuzzy (neutrsophic) notions are used to make sense about the material of this study and the outline of this study uses some new notions which are crisp and fuzzy (neutrsophic).

Keywords: fuzzy (neutrsophic) Graphs, Neutrosophic Graphs, Dimension
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1   Background

To clarify about the definitions, I use some examples and in this way, exemplifying has key role to make sense about the definitions and to introduce new ways to use on these models in the terms of new notions. The concept of complete is used to classify specific graph in every environment. To differentiate, I use an adjective or prefix in every definition. Two adjectives "fuzzy" and "neutrosophic" are used to distinguish every graph or classes of graph or any notion on them.

$G : (V, E)$ is called a **crisp graph** where V is a set of objects and E is a subset of $V \times V$ such that this subset is symmetric. A crisp graph $G : (V, E)$ is called a **fuzzy graph** $G : (\sigma, \mu)$ where $\sigma : V \to [0, 1]$ and $\mu : E \to [0, 1]$ such that $\mu(xy) \leq \sigma(x) \wedge \sigma(y)$ for all $xy \in E$. A crisp graph $G : (V, E)$ is called a **neutrosophic graph** $G : (\sigma, \mu)$ where $\sigma = (\sigma_1, \sigma_2, \sigma_3) : V \to [0, 1]$ and $\mu = (\mu_1, \mu_2.\mu_3) : E \to [0, 1]$ such that $\mu(xy) \leq \sigma(x) \wedge \sigma(y)$ for all $xy \in E$. A crisp graph $G : (V, E)$ is called a **crisp complete** where $\forall x \in V, \ \forall y \in V, \ xy \in E$. A fuzzy graph $G : (\sigma, \mu)$ is called **fuzzy complete** where it's complete and $\mu(xy) = \sigma(x) \wedge \sigma(y)$ for all $xy \in E$. A neutrosophic graph $G : (\sigma, \mu)$ is called a **neutrosophic complete** where it's complete and $\mu(xy) = \sigma(x) \wedge \sigma(y)$ for all $xy \in E$. A crisp graph $G : (V, E)$ is called a **crisp strong**. A fuzzy graph $G : (\sigma, \mu)$ is called **fuzzy strong** where $\mu(xy) = \sigma(x) \wedge \sigma(y)$ for all $xy \in E$. A neutrosophic graph $G : (\sigma, \mu)$ is called a **neutrosophic strong** where $\mu(xy) = \sigma(x) \wedge \sigma(y)$ for all $xy \in E$. A distinct sequence of vertices $v_0, v_1, \cdots, v_n$ in a crisp graph $G : (V, E)$ is called **crisp path** with length n from v_0 to v_n where $v_i v_{i+1} \in E, \ i = 0, 1, \cdots, n - 1$. If one edge is incident to a vertex, the vertex is called **leaf**. A path $v_0, v_1, \cdots, v_n$ is called **fuzzy path** where $\mu(v_i v_{i+1}) > 0, \ i = 0, 1, \cdots, n - 1$. A path $v_0, v_1, \cdots, v_n$ is called **neutrosophic path** where $\mu(v_i v_{i+1}) > 0, \ i = 0, 1, \cdots, n - 1$. A path $v_0, v_1, \cdots, v_n$ with exception of v_0 and

v_n in a crisp graph $G : (V, E)$ is called **crisp cycle** with length n for v_0 where $v_0 = v_n$. A cycle $v_0, v_1, \cdots, v_0$ is called **fuzzy cycle** where there are two edges xy and uv such that $\mu(xy) = \mu(uv) = \bigwedge_{i=0,1,\cdots,n-1} \mu(v_i v_{i+1})$. A cycle $v_0, v_1, \cdots, v_0$ is called **neutrosophic cycle** where there are two edges xy and uv such that $\mu(xy) = \mu(uv) = \bigwedge_{i=0,1,\cdots,n-1} \mu(v_i v_{i+1})$. A set is **n-set** if its cardinality is n. A **fuzzy**

Table 1. Crisp-fying, Fuzzy-fying and Neutrosophic-fying

Crisp Graphs	Fuzzy Graphs	Neutrosophic Graphs	
Crisp Complete	Fuzzy Complete	Neutrosophic Complete	
Crisp Strong	Fuzzy Strong	Neutrosophic Strong	
Crisp Path	Fuzzy Path	Neutrosophic Path	
Crisp Cycle	Fuzzy Cycle	Neutrosophic Cycle	

vertex set is the subset of vertex set of (neutrsophic) fuzzy graph such that the values of these vertices are considered. A **fuzzy edge set** is the subset of edge set of (neutrsophic) fuzzy graph such that the values of these edges are considered. Let $\mathcal{G}$ be a family of fuzzy graphs or neutrosophic graphs. This family have **fuzzy (neutrsophic) common** vertex set if all graphs have same vertex set and its values but edges set is subset of fuzzy edge set. A (neutrsophic) fuzzy graph is called **fixed-edge fuzzy (neutrsophic) graph** if all edges have same values. A (neutrsophic) fuzzy graph is called **fixed-vertex fuzzy (neutrsophic) graph** if all vertices have same values. A couple of vertices x and y is called **crisp twin** vertices if either $N(x) = N(y)$ or $N[x] = N[y]$ where $\forall x \in V, \ N(x) = \{y| \ xy \in E\}, \ N[x] = N(x) \cup \{x\}$. Two vertices t and t' are called **fuzzy (neutrsophic) twin** vertices if $N(t) = N(t')$ and $\mu(ts) = \mu(t's)$, for all $s \in N(t) = N(t')$. For using material look at [1–15].

Table 2. Crisp-fying, Fuzzy-fying and Neutrosophic-fying

| Crisp Vertex Set	Fuzzy Vertex Set	Neutrosophic Vertex Set	
Crisp Edge Set	Fuzzy Edge Set	Neutrosophic Edge Set	
Crisp Common	Fuzzy Common	Neutrosophic Common	
Crisp Fixed-edge	Fuzzy Fixed-edge	Neutrosophic Fixed-edge	
Crisp Fixed-vertex	Fuzzy Fixed-vertex	Neutrosophic Fixed-vertex	
Crisp Twin-vertex	Fuzzy Twin	Neutrosophic Twin	

2 Definitions

We use the notion of vertex in fuzzy (neutrsophic) graphs to define new notions which state the relation amid vertices. In this way, the set of vertices are distinguished by another set of vertices.

Definition 2.1. Let $G = (V, \sigma, \mu)$ be a fuzzy (neutrsophic) graph. A vertex m *fuzzy (neutrsophic)-resolves* vertices f_1 and f_2 if $d(m, f_1) \neq d(m, f_2)$. A set M is *fuzzy (neutrsophic) resolving set* if for every couple of vertices $f_1, f_2 \in V \setminus M$, there's a vertex $m \in M$ such that m fuzzy (neutrsophic)-resolves f_1 and f_2. $|M|$ is called *fuzzy (neutrsophic) metric number* of G and $\min_M \Sigma_{m \in M} \sigma(m)$ is called *fuzzy (neutrsophic) metric dimension* of G and if fuzzy (neutrsophic) metric number of set M equals fuzzy (neutrsophic) metric dimension, then M is called *fuzzy (neutrsophic) metric set* of G.

Example 2.2. Let G be a fuzzy (neutrsophic) graph as figure (1). By applying Table (3), the 1-set is explored which its cardinality is minimum. $\{f_6\}$ and $\{f_4\}$ are 1-set which has minimum cardinality amid all sets of vertices but $\{f_4\}$ isn't fuzzy (neutrsophic) resolving set and $\{f_6\}$ is fuzzy (neutrsophic) resolving set. Thus there's no

fuzzy (neutrsophic) metric set but $\{f_6\}$. f_6 fuzzy (neutrsophic)-resolves all given couple
of vertices. Therefore one is fuzzy (neutrsophic) metric number of G and 0.13 is fuzzy
(neutrsophic) metric dimension of G. By using Table (3), f_4 doesn't fuzzy
(neutrsophic)-resolve f_2 and f_6. f_4 doesn't fuzzy (neutrsophic)-resolve f_1 and f_5, too.
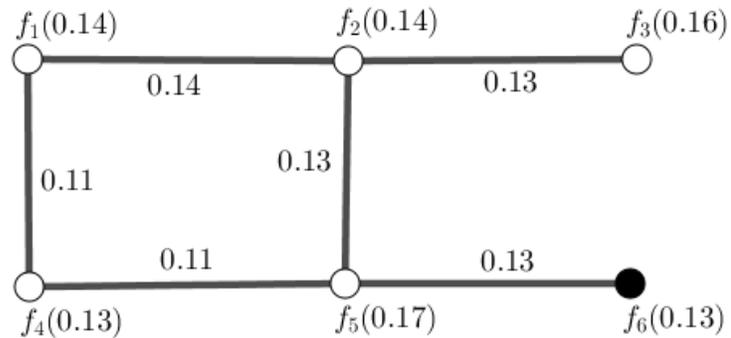
Figure 1. Black vertex $\{f_6\}$ is only fuzzy (neutrsophic) metric set amid all sets of
vertices for fuzzy (neutrsophic) graph G.

Table 3. Distances of Vertices from sets of vertices $\{f_6\}$ and $\{f_4\}$ in fuzzy (neutrsophic)
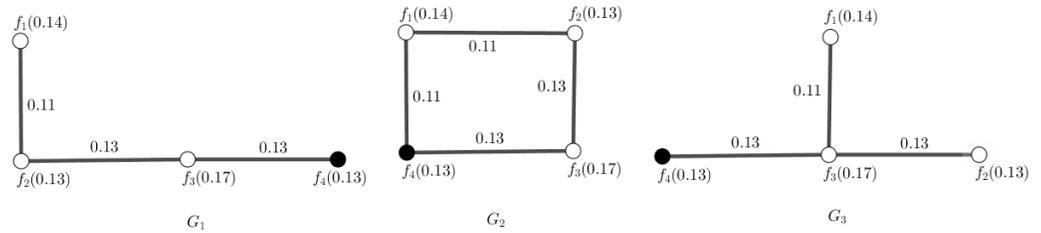Graph G.

Vertices	f_1	f_2	f_3	f_4	f_5	f_6
f_6	0.22	0.26	0.39	0.24	0.13	0
Vertices	f_1	f_2	f_3	f_4	f_5	f_6
f_4	0.11	0.24	0.37	0	0.11	0.24

Definition 2.3. Consider $\mathcal{G}$ as a family of fuzzy (neutrsophic) graphs on a common
vertex set V. A vertex m *simultaneously fuzzy (neutrsophic)-resolves* vertices f_1 and f_2
if $d_G(m, f_1) \neq d_G(m, f_2)$, for all $G \in \mathcal{G}$. A set M is *simultaneously fuzzy (neutrsophic)*
resolving set if for every couple of vertices $f_1, f_2 \in V \setminus M$, there's a vertex $m \in M$ such
that m resolves f_1 and f_2, for all $G \in \mathcal{G}$. $|M|$ is called *simultaneously fuzzy*
(neutrsophic) metric number of $\mathcal{G}$ and $\min \sigma_{m \in V} \sigma(m)$ is called *simultaneously fuzzy*
(neutrsophic) metric dimension of $\mathcal{G}$ and if the simultaneously fuzzy (neutrsophic)
cardinality of set M equals simultaneously fuzzy (neutrsophic) metric dimension, then
M is called *simultaneously fuzzy (neutrsophic) metric set* of $\mathcal{G}$.

Example 2.4. Let $\mathcal{G} = \{G_1, G_2, G_3\}$ be a collection of fuzzy (neutrsophic) graphs with
common fuzzy (neutrsophic) vertex set and a subset of fuzzy (neutrsophic) edge set as
figure (2). By applying Table (4), the 1-set is explored which its cardinality is minimum.
$\{f_2\}$ and $\{f_4\}$ are 1-set which has minimum cardinality amid all sets of vertices. $\{f_4\}$ is
as fuzzy (neutrsophic) resolving set as $\{f_6\}$ is. Thus there's no fuzzy (neutrsophic)
metric set but $\{f_4\}$ and $\{f_6\}$. f_6 as fuzzy (neutrsophic)-resolves all given couple of
vertices as f_4. Therefore one is fuzzy (neutrsophic) metric number of $\mathcal{G}$ and 0.13 is fuzzy
(neutrsophic) metric dimension of $\mathcal{G}$. By using Table (4), f_4 fuzzy (neutrsophic)-resolves
all given couple of vertices.

3   General Relationships

Proposition 3.1. *Let G be a fuzzy (neutrsophic) path. Then every leaf is fuzzy*
(neutrsophic) resolving set.

Figure 2. Black vertex $\{f_4\}$ and the set of vertices $\{f_2\}$ are simultaneously fuzzy (neutrsophic) metric set amid all sets of vertices for family of fuzzy (neutrsophic) graphs $\mathcal{G}$.

Table 4. Distances of Vertices from set of vertices $\{f_6\}$ in Family of fuzzy (neutrsophic) Graphs $\mathcal{G}$.

Vertices of G_1	f_1	f_2	f_3	f_4
f_4	0.37	0.26	0.13	0
Vertices of G_2	f_1	f_2	f_3	f_4
f_4	0.11	0.22	0.13	0
Vertices of G_3	f_1	f_2	f_3	f_4
f_4	0.24	0.26	0.13	0

Proof. Let l be a leaf. For every given a couple of vertices f_i and f_j, we get $d(l, f_i) \neq d(l, f_j)$. Since if we reassign indexes to vertices such that every vertex f_i and l have i vertices amid themselves, then $d(l, f_i) = \Sigma_{j \leq i} \mu(f_j f_i) \leq i$. Thus $j \leq i$ implies

$$\Sigma_{t \leq j} \mu(f_t f_j) + \Sigma_{j \leq s \leq i} \mu(f_s f_i) > \Sigma_{j \leq i} \mu(f f_i) \equiv d(l, f_j) + c = d(l, f_i) \equiv d(l, f_j) < d(l, f_i).$$

Therefore, by $d(l, f_j) < d(l, f_i)$, we get $d(l, f_i) \neq d(l, f_j)$. f_i and f_j are arbitrary so l fuzzy (neutrsophic)-resolves any given couple of vertices f_i and f_j which implies $\{l\}$ is a fuzzy (neutrsophic) resolving set. □

Corollary 3.2. *Let G be a fixed-edge fuzzy (neutrsophic) path. Then every leaf is fuzzy (neutrsophic) resolving set.*

Proof. Let l be a leaf. For every given couple of vertices, f_i and f_j, we get $d(l, f_i) = ci \neq d(l, f_j) = cj$. It implies l fuzzy (neutrsophic)-resolves any given couple of vertices f_i and f_j which implies $\{l\}$ is a fuzzy (neutrsophic) resolving set. □

Corollary 3.3. *Let G be a fixed-vertex fuzzy (neutrsophic) path. Then every leaf is fuzzy (neutrsophic) metric set, fuzzy (neutrsophic) metric number is one and fuzzy (neutrsophic) metric dimension is c where $c = \sigma(f)$, $f \in V$.*

Proof. By Proposition (3.1), every leaf is fuzzy (neutrsophic) resolving set. By $c = \sigma(f)$, $\forall f \in V$, every leaf is fuzzy (neutrsophic) metric set, fuzzy (neutrsophic) metric number is one and fuzzy (neutrsophic) metric dimension is c. □

Proposition 3.4. *Let G be a fuzzy (neutrsophic) path. Then a set including every couple of vertices is fuzzy (neutrsophic) resolving set.*

Proof. Let f and f' be a couple of vertices. For every given a couple of vertices f_i and f_j, we get either $d(f, f_i) \neq d(f, f_j)$ or $d(f', f_i) \neq d(f', f_j)$. □

Corollary 3.5. *Let G be a fixed-edge fuzzy (neutrsophic) path. Then every set containing couple of vertices is fuzzy (neutrsophic) resolving set.*

Proof. Consider G is a fuzzy (neutrsophic) path. Thus by Proposition (3.4), every set containing couple of vertices is fuzzy (neutrsophic) resolving set. So it holds for any given fixed-edge path fuzzy (neutrsophic) graph. □

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Proposition 3.6. *Let G be a fuzzy (neutrsophic) graph. An $(k-1)$-set from an k-set of fuzzy (neutrsophic) twin vertices is subset of a fuzzy (neutrsophic) resolving set.*

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Proof. If t and t' are fuzzy (neutrsophic) twin vertices, then $N(t) = N(t')$ and $\mu(ts) = \mu(t's)$, for all $s \in N(t) = N(t')$. □

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Corollary 3.7. *Let G be a fuzzy (neutrsophic) graph. The number of fuzzy (neutrsophic) twin vertices is $n-1$. Then fuzzy (neutrsophic) metric number is $n-2$.*

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Proof. Let f and f' be two vertices. By supposition, the cardinality of set of fuzzy (neutrsophic) twin vertices is $n-2$. Thus there are two cases. If both are fuzzy (neutrsophic) twin vertices, then $N(f) = N(f')$ and $\mu(fs) = \mu(f's')$, $\forall s \in N(f)$, $\forall s' \in N(f')$. It implies $d(f,t) = d(f,t)$ for all $t \in V$. Thus suppose if not, then let f be a vertex which isn't fuzzy (neutrsophic) twin vertices with any given vertex and let f' be a vertex which is fuzzy (neutrsophic) twin vertices with any given vertex but not f'. By supposition, it's possible and this is only case. Therefore, any given distinct vertex fuzzy (neutrsophic)-resolves f and f'. Then $V \setminus \{f, f'\}$ is fuzzy (neutrsophic) resolving set. It implies fuzzy (neutrsophic) metric number is $n-2$. □

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Corollary 3.8. *Let G be a fuzzy (neutrsophic) graph. The number of fuzzy (neutrsophic) twin vertices is n. Then G is fixed-edge fuzzy (neutrsophic) graph.*

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Proof. Suppose f and f' are two given edges. By supposition, every couple of vertices are fuzzy (neutrsophic) twin vertices. It implies $\mu(f) = \mu(f')$. f and f' are arbitrary so every couple of edges have same values. It induces G is fixed-edge fuzzy (neutrsophic) graph. □

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Corollary 3.9. *Let G be a fixed-vertex fuzzy (neutrsophic) graph. The number of fuzzy (neutrsophic) twin vertices is $n-1$. Then fuzzy (neutrsophic) metric number is $n-2$, fuzzy (neutrsophic) metric dimension is $(n-2)\sigma(m)$ where m is fuzzy (neutrsophic) twin vertex with a vertex. Every $(n-2)$-set including fuzzy (neutrsophic) twin vertices is fuzzy (neutrsophic) metric set.*

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Proof. By Corollary (3.7), fuzzy (neutrsophic) metric number is $n-2$. By G is a fixed-vertex fuzzy (neutrsophic) graph, fuzzy metric dimension is $(n-2)\sigma(m)$ where m is fuzzy (neutrsophic) twin vertex with a vertex. One vertex doesn't belong to set of fuzzy (neutrsophic) twin vertices and a vertex from that set, are out of fuzzy metric set. It induces every $(n-2)$-set including fuzzy (neutrsophic) twin vertices is fuzzy metric set. □

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Proposition 3.10. *Let G be a fixed-vertex fuzzy (neutrsophic) graph such that it's fuzzy (neutrsophic) complete. Then fuzzy (neutrsophic) metric number is $n-1$, fuzzy (neutrsophic) metric dimension is $(n-1)\sigma(m)$ where m is a given vertex. Every $(n-1)$-set is fuzzy (neutrsophic) metric set.*

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Proof. In complete graph, every couple of vertices are twin vertices. By G is a fixed-vertex fuzzy (neutrsophic) graph and it's fuzzy (neutrsophic) complete, every couple of vertices are fuzzy (neutrsophic) twin vertices. Thus by Proposition (3.6), the result follows. □

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Proposition 3.11. *Let $\mathcal{G}$ be a family of fuzzy (neutrsophic) graphs with common vertex set. Then simultaneously fuzzy (neutrsophic) metric number of $\mathcal{G}$ is $n-1$.*

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Proof. Consider $(n-1)$-set. Thus there's no couple of vertices to be fuzzy   149
(neutrsophic)-resolved. Therefore, every $(n-1)$-set is fuzzy (neutrsophic) resolving set   150
for any given fuzzy (neutrsophic) graph. Then it holds for any fuzzy (neutrsophic)   151
graph. It implies it's fuzzy (neutrsophic) resolving set and its cardinality is fuzzy   152
(neutrsophic) metric number. $(n-1)$-set has the cardinality $n-1$. Then it holds for any   153
fuzzy (neutrsophic) graph. It induces it's simultaneously fuzzy (neutrsophic) resolving   154
set and its cardinality is simultaneously fuzzy (neutrsophic) metric number.   □   155

Proposition 3.12. *Let $\mathcal{G}$ be a family of fuzzy (neutrsophic) graphs with common*   156
vertex set. Then simultaneously fuzzy (neutrsophic) metric number of $\mathcal{G}$ is greater than   157
the maximum fuzzy (neutrsophic) metric number of $G \in \mathcal{G}$.   158

Proof. Suppose t and t' are simultaneously fuzzy (neutrsophic) metric number of $\mathcal{G}$ and   159
fuzzy (neutrsophic) metric number of $G \in \mathcal{G}$.. Thus t is fuzzy (neutrsophic) metric   160
number for any $G \in \mathcal{G}$. Hence, $t \geq t'$. So simultaneously fuzzy (neutrsophic) metric   161
number of $\mathcal{G}$ is greater than the maximum fuzzy (neutrsophic) metric number of   162
$G \in \mathcal{G}$.   □   163

Proposition 3.13. *Let $\mathcal{G}$ be a family of fuzzy (neutrsophic) graphs with common*   164
vertex set. Then simultaneously fuzzy (neutrsophic) metric number of $\mathcal{G}$ is greater than   165
simultaneously fuzzy (neutrsophic) metric number of $\mathcal{H} \subseteq \mathcal{G}$.   166

Proof. Suppose t and t' are simultaneously fuzzy (neutrsophic) metric number of $\mathcal{G}$ and   167
$\mathcal{H}$. Thus t is fuzzy (neutrsophic) metric number for any $G \in \mathcal{G}$. It implies Thus t is   168
fuzzy (neutrsophic) metric number for any $G \in \mathcal{H}$. So t is simultaneously fuzzy   169
(neutrsophic) metric number of $\mathcal{H}$. By applying Definition about being the minimum   170
number, $t \geq t'$. So simultaneously fuzzy (neutrsophic) metric number of $\mathcal{G}$ is greater   171
than simultaneously fuzzy (neutrsophic) metric number of $\mathcal{H} \subseteq \mathcal{G}$.   □   172

Theorem 3.14. *fuzzy (neutrsophic) twin vertices aren't resolved in any given fuzzy*   173
(neutrsophic) graph.   174

Proof. Let t and t' are fuzzy (neutrsophic) twin vertices. Then $N(t) = N(t')$ and   175
$\mu(ts) = \mu(t's)$, for all edges $ts, t's \in E$. Thus for every given vertex   176
$s' \in V$, $d_G(s', t) = d_G(s, t)$ where G is a given fuzzy (neutrsophic) graph. It means that   177
t and t' aren't resolved in any given fuzzy (neutrsophic) graph. t and t' are arbitrary so   178
fuzzy (neutrsophic) twin vertices aren't resolved in any given fuzzy (neutrsophic)   179
graph.   □   180

Proposition 3.15. *Let G be a fixed-vertex fuzzy (neutrsophic) graph. If G is fuzzy*   181
(neutrsophic) complete, then every couple of vertices are fuzzy (neutrsophic) twin   182
vertices.   183

Proof. Let t and t' be couple of given vertices. By G is fuzzy (neutrsophic) complete,   184
$N(t) = N(t')$. By G is a fixed-vertex fuzzy (neutrsophic) graph, $\mu(ts) = \mu(t's)$, for all   185
edges $ts, t's \in E$. Thus t and t' are fuzzy (neutrsophic) twin vertices. t and t' are   186
arbitrary couple of vertices, hence every couple of vertices are fuzzy (neutrsophic) twin   187
vertices.   □   188

Theorem 3.16. *Let $\mathcal{G}$ be a family of fuzzy (neutrsophic) graphs with common vertex*   189
set and $G \in \mathcal{G}$ is a fixed-vertex fuzzy (neutrsophic) graph such that it's fuzzy   190
(neutrsophic) complete. Then simultaneously fuzzy (neutrsophic) metric number is   191
$n-1$, simultaneously fuzzy (neutrsophic) metric dimension is $(n-1)\sigma(m)$ where m is a   192
given vertex. Every $(n-1)$-set is simultaneously fuzzy (neutrsophic) metric set for $\mathcal{G}$.   193

Proof. G is fixed-vertex fuzzy (neutrsophic) graph and it's fuzzy (neutrsophic) complete. So by Proposition (3.15), we get every couple of vertices in fuzzy (neutrsophic) complete are fuzzy (neutrsophic) twin vertices. So every couple of vertices, by Theorem (3.14), aren't resolved. $\square$

Theorem 3.17. *Let $\mathcal{G}$ be a family of fuzzy (neutrsophic) graphs with common vertex set and for every given couple of vertices, there's a $G \in \mathcal{G}$ such that in that, they're fuzzy (neutrsophic) twin vertices. Then simultaneously fuzzy (neutrsophic) metric number is $n-1$, simultaneously fuzzy (neutrsophic) metric dimension is $(n-1)\sigma(m)$ where m is a given vertex. Every $(n-1)$-set is simultaneously fuzzy (neutrsophic) metric set for $\mathcal{G}$.*

Proof. By Proposition (3.11), simultaneously fuzzy (neutrsophic) metric number is $n-1$. By Theorem (3.14), simultaneously fuzzy (neutrsophic) metric dimension is $(n-1)\sigma(m)$ where m is a given vertex. Also, every $(n-1)$-set is simultaneously fuzzy (neutrsophic) metric set for $\mathcal{G}$. $\square$

Theorem 3.18. *Let $\mathcal{G}$ be a family of fuzzy (neutrsophic) graphs with common vertex set. If $\mathcal{G}$ contains three fixed-vertex fuzzy (neutrsophic) stars with different center, then simultaneously fuzzy (neutrsophic) metric number is $n-2$, simultaneously fuzzy (neutrsophic) metric dimension is $(n-2)\sigma(m)$ where m is a given vertex. Every $(n-2)$-set is simultaneously fuzzy (neutrsophic) metric set for $\mathcal{G}$.*

Proof. The cardinality of set of twin vertices is $n-1$. Thus by Corollary (3.9), the result follows. $\square$

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