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Research Article

Certain Concepts of Interval-Valued Intuitionistic Fuzzy Graphs with an Application

Peng Xu[1,2] **Hao Guan**[1] **A. A. Talebi,**[3] **M. Ghassemi,**[3] **and Hossein Rashmanlou**[3]

[1]*Institute of Computational Science and Technology, Guangzhou University, Guangzhou, Guangdong 510006, China*
[2]*School of Computer Science of Information Technology, Qiannan Normal University for Nationalities, Duyun, Guizhou 558000, China*
[3]*Department of Mathematics, University of Mazandaran, Babolsar, Iran*

Correspondence should be addressed to Hao Guan; guanhao@gzhu.edu.cn

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Interval-valued intuitionistic fuzzy graph (IVIFG), belonging to the FGs family, has good capabilities when facing with problems that cannot be expressed by FGs. When an element membership is not clear, neutrality is a good option that can be well supported by an IVIFG. The previous definitions of limitations in edge irregular FG have led us to offer new definitions in IVIFGs. Hence, in this paper, some types of edge irregular interval-valued intuitionistic fuzzy graphs (EI-IVIFGs) such as neighborly edge totally irregular (NETI), strongly edge irregular (SEI), and strongly edge totally irregular (SETI) are introduced. A comparative study between NEI-IVIFGs and NETI-IVIFGs is done. With the help of IVIFGs, the most efficient person in an organization can be identified according to the important factors that can be useful for an institution. Finally, an application of IVIFG has been introduced.

1. Introduction

The FG concept serves as one of the most dominant and extensively employed tools for multiple real-word problem representations, modeling, and analysis. To specify the objects and the relations between them, the graph vertices or nodes and edges or arcs are applied, respectively. Graphs have long been used to describe objects and the relationships between them. Many of the issues and phenomena around us are associated with complexities and ambiguities that make it difficult to express certainty. These difficulties were alleviated by the introduction of fuzzy sets by Zadeh [1]. The fuzzy set focuses on the membership degree of an object in a particular set. Kaufman [2] represented FGs based on Zadeh's fuzzy relation [3, 4]. Rosenfeld [5] described the structure of FGs obtaining analogs of several graph theoretical concepts. Bhattacharya [6] gave some remarks on FGs. Several concepts on FGs were introduced by Mordeson and Nair [7]. The existence of a single degree for a true membership could not resolve the ambiguity on uncertain issues, so the need for a degree of membership was felt. Afterward, to overcome the existing ambiguities, Atanassov [8] defined an extension of fuzzy set by introducing nonmembership function and defined intuitionistic fuzzy set (IFS). But after a while, Atanassov and Gargov [9] developed IFS and presented interval-valued intuitionistic fuzzy set (IVIFS). In 1999, Atanassov [10] defined intuitionistic fuzzy graph (IFG), but Akram and Davvaz investigated it in more details in [11]. Hongmei and Lianhua [12] defined interval-valued fuzzy graph and studied its properties. Karunambigai et al. [13] discussed edge regular IFG. Mishra and Pal [14] introduced product of IVIFG. Nagoorgani and Radha [15, 16] studied the concept of regular fuzzy graphs and defined degree of a vertex in FGs. Nagoorgani and Latha [17] investigated the concept of IFGs, NI-FGs, and HI-FGs in 2008. Shao et al. [18] discussed new concepts in IFG. Nandhini and Nandhini [19] described the concept of SI-FGs and studied its properties. Santhi Maheswari and Sekar defined the concepts of edge irregular FGs and edge totally irregular FGs [20]. Also, they analyzed some properties of NEI-FGs, NETI-FGs, SEI-FGs, and SETI-FGs [21, 22]. Rao et al. [23–25] studied dominating set, equitable dominating set, valid degree, isolated vertex, and some properties of VGs with novel application. Shi and Kosari [26] introduced total dominating set and global dominating set in product vague graphs. Talebi et al. [27–30] defined new concepts of irregularity in single-valued neutrosophic graphs and intuitionistic fuzzy graphs. Kou et al. [31] studied vague graphs with application in transportation systems. Kalaiarasi and Mahalakshmi [32] investigated regular and irregular m-polar fuzzy graphs. Selvanayaki [33] introduced strong and balanced irregular interval-valued fuzzy graphs. Rashmanlou et al. [34] investigate new results in cubic graphs. Poulik and Ghorai [35–37] initiated degree of nodes, detour g-interior nodes, and indices of bipolar fuzzy graphs with applications in real-life systems. Pramanik et al. [38] defined fuzzy competition graph and its uses in manufacturing industries. Muhiuddin et al. [39] introduced reinforcement number of a graph with respect to half-domination. Amanathulla et al. [40] studied on distance two surjective labeling of paths and interval graphs. Ramprasad et al. [41] investigated some properties of highly irregular, edge regular, and totally edge regular m-polar fuzzy graphs. Nazeer et al. [42] introduced an application of product intuitionistic fuzzy incidence graphs in textile industry. Bhattacharya and Pal [43] studied fuzzy covering problem of fuzzy graphs and its application. Borzooei et al. [44] defined inverse fuzzy graphs.

IVIFGs have a wide range of applications in the field of psychological sciences as well as the identification of individuals based on oncological behaviors. With the help of IVIFGs, the most efficient person in an organization can be identified according to the important factors that can be useful for an institution. So, in this paper, some types of EI-IVIFGs such as neighborly edge totally irregular- (NETI-) IVIFGs, strongly edge irregular- (SEI-) IVIFGs, and strongly edge totally irregular- (SETI-) IVIFGs are introduced. Also, we have given some interesting results about EI-IVIFGs, and several examples are investigated. Finally, an application of IVIFG is presented.

2. Preliminaries

A graph $G=(V,E)$ is a mathematical model consisting of a set of nodes V and a set of edges E, where each is an unordered pair of distinct nodes.

Definition 1 (see [5]). A FG $Z=(V,\nu,\xi)$ is a nonempty set V together with a pair of functions $\nu : V \longrightarrow [0,1]$ and $\xi : V \times V \longrightarrow [0,1]$ so that $\xi(xy) \leq \min\{\nu(x),\nu(y)\}, \forall x,y \in V$.

Definition 2 (see [11]). An IFG is of the form $G:(\eta,\varsigma)$ which $\eta=(\eta_1,\eta_2)$ and $\varsigma=(\varsigma_1,\varsigma_2)$ so that

(i) The functions $\eta_1 : V \longrightarrow [0,1]$ and $\eta_2 : V \longrightarrow [0,1]$ denotes the MD and NM-D of the element $w \in V$, respectively, and $0 \leq \eta_1(w)+\eta_2(w) \leq 1$ for each $w \in V$

(ii) The functions $\varsigma_1 : V \times V \longrightarrow [0,1]$ and $\varsigma_2 : V \times V \longrightarrow [0,1]$ are the MD and NM-D of the edge $xw \in E$, respectively, so that $\varsigma_1(xw) \leq \min(\eta_1(x),\eta_1(w))$ and $\varsigma_2(xw) \geq \max(\eta_2(x),\eta_2(w))$ and $0 \leq \varsigma_1(xw)+\varsigma_2(xw) \leq 1$, for each xw in E

Definition 3 (see [11]). An IVFG is of the form $G:(\theta,\zeta)$ which $\theta=[\theta^-,\theta^+]$ is an IVFS in V and $\zeta=(\zeta^-,\zeta^+)$ is an IVFS in $E \subseteq V \times V$ so that $\zeta^-(xw) \leq \min(\theta^-(x),\theta^-(w))$ and $\zeta^+(xw) \leq \min(\theta^+(x),\theta^+(w))$ for each xw in E.

All the basic notations are shown in Table 1.

3. New Concepts of Irregular IVIFGs

Definition 4. An IVIFG is of the form $G:(\sigma,\mu)$ which $\sigma=(\sigma_1,\sigma_2)=((\sigma_1^-,\sigma_1^+),(\sigma_2^-,\sigma_2^+))$ and $\mu=(\mu_1,\mu_2)=((\mu_1^-,\mu_1^+),(\mu_2^-,\mu_2^+))$ so that

(i) The functions $\sigma_1 : V \longrightarrow D[0,1]$ and $\sigma_2 : V \longrightarrow D[0,1]$ denote the degree of IVM and IV-NM of the element $w \in V$, respectively, so that $0 \leq \sigma_1^+(w)+\sigma_2^+(w) \leq 1$, for each $w \in V$

(ii) The functions $\mu_1 : V \times V \longrightarrow D[0,1]$ and $\mu_2 : V \times V \longrightarrow D[0,1]$ denote the degree of IVM and IV-NM of the edge $wz \in E$, respectively, are defined by the following:

(i) $\mu_1^-(wz) \leq \min(\sigma_1^-(w),\sigma_1^-(z))$ and $\mu_1^+(wz) \leq \min(\sigma_1^+(w),\sigma_1^+(z))$

(ii) $\mu_2^-(wz) \geq \max(\sigma_2^-(w),\sigma_2^-(z))$ and $\mu_2^+(wz) \geq \max(\sigma_2^+(w),\sigma_2^+(z))$

so that $0 \leq \mu_1^+(wz)+\mu_2^+(wz) \leq 1$, for each wz in E.

Definition 5. Let G be an IVIFG. Then, the degree of a node w is defined as $d_G(w)=((d_{\sigma_1^-}(w),d_{\sigma_1^+}(w)),(d_{\sigma_2^-}(w),d_{\sigma_2^+}(w)))$, where $d_{\sigma_1^-}(w)=\Sigma_{z\neq w}\mu_1^-(w,z)$, $d_{\sigma_1^+}(w)=\Sigma_{z\neq w}\mu_1^+(w,z)$, $d_{\sigma_2^-}(w)=\Sigma_{z\neq w}\mu_2^-(w,z)$, and $d_{\sigma_2^+}(w)=\Sigma_{z\neq w}\mu_2^+(w,z)$.

Definition 6. Let G be an IVIFG. Then, the TD of a node w is defined as $td_G(w)=((td_{\sigma_1^-}(w),td_{\sigma_1^+}(w)),(td_{\sigma_2^-}(w),td_{\sigma_2^+}(w)))$ which $td_{\sigma_1^-}(w)=\Sigma_{z\neq w}\mu_1^-(w,z)+\sigma_1^-(w)$, $td_{\sigma_1^+}(w)=\Sigma_{z\neq w}\mu_1^+(w,z)+\sigma_1^+(w)$, $td_{\sigma_2^-}(w)=\Sigma_{z\neq w}\mu_2^-(w,z)+\sigma_2^-(w)$, and $td_{\sigma_2^+}(w)=\Sigma_{z\neq w}\mu_2^+(w,z)+\sigma_2^+(w)$.

Definition 7. Let G be an IVIFG on. Then,

(i) G is irregular, if there is a node which is a neighbor to nodes with VDs

(ii) G is TI, if there is a node which is a neighbor to nodes with various TDs

Table 1: Some basic notations.

Notation	Meaning
IFG	Intuitionistic fuzzy graph
IVFG	Interval-valued fuzzy graph
IVIFG	Interval-valued intuitionistic fuzzy graph
IVM	Interval valued membership
IV-NM	Interval-valued nonmembership
I-FG	Irregular fuzzy graph
SI	Strongly irregular
HI	Highly irregular
NI	Neighborly irregular
VD	Various degree
TD	Total degree
TI	Total irregular
MD	Membership degree
NE	Neighbor edge
NEI-IVIFG	Neighborly edge irregular interval-valued intuitionistic fuzzy graph
CIVIFG	Connected interval-valued intuitionistic fuzzy graph
IVFS	Interval-valued fuzzy set
NEI	Neighborly edge irregular
NETI	Neighborly edge totally irregular
TER	Totally edge regular
SETI	Strongly edge totally irregular
SEI	Strongly edge irregular
HEI	Highly edge irregular
HETI	Highly edge totally irregular
CF	Constant function

Definition 8. Let G be a CIVIFG. Then, G is called an

(i) NI-IVIFG if each pair of neighbor nodes has VDs

(ii) NTI-IVIFG if each pair of neighbor nodes has various TDs

(iii) SI-IVIFG if each pair of nodes has VDs

(iv) STI-IVIFG if each pair of nodes has various TDs

(v) HI-IVIFG if each node in G is neighbor to the nodes having VDs

(vi) HTI-IVIFG if each node in G is neighbor to the nodes having various TDs

Definition 9. Let G be an IVIFG on. The degree of an edge wz is described as $d_G(wz) = ((d_{\mu_1^-}(wz), d_{\mu_1^+}(wz)), (d_{\mu_2^-}(wz), d_{\mu_2^+}(wz)))$ which $d_{\mu_i^-}(wz) = d_{\sigma_i^-}(w) + d_{\sigma_i^-}(z) - 2\mu_i^-(wz)$ and $d_{\mu_i^+}(wz) = d_{\sigma_i^+}(w) + d_{\sigma_i^+}(z) - 2\mu_i^+(wz)$, for $i = 1, 2$.

Definition 10. Let G be an IVIFG. The TD of an edge wz is presented as $td_G(wz) = ((td_{\mu_1^-}(wz), td_{\mu_1^+}(wz)), (td_{\mu_2^-}(wz), td_{\mu_2^+}(wz)))$ where $td_{\mu_i^-}(wz) = d_{\sigma_i^-}(w) + d_{\sigma_i^-}(z) - \mu_i^-(wz) = d_{\mu_i^-}(wz) + \mu_i^-(wz)$ and $td_{\mu_i^+}(wz) = d_{\sigma_i^+}(w) + d_{\sigma_i^+}(z) - \mu_i^+(wz) = d_{\mu_i^+}(wz) + \mu_i^+(wz)$, for $i = 1, 2$.

Definition 11. Let G be a CIVIFG. Then, G is called an

(i) NEI-IVIFG if each pair of NEs has VDs

(ii) NETI-IVIFG if each pair of NEs has various TDs

Example 12. Graph which is both NEI-IVIFG and NETI-IVIFG.

Consider G^* which $V = \{u, v, w, x\}$ and $E = \{uv, vw, wx, xu\}$.

From Figure 1, $d_G(u) = d_G(v) = d_G(w) = d_G(x) = ((0.3,0.5), (0.5,1.0))$, $d_G(uv) = d_G(wx) = ((0.4,0.6), (0.4,0.8))$, and $d_G(vw) = d_G(xu) = ((0.2,0.4), (0.6,1.2))$.

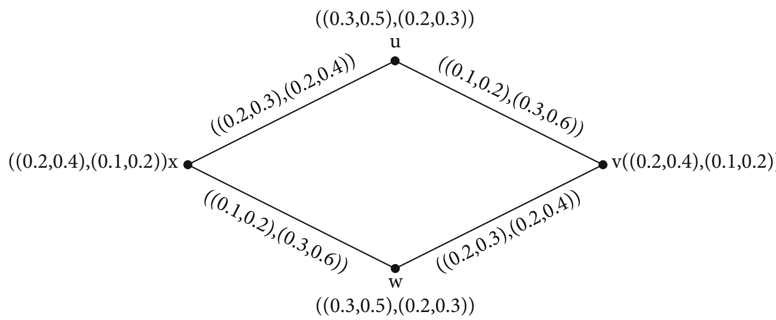

Figure 1: G is both NEI-IVIFG and NETI-IVIFG.

Clearly, neighbor edges have VDs. Hence, G is a NEI-IVIFG.

For TDs, we have the following:

$$\begin{aligned} td_G(uv) &= td_G(wx) = ((0.5,0.8),(0.7,1.4)), \\ td_G(vw) &= td_G(xu) = ((0.4,0.7),(0.8,1.6)). \end{aligned} \tag{1}$$

Obviously, neighbor edges have various TDs. So, G is a NETI-IVIFG. Hence, G is both NEI-IVIFG and NETI-IVIFG.

Example 13. NEI-IVIFG needs not to be NETI-IVIFG.

Consider G be an IVIFG and G^* a star includes four nodes.

From Figure 2, $d_G(u) = ((0.2,0.3),(0.3,0.4))$, $d_G(v) = ((0.1,0.2),(0.4,0.5))$, $d_G(w) = ((0.0,0.1),(0.5,0.6))$, $d_G(x) = ((0.3,0.6),(1.2,1.5))$, $d_G(ux) = ((0.1,0.3),(0.9,1.1))$, $d_G(vx) = ((0.2,0.4),(0.8,1.0))$, $d_G(wx) = ((0.3,0.5),(0.7,0.9))$, and $td_G(ux) = td_G(vx) = td_G(wx) = ((0.3,0.6),(1.2,1.5))$.

Here, $d_G(ux) \neq d_G(vx) \neq d_G(wx)$. Hence, G is a NEI-IVIFG. But G is not a NETI-IVIFG, since all edges have same TDs.

Example 14. NETI-IVIFGs need not to be NEI-IVIFGs. The following shows this subject:

Consider G be an IVIFG so that G^* a path consists of 4 nodes.

From Figure 3, $d_G(u) = d_G(x) = ((0.05,0.20),(0.15,0.25))$, $d_G(v) = d_G(w) = ((0.15,0.60),(0.45,0.75))$, $d_G(uv) = d_G(vw) = d_G(wx) = ((0.1,0.4),(0.3,0.5))$, $td_G(uv) = ((0.15,0.60),(0.45,0.75))$, $td_G(vw) = ((0.2,0.8),(0.6,1.0))$, and $td_G(wx) = ((0.15,0.60),(0.45,0.75))$.

Here, $d_G(uv) = d_G(vw) = d_G(wx)$. Hence, G is not a NEI-IVIFG. But G is a NETI-IVIFG, since $td_G(uv) \neq td_G(vw)$ and $td_G(vw) \neq td_G(wx)$.

Theorem 15. *Suppose G is a CIVIFG and μ is a CF. Then, G is a NEI-IVIFG if G is a NETI-IVIFG.*

Proof. Assume that μ is a CF and $\mu(wz) = f$, $\forall wz$ in E, which $f = ((f_1^-,f_1^+),(f_2^-,f_2^+))$ is constant.

Let wz and zy be pairs of neighbor edges in E; then, we have the following:

$$\begin{aligned} & d_G(wz) \neq d_G(zy) \Leftrightarrow d_G(wz) + d \neq d_G(zy) + d \Leftrightarrow \left(\left(d_{\mu_1^-}(wz), d_{\mu_1^+}(wz)\right), \left(d_{\mu_2^-}(wz), d_{\mu_2^+}(wz)\right)\right) \\ & \quad + ((f_1^-,f_1^+),(f_2^-,f_2^+)) \neq \left(\left(d_{\mu_1^-}(zy), d_{\mu_1^+}(zy)\right), \left(d_{\mu_2^-}(zy), d_{\mu_2^+}(zy)\right)\right) \\ & \quad + ((f_1^-,f_1^+),(f_2^-,f_2^+)) \Leftrightarrow \left(\left(d_{\mu_1^-}(wz) + f_1^-, d_{\mu_1^+}(wz) + f_1^+\right), \left(d_{\mu_2^-}(wz)\right.\right. \\ & \quad \left.\left. + f_2^-, d_{\mu_2^+}(wz) + f_2^+\right)\right) \neq \left(\left(d_{\mu_1^-}(zy) + f_1^-, d_{\mu_1^+}(zy) + f_1^+\right),\right. \\ & \quad \left. \cdot \left(d_{\mu_2^-}(zy) + f_2^-, d_{\mu_2^+}(zy) + f_2^+\right)\right) \Leftrightarrow \left(\left(d_{\mu_1^-}(wz) + \mu_1^-(wz), d_{\mu_1^+}(wz) + \mu_1^+(wz)\right),\right. \\ & \quad \left. \cdot \left(d_{\mu_2^-}(wz) + \mu_2^-(wz), d_{\mu_2^+}(wz) + \mu_2^+(wz)\right)\right) \neq \left(\left(d_{\mu_1^-}(zy) + \mu_1^-(zy), d_{\mu_1^+}(zy)\right.\right. \\ & \quad \left.\left. + \mu_1^+(zy)\right), \left(d_{\mu_2^-}(zy) + \mu_2^-(zy), d_{\mu_2^+}(zy) + \mu_2^+(zy)\right)\right) \Leftrightarrow \left(\left(td_{\mu_1^-}(wz), td_{\mu_1^+}(wz)\right),\right. \\ & \quad \left. \cdot \left(td_{\mu_2^-}(wz), td_{\mu_2^+}(wz)\right)\right) \neq \left(\left(td_{\mu_1^-}(zy), td_{\mu_1^+}(zy)\right),\right. \\ & \quad \left. \cdot \left(td_{\mu_2^-}(zy), td_{\mu_2^+}(zy)\right)\right) \Leftrightarrow td_G(wz) \neq td_G(zy). \end{aligned} \tag{2}$$

Therefore, neighbor edges have VDs if they have various TDs. Hence, G is a NEI-IVIFG if G is a NETI-IVIFG. □

Remark 16. Let G be a CIVIFG. If G is both NEI-IVIFG and NETI-IVIFG, then μ needs not to be a CF.

Example 17. Suppose G is an IVIFG and G^* a path consists of four nodes.

From Figure 4, $d_G(u) = d_G(x) = ((0.2,0.3),(0.4,0.5))$, $d_G(v) = d_G(w) = ((0.3,0.5),(0.7,0.9))$, $d_G(uv) = ((0.1,0.2),(0.3,0.4))$, $d_G(vw) = ((0.4,0.6),(0.8,1.0))$, $d_G(wx) = ((0.1,0.2),(0.3,0.4))$, $td_G(uv) = ((0.3,0.5),(0.7,0.9))$, $td_G(vw) = ((0.5,0.8),(1.1,1.4))$, and $td_G(wx) = ((0.3,0.5),(0.7,0.9))$.

Here, $d_G(uv) \neq d_G(vw)$ and $d_G(vw) \neq d_G(wx)$. Hence, G is a NEI-IVIFG. Also, $td_G(uv) \neq td_G(vw)$ and $td_G(vw) \neq td_G(wx)$. Hence, G is a NETI-IVIFG but μ is not CF.

Theorem 18. *Let G be a CIVIFG and μ a CF. If G is a SI-IVIFG, then, G is a NEI-IVIFG.*

Proof. Assume G is a CIVIFG, μ is a CF, and $\mu(wz) = f$, $\forall wz$ in E, which $f = ((f_1^-,f_1^+),(f_2^-,f_2^+))$ is constant.

Let wz and zy be any two NEs in G. Assume that G is a SI-IVIFG. Then, each pair of nodes in G has VDs, and

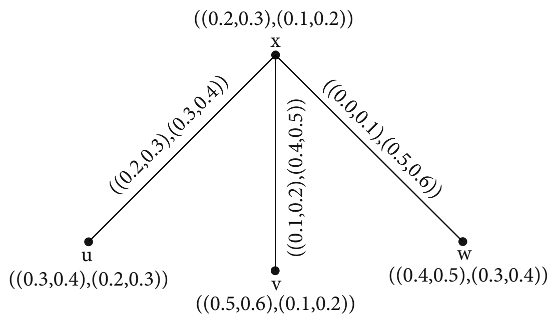

Figure 2: G is NEI-IVIFG but it is not NETI-IVIFG.

hence,

$$
\begin{aligned}
&d_G(w) \neq d_G(z) \neq d_G(y) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w), d_{\sigma_1^+}(w)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(w), d_{\sigma_2^+}(w)\Big)\Big) \neq \Big(\Big(d_{\sigma_1^-}(z), d_{\sigma_1^+}(z)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(z), d_{\sigma_2^+}(z)\Big)\Big) \neq \Big(\Big(d_{\sigma_1^-}(y), d_{\sigma_1^+}(y)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(y), d_{\sigma_2^+}(y)\Big)\Big) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w), d_{\sigma_1^+}(w)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(w), d_{\sigma_2^+}(w)\Big)\Big) + \Big(\Big(d_{\sigma_1^-}(z), d_{\sigma_1^+}(z)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(z), d_{\sigma_2^+}(z)\Big)\Big) - 2\big(\big(f_1^-, f_1^+\big), \big(f_2^-, f_2^+\big)\big) \neq \Big(\Big(d_{\sigma_1^-}(z), d_{\sigma_1^+}(z)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(z), d_{\sigma_2^+}(z)\Big)\Big) + \Big(\Big(d_{\sigma_1^-}(y), d_{\sigma_1^+}(y)\Big), \Big(d_{\sigma_2^-}(y), d_{\sigma_2^+}(y)\Big)\Big)\\
&\quad - 2\big(\big(f_1^-, f_1^+\big), \big(f_2^-, f_2^+\big)\big) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w) + d_{\sigma_1^-}(z) - 2f_1^-, d_{\sigma_1^+}(w) + d_{\sigma_1^+}(z) - 2f_1^+\Big),\\
&\cdot \Big(d_{\sigma_2^-}(w) + d_{\sigma_2^-}(z) - 2f_2^-, d_{\sigma_2^+}(w) + d_{\sigma_2^+}(z) - 2f_2^+\Big)\Big) \neq \Big(\Big(d_{\sigma_1^-}(z) + d_{\sigma_1^-}(y)\\
&\quad - 2f_1^-, d_{\sigma_1^+}(z) + d_{\sigma_1^+}(y) - 2f_1^+\Big), \Big(d_{\sigma_2^-}(z) + d_{\sigma_2^-}(y) - 2f_2^-, d_{\sigma_2^+}(z) + d_{\sigma_2^+}(y)\\
&\quad - 2f_2^+\Big)\Big) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w) + d_{\sigma_1^-}(z) - 2\mu_1^-(wz), d_{\sigma_1^+}(w) + d_{\sigma_1^+}(z) - \mu_1^+(wz)\Big),\\
&\cdot \Big(d_{\sigma_2^-}(w) + d_{\sigma_2^-}(z) - 2\mu_2^-(wz), d_{\sigma_2^+}(w) + d_{\sigma_2^+}(z) - 2\mu_2^+(wz)\Big)\Big) \neq \Big(\Big(d_{\sigma_1^-}(z)\\
&\quad + d_{\sigma_1^-}(y) - 2\mu_1^-(zy), d_{\sigma_1^+}(z) + d_{\sigma_1^+}(y) - 2\mu_1^+(zy)\Big), \Big(d_{\sigma_2^-}(z) + d_{\sigma_2^-}(y)\\
&\quad - 2\mu_2^-(zy), d_{\sigma_2^+}(z) + d_{\sigma_2^+}(y) - 2\mu_2^+(zy)\Big)\Big) \Rightarrow \Big(\Big(d_{\mu_1^-}(wz), d_{\mu_1^+}(wz)\Big),\\
&\cdot \Big(d_{\mu_2^-}(wz), d_{\mu_2^+}(wz)\Big)\Big) \neq \Big(\Big(d_{\mu_1^-}(zy), d_{\mu_1^+}(zy)\Big),\\
&\cdot \Big(d_{\mu_2^-}(zy), d_{\mu_2^+}(zy)\Big)\Big) \Rightarrow d_G(wz) \neq d_G(zy).
\end{aligned} \tag{3}
$$

Hence, neighbor edges have VDs. Thus, G is a NEIIVIFG. □

Theorem 19. *Let G be a CIVIFG on G^* and μ a CF. If G is a SI-IVIFG, then G is a NETI-IVIFG.*

Proof. It is similar to Theorem 18. □

Remark 20. Converse of Theorem 19 is not generally true.

Example 21. Let G be an IVIFG so that G^* consists of four nodes.

From Figure 5, $d_G(u) = d_G(x) = ((0.1,0.3), (0.2,0.4))$ and $d_G(v) = d_G(w) = ((0.2,0.6), (0.4,0.8))$.

Here, G is not a SI-IVIFG. $d_G(uv) = ((0.1,0.3), (0.2,0.4))$, $d_G(vw) = ((0.2,0.6), (0.4,0.8))$, $d_G(wx) = ((0.1,0.3), (0.2,0.4))$, $td_G(uv) = ((0.2,0.6), (0.4,0.8))$, $td_G(vw) = ((0.3,0.9), (0.6,1.2))$, and $td_G(wx) = ((0.2,0.6), (0.4,0.8))$.

Hence, $d_G(uv) \neq d_G(vw)$ and $d_G(vw) \neq d_G(wx)$. Furthermore, $td_G(uv) \neq td_G(vw)$ and $td_G(vw) \neq td_G(wx)$. Hence, G is both NEI-IVIFG and NETI-IVIFG. But G is not a SI-IVIFG.

Theorem 22. *Let G be a CIVIFG and μ a CF. Then, G is a HI-IVIFG if G is a NEI-IVIFG.*

Proof. Assume G is a CIVIFG and μ is a CF. Consider $\mu(wz) = f$, $\forall wz$ in E, which $f = ((f_1^-, f_1^+), (f_2^-, f_2^+))$ is CF.

Let wz and zy be any two neighbor edges in G. Then,

$$
\begin{aligned}
&d_G(w) \neq d_G(y) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w), d_{\sigma_1^+}(w)\Big), \Big(d_{\sigma_2^-}(w), d_{\sigma_2^+}(w)\Big)\Big) \neq \Big(\Big(d_{\sigma_1^-}(y), d_{\sigma_1^+}(y)\Big),\\
&\quad \cdot \Big(d_{\sigma_2^-}(y), d_{\sigma_2^+}(y)\Big)\Big) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w), d_{\sigma_1^+}(w)\Big), \Big(d_{\sigma_2^-}(w), d_{\sigma_2^+}(w)\Big)\Big)\\
&\qquad + \Big(\Big(d_{\sigma_1^-}(z), d_{\sigma_1^+}(z)\Big), \Big(d_{\sigma_2^-}(z), d_{\sigma_2^+}(z)\Big)\Big)\\
&\qquad - 2\big(\big(f_1^-, f_1^+\big), \big(f_2^-, f_2^+\big)\big) \neq \Big(\Big(d_{\sigma_1^-}(z), d_{\sigma_1^+}(z)\Big), \Big(d_{\sigma_2^-}(z), d_{\sigma_2^+}(z)\Big)\Big)\\
&\qquad + \Big(\Big(d_{\sigma_1^-}(y), d_{\sigma_1^+}(y)\Big), \Big(d_{\sigma_2^-}(y), d_{\sigma_2^+}(y)\Big)\Big)\\
&\qquad - 2\big(\big(f_1^-, f_1^+\big), \big(f_2^-, f_2^+\big)\big) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w) + d_{\sigma_1^-}(z) - 2f_1^-, d_{\sigma_1^+}(w) + d_{\sigma_1^+}(z)\\
&\qquad - 2f_1^+\Big), \Big(d_{\sigma_2^-}(w) + d_{\sigma_2^-}(z) - 2f_2^-, d_{\sigma_2^+}(w) + d_{\sigma_2^+}(z) - 2f_2^+\Big)\Big)\\
&\qquad \neq \Big(\Big(d_{\sigma_1^-}(z) + d_{\sigma_1^-}(y) - 2f_1^-, d_{\sigma_1^+}(z) + d_{\sigma_1^+}(y) - 2f_1^+\Big), \Big(d_{\sigma_2^-}(z) + d_{\sigma_2^-}(y)\\
&\qquad - 2f_2^-, d_{\sigma_2^+}(z) + d_{\sigma_2^+}(y) - 2f_2^+\Big)\Big) \Rightarrow \Big(\Big(d_{\sigma_1^-}(w) + d_{\sigma_1^-}(z) - 2\mu_1^-(wz), d_{\sigma_1^+}(w)\\
&\qquad + d_{\sigma_1^+}(z) - \mu_1^+(wz)\Big), \Big(d_{\sigma_2^-}(w) + d_{\sigma_2^-}(z) - 2\mu_2^-(wz), d_{\sigma_2^+}(w) + d_{\sigma_2^+}(z)\\
&\qquad - 2\mu_2^+(wz)\Big)\Big) \neq \Big(\Big(d_{\sigma_1^-}(z) + d_{\sigma_1^-}(y) - 2\mu_1^-(zy), d_{\sigma_1^+}(z) + d_{\sigma_1^+}(y)\\
&\qquad - 2\mu_1^+(zy)\Big), \Big(d_{\sigma_2^-}(z) + d_{\sigma_2^-}(y) - 2\mu_2^-(zy), d_{\sigma_2^+}(z) + d_{\sigma_2^+}(y)\\
&\qquad - 2\mu_2^+(zy)\Big)\Big) \Rightarrow \Big(\Big(d_{\mu_1^-}(wz), d_{\mu_1^+}(wz)\Big), \Big(d_{\mu_2^-}(wz), d_{\mu_2^+}(wz)\Big)\Big)\\
&\qquad \neq \Big(\Big(d_{\mu_1^-}(zy), d_{\mu_1^+}(zy)\Big), \Big(d_{\mu_2^-}(zy), d_{\mu_2^+}(zy)\Big)\Big) \Rightarrow d_G(wz) \neq d_G(zy).
\end{aligned} \tag{4}
$$

Therefore, neighbor edges have VDs, if each node neighbor to the nodes has VDs. Hence, G is a HIIVIFG, if G is a NEIIVIFG. □

Theorem 23. *Suppose G is a CIVIFG and μ is a CF. Then, G is HI-IVIFG if and only if G is NETI-IVIFG.*

Proof. It is clear. □

Theorem 24. *Let G be an IVIFG on G^*, a star $K_{1,n}$. Then, G is a TER-IVIFG. If the degrees of IVM and IV-NM of no two edges are similar, then G is a NEI-IVIFG.*

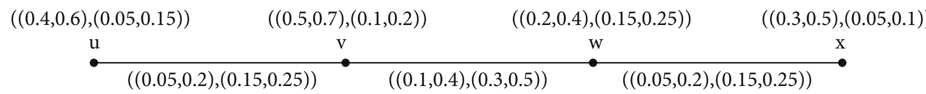

Figure 3: G is NETI-IVIFG but it is not NEI-IVIFG.

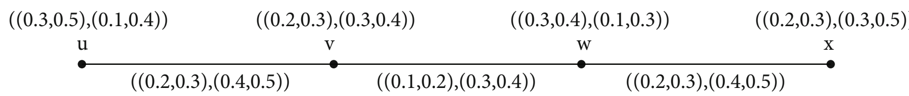

Figure 4: μ is not a CF.

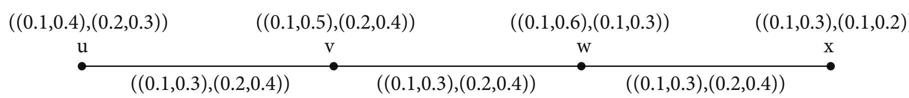

Figure 5: G is both NEI-IVIFG and NETI-IVIFG, not SI-IVIFG.

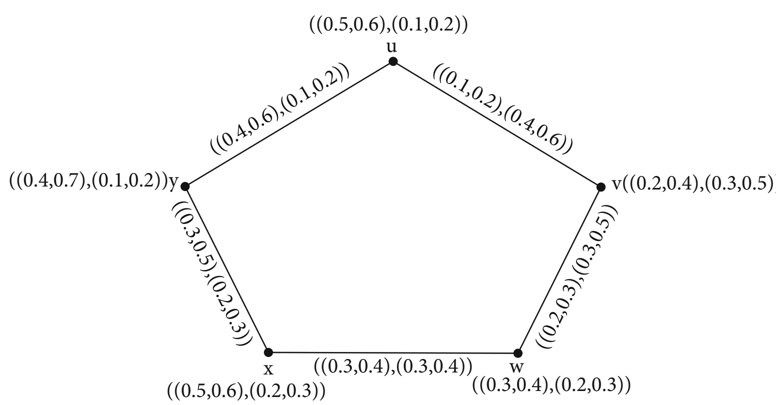

Figure 6: G is both SEI-IVIFG and SETI-IVIFG.

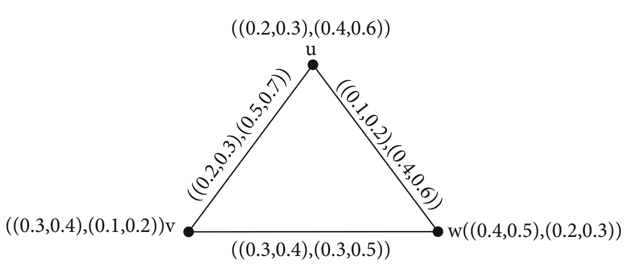

Figure 7: G is SEI-IVIFG but it is not SETI-IVIFG.

Proof. Suppose $v_1, v_2, v_3, \cdots, v_n$ are the nodes neighbor to the node x. Assume $e_1, e_2, e_3, \cdots, e_n$ are the edges of a star G^* in that order having degrees of IVM $m_1, m_2, m_3, \cdots, m_n$ and degrees of IV-NM $n_1, n_2, n_3, \cdots, n_n$ which $m_i = (m_i^-, m_i^+)$ and $n_i = (n_i^-, n_i^+)$, for $i = 1, 2$ so that $0 \leq m_i^+ + n_i^+ \leq 1$, for each $1 \leq i \leq n$.

Then,

$$\begin{aligned} td_G(e_i) &= \left(\left(td_{\mu_1^-}(e_i), td_{\mu_1^+}(e_i)\right), \left(td_{\mu_2^-}(e_i), td_{\mu_2^+}(e_i)\right)\right) \\ &= \left(\left(d_{\mu_1^-}(e_i) + \mu_1^-(e_i), d_{\mu_1^+}(e_i) + \mu_1^+(e_i)\right), \right. \\ &\quad \left. \cdot \left(d_{\mu_2^-}(e_i) + \mu_2^-(e_i), d_{\mu_2^+}(e_i) + \mu_2^+(e_i)\right)\right) \\ &= \left(\left(\sum_{k=1}^{n} m_k^- - m_i^- + m_i^-, \sum_{k=1}^{n} m_k^+ - m_i^+ + m_i^+\right), \right. \\ &\quad \left. \cdot \left(\sum_{k=1}^{n} n_k^- - n_i^- + n_i^-, \sum_{k=1}^{n} n_k^+ - n_i^+ + n_i^+\right)\right) \\ &= \left(\left(\sum_{k=1}^{n} m_k^-, \sum_{k=1}^{n} m_k^+\right), \left(\sum_{k=1}^{n} n_k^-, \sum_{k=1}^{n} n_k^+\right)\right). \end{aligned} \tag{5}$$

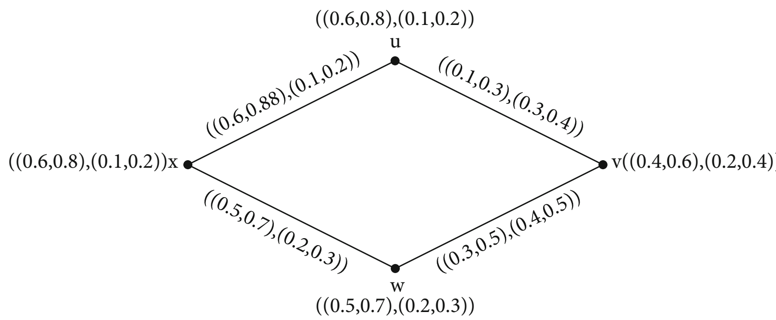

Figure 8: G is SETI-IVIFG but it is not SEI-IVIFG.

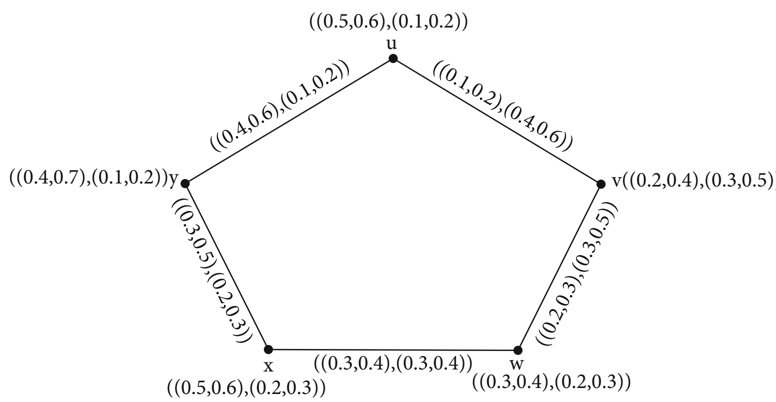

Figure 9: μ is not a CF.

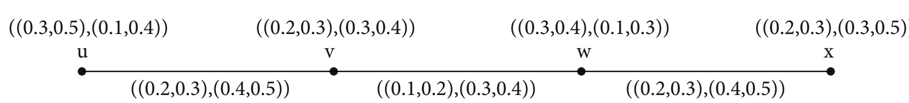

Figure 10: G is NEI and NETI-IVIFG but it is not SEI and SETI-IVIFG.

Table 2: The names of the staff and their specialization in the hospital.

Name	Services
Jafari (Ja)	Medical equipment expert
Mohseni (Mo)	Head of security guard
Alavi (Al)	Head of admissions
Samie (Sa)	Expert radiology and laboratory
Rezai (Re)	Hospital head
Ghoreishi (Gh)	IT expert
Khorami (Kh)	Head of finance

Table 3: Employee power based on degree of membership and nonmembership.

	Jafari	Mohseni	Alavi	Samie	Rezai	Ghoreishi	Khorami
σ_1^-	0.85	0.85	0.75	0.65	0.55	0.55	0.45
σ_1^+	0.95	0.95	0.85	0.75	0.65	0.65	0.55
σ_2^-	0	0	0.05	0.05	0.25	0.25	0.25
σ_2^+	0.05	0.05	0.15	0.15	0.35	0.35	0.35

All edges e_i, $(1 \leq i \leq n)$, have same TDs. Hence, G is a TER-IVIFG. Now, if $m_i^- \neq m_j^-$, $m_i^+ \neq m_j^+$, $n_i^- \neq n_j^-$, and $n_i^+ \neq n_j^+$, for each $1 \leq i, j \leq n$, then we have the following:

$$\begin{aligned} d_G(e_i) &= \left(\left(d_{\mu_1^-}(e_i), d_{\mu_1^+}(e_i)\right), \left(d_{\mu_2^-}(e_i), d_{\mu_2^+}(e_i)\right)\right) \\ &= \left(\left(d_{\sigma_1^-}(x) + d_{\sigma_1^-}(v_i) - 2\mu_1^-(xv_i), d_{\sigma_1^+}(x) + d_{\sigma_1^+}(v_i) - 2\mu_1^+(xv_i)\right),\right. \\ &\quad \left.\cdot\left(d_{\sigma_2^-}(x) + d_{\sigma_2^-}(v_i) - 2\mu_2^-(xv_i), d_{\sigma_2^+}(x) + d_{\sigma_2^+}(v_i) - 2\mu_2^+(xv_i)\right)\right) \\ &= \left(\left(\sum_{k=1}^n m_k^- + m_i^- - 2m_i^-, \sum_{k=1}^n m_k^+ + m_i^+ - 2m_i^+\right),\right. \\ &\quad \left.\cdot\left(\sum_{k=1}^n n_k^- + n_i^- - 2n_i^-, \sum_{k=1}^n n_k^+ + n_i^+ - 2n_i^+\right)\right) \\ &= \left(\left(\sum_{k=1}^n m_k^- - m_i^-, \sum_{k=1}^n m_k^+ - m_i^+\right), \left(\sum_{k=1}^n n_k^- - n_i^-, \sum_{k=1}^n n_k^+ - n_i^+\right)\right), \\ &\qquad \text{for each } 1 \leq i \leq n. \end{aligned} \tag{6}$$

Therefore, all edges e_i,$(1 \leq i \leq n)$, have VDs. Hence, G is a NEI-IVIFG. □

Definition 25. Let G be a CIVIFG on G^*. Then, G is called to be a:

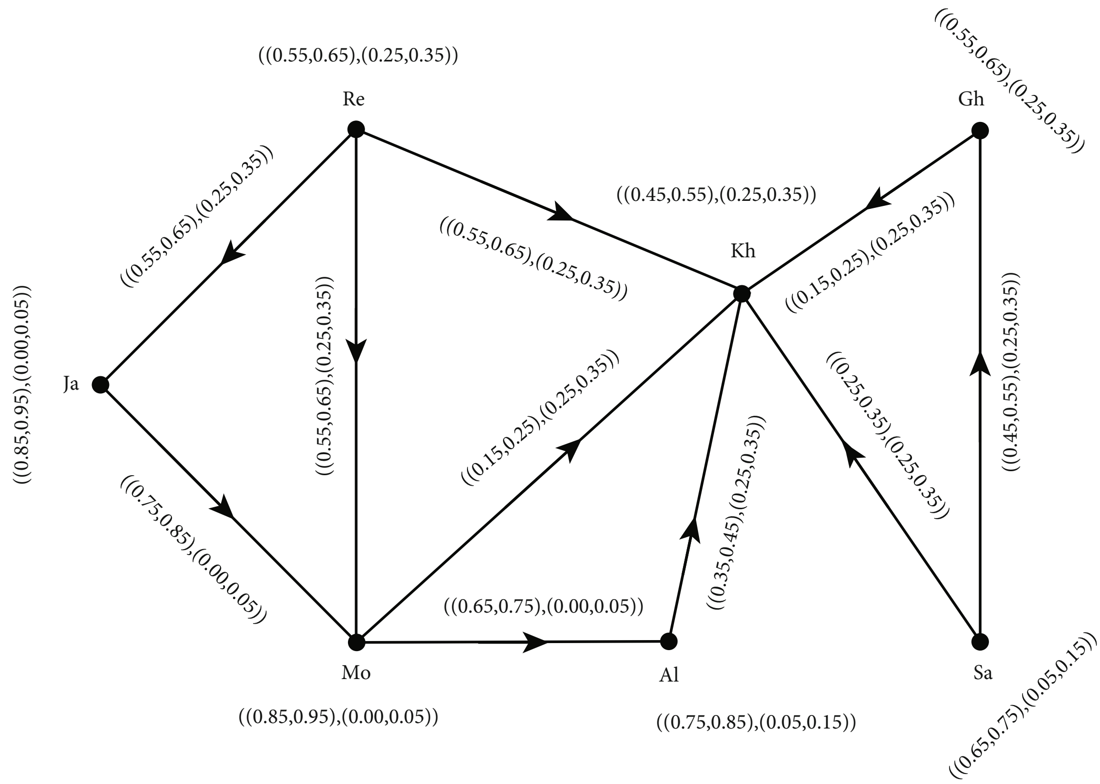

Figure 11: IVIF digraph (influence graph).

Table 4: Adjacency matrix corresponding to Figure 11.

	Ja	Mo	Al	Sa	Re	Gh	Kh
Ja	0	((0.75,0.85), (0,0.05))	0	0	0	0	0
Mo	0	0	((0.65,0.75), (0,0.05))	0	0	0	((0.15,0.25), (0.25,0.35))
Al	0	0	0	0	0	0	((0.35,0.45), (0.25,0.35))
Sa	0	0	0	0	0	((0.45,0.55), (0.25,0.35))	((0.25,0.35), (0.25,0.35))
Re	((0.55,0.65), (0.25,0.35))	((0.55,0.65), (0.25,0.35))	0	0	0	0	((0.25,0.35), (0.25,0.35))
Gh	0	0	0	0	0	0	((0.15,0.25), (0.25,0.35))
Kh	0	0	0	0	0	0	0

(i) SEI-IVIFG if each pair of edges has VDs

(ii) SETI-IVIFG if each pair of edges has various TDs

Example 26. Graph that is both SEI-IVIFG and SETI-IVIFG.

Let G be a CIVIFG on G^* which is a cycle of length five.

From Figure 6, $d_G(u) = ((0.5,0.8), (0.5,0.8))$, $d_G(v) = ((0.3,0.5), (0.7,1.1))$, $d_G(w) = ((0.5,0.7), (0.6,0.9))$, $d_G(x) = ((0.6,0.9), (0.5,0.7))$, $d_G(y) = ((0.7,1.1), (0.3,0.5))$, $d_G(uv) = ((0.6,0.9), (0.4,0.7))$, $d_G(vw) = ((0.4,0.6), (0.7,1.0))$, $d_G(wx) = ((0.5,0.8), (0.5,0.8))$, $d_G(xy) = ((0.7,1.0), (0.4,0.6))$, and $d_G(yu) = ((0.4,0.7), (0.6,0.9))$.

Thus, G is a SEI-IVIFG.

$td_G(uv) = ((0.7,1.1), (0.8,1.3))$, $td_G(vw) = ((0.6,0.9), (1.0,1.5))$, $td_G(wx) = ((0.8,1.2), (0.8,1.2))$, $td_G(xy) = ((1.0,1.5), (0.6,0.9))$, and $td_G(yu) = ((0.8,1.3), (0.7,1.1))$.

The above calculations show that each edge has various TD. Therefore, G is a SETI-IVIFG.

So, G is both SEI-IVIFG and SETI-IVIFG.

Example 27. SEI-IVIFG needs not be SETI-IVIFG.

Let G be an IVIFG so that G^*, a cycle of length three.

From Figure 7, $d_G(u) = ((0.3,0.5), (0.9,1.3))$, $d_G(v) = ((0.5,0.7), (0.8,1.2))$, $d_G(w) = ((0.4,0.6), (0.7,1.1))$, $d_G(uv) = ((0.4,0.6), (0.7,1.1))$, $d_G(vw) = ((0.3,0.5), (0.9,1.3))$, $d_G(wu) = ((0.5,0.7), (0.8,1.2))$, and $td_G(uv) = td_G(vw) = td_G(wu) = ((0.6,0.9), (1.2,1.8))$.

Note that G is SEI-IVIFG, since each pair of edges has VDs. Also, G is not SETI-IVIFG, since all the edges have same TDs. Hence, SEI-IVIFG needs not to be SETI-IVIFG.

Example 28. SETI-IVIFG needs not to be SEI-IVIFG.

Suppose G is an IVIFG so that G^*, a cycle of length four.

From Figure 8, $d_G(u) = ((0.7,1.1), (0.4,0.6))$, $d_G(v) = ((0.4,0.8), (0.7,0.9))$, $d_G(w) = ((0.8,1.2), (0.6,0.8))$, $d_G(x) = ((1.1,1.5), (0.3,0.5))$, $d_G(uv) = d_G(wx) = ((0.9,1.3), (0.5,0.7))$, $d_G(vw) = d_G(xu) = ((0.6,1.0), (0.5,0.7))$, $td_G(uv) = ((1.0,1.6), (0.8,1.1))$, $td_G(vw) = ((0.9,1.5), (0.9,1.2))$, $td_G(wx) = ((1.4,2.0), (0.7,1.0))$, and $d_G(xu) = ((1.2,1.8), (0.6,0.9))$.

It is noted that $d_G(uv) = d_G(wx)$. So, G is not SEI-IVIFG.

But G is SETI-IVIFG, since $td_G(uv) \neq td_G(vw) \neq td_G(wx) \neq td_G(xu)$. Hence, SETI-IVIFG needs not to be SEI-IVIFG.

Remark 29. Let G be a CIVIFG on G^*. If G is both SEI-IVIFG and SETI-IVIFG, then μ needs not to be a CF.

Example 30. Consider G be an IVIFG so that G^* is a cycle of length five.

From Figure 9, $d_G(u) = ((0.5,0.8), (0.5,0.8))$, $d_G(v) = ((0.3,0.5), (0.7,1.1))$, $d_G(w) = ((0.5,0.7), (0.6,0.9))$, $d_G(x) = ((0.6,0.9), (0.5,0.7))$, and $d_G(y) = ((0.7,1.1), (0.3,0.5))$. Also, $d_G(uv) = ((0.6,0.9), (0.4,0.7))$, $d_G(vw) = ((0.4,0.6), (0.7,1.0))$, $d_G(wx) = ((0.5,0.8), (0.5,0.8))$, $d_G(xy) = ((0.7,1.0), (0.4,0.6))$, and $d_G(yu) = ((0.4,0.7), (0.6,0.9))$.

Clearly, each edge in G has VD. Therefore, G is a SEI-IVIFG.

Also, $td_G(uv) = ((0.7,1.1), (0.8,1.3))$, $td_G(vw) = ((0.6,0.9), (1.0,1.5))$, $td_G(wx) = ((0.8,1.2), (0.8,1.2))$, $td_G(xy) = ((1.0,1.5), (0.6,0.9))$, and $td_G(yu) = ((0.8,1.3), (0.7,1.1))$.

Thus, each edge in G has various TD. So, G is a SETI-IVIFG. Hence, G is both SEI-IVIFG and SETI-IVIFG. But μ is not a CF.

Theorem 31. *Let G be an IVIFG on G^*. If G is a SEI-IVIFG, then G is a NEI-IVIFG.*

Proof. Let G be an IVIFG on G^* that is SEI-IVIFG. Then, each edge in G has VD. Thus, each neighbor edge has VD. So, G is a NEI-IVIFG. □

Theorem 32. *Let G be an IVIFG on G^*. If G is a SETI-IVIFG, then G is a NETI-IVIFG.*

Proof. Let G be an IVIFG on G^* that is SETI-IVIFG. Then, each pair of edges in G has various TDs. Hence, each pair of neighbor edges has various TDs. Therefore, G is a NETI-IVIFG. □

Remark 33. The inverse of Theorems 31 and 32 is not generally true.

Example 34. Let G be an IVIFG so that G^* is a path with four nodes.

From Figure 10, $d_G(u) = d_G(x) = ((0.2,0.3), (0.4,0.5))$, $d_G(v) = d_G(w) = ((0.3,0.5), (0.7,0.9))$, $d_G(uv) = ((0.1,0.2), (0.3,0.4))$, $d_G(vw) = ((0.4,0.6), (0.8,1.0))$, $d_G(wx) = ((0.1,0.2), (0.3,0.4))$, $td_G(uv) = ((0.3,0.5), (0.7,0.9))$, $td_G(vw) = ((0.5,0.8), (1.1,1.4))$, and $td_G(wx) = ((0.3,0.5), (0.7,0.9))$.

Here, $d_G(uv) \neq d_G(vw)$ and $d_G(vw) \neq d_G(wx)$. Hence, G is a NEI-IVIFG. But G is not a SEI-IVIFG, since $d_G(uv) \neq d_G(wx)$. Also, note that $td_G(uv) \neq td_G(vw)$ and $td_G(vw) \neq td_G(wx)$. So, G is a NETI-IVIFG. But G is not a SETI-IVIFG, since $td_G(uv) \neq td_G(wx)$.

4. Application of IVIF Influence Digraph to Find the Most Effective Person in a Hospital

Serving the people has always been an important duty of any government, and this has also played a significant role in the growth and prosperity of any country, because if the people are satisfied with the government of their country, then they will perform their duties in the best possible way. As a result, a healthier society will be formed with more progress. One of these very important services is taking care of people's health. Hospitals and medical centers must also serve patients in the best possible way and not neglect to admit and treat patients. But a very important issue that can be important in the service and treatment of patients in the fastest possible time is the rapid and correct management of hospital wards and health centers. If a manager can properly guide the staff under her supervision and give them the necessary training to treat patients, then the service will be provided in the best possible way. Therefore, in this section, we try to introduce the most effective staff of a hospital with the help of an IVIFG. To do this, we consider the nodes of this influence graph as the staff of a hospital and the edges as the influence of one employee on another employee. The names of the staff and their specialization in the hospital are shown in Table 2. For this hospital, the staff is as follows:

$$E = \{\text{Jafari, Mohseni, Alavi, Samie, Rezai, Ghoreishi, Khorami}\}. \tag{7}$$

(i) Mohseni has been working with Samie for 12 years and values his views on issues

(ii) Rezai has been the head of the hospital, and not only Mohseni but also Samie is very satisfied with Rezai's performance

(iii) The safety of hospital staff and also the care of hospital equipment is a very important issue. Mohseni is an expert for this

(iv) Alavi and Ghoreishi have a long history of conflict

(v) Samie is very effective in laboratory and radiology affairs of the hospital

Considering the above points, the influence graph can be very important. But such a graph cannot show the power of employees within a hospital and the degree of influence of employees on each other. Since power and influence do not have defined boundaries, they can be represented as an interval-valued fuzzy set. On the other hand, there can be no fair interpretation of the power and influence of individuals, because evaluations are always accompanied by skepticism. So, here we use the interval-valued intuitionistic fuzzy degrees, which is very useful for influence and conflicts between employees. The interval-valued intuitionistic fuzzy set of employees is shown in Table 3.

We have shown the influence of persons in the IVIF digraph with an edge. This graph is shown in Figure 11, and its adjacency matrix is shown in Table 4.

Hospital staff are the vertices of the IVIF digraph of Figure 11, and their strength in terms of conditions, degrees of IVM, and IV-NM is that it can also be expressed as a percentage. For example, Mr. Alavi has 75% to 85% of power and between 5% and 15% does not have this power. Also, the edges of this graph indicate the influence of one person on another. Degree of IVM and IV-NM can be described in terms of positive and negative influence. For example, between 55% and 65% of the time, Mr. Jafari is influenced by Mr. Rezaei's thoughts and ideas, but 25% to 35% of the time he is not influenced by his opinions.

In Figure 11, it is clear that Mr. Rezaei controls both the medical equipment experts: Mr. Jafari and the head of security guard, Mr. Mohseni. His influence on both of them is the same. Because the IV membership rate in both of them is (0.55, 0.65), i.e., 55% to 65%. But in the case of Mr. Rezaei and Mr. Mohseni, the degree of doubt is between 0% and 20% because

$$(1 - 0.65 - 0.35, 1 - 0.55 - 0.25) = (0, 0.20), \tag{8}$$

and in the case of Mr. Jafari and Mohseni, it is between 10% and 25% because

$$(1 - 0.85 - 0.05, 1 - 0.75 - 0) = (0.10, 0.25). \tag{9}$$

The implication is that Mr. Jafari is more skeptical than Mr. Rezaei. Clearly, Mr. Rezaei has the most influence in the organization, because he dominates both the equipment expert and the security guard; these two people have the most power in the hospital, i.e., between 85% and 95%.

5. Conclusions

Interval-valued intuitionistic fuzzy graphs have various uses in modern science and technology, especially in the fields of neural networks, computer science, operation research, and decision-making. Also, they have a wide range of applications in the field of psychological sciences as well as the identification of individuals based on oncological behaviors. With the help of IVIFGs, the most effective person in an organization can be identified according to the important factors that can be useful for an institution. Therefore, in this research, some types of EI-IVIFGs such as NETI-IVIFGs, SEI-IVIFGs, and SETI-IVIFGs are introduced. A comparative study between NEI-IVIFGs and NETI-IVIFGs is presented. Finally, an application of IVIF influence digraph has presented. In our future work, we will introduce connectivity index, Winer index, and Randic index in interval-valued intuitionistic fuzzy graphs and investigate some of their properties. Also, we will investigate some types of energy, including Laplacian and skew Laplacian in both interval-valued intuitionistic fuzzy graphs and interval-valued intuitionistic fuzzy digraphs.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Acknowledgments

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References

[1] L. A. Zadeh, "Fuzzy sets," *Information and Control*, vol. 8, pp. 338–353, 1965.

[2] A. Kaufman, "Introduction a la theorie des sous-emsembles flous," *Masson et Cie*, vol. 1, 1973.

[3] L. A. Zadeh, "Similarity relations and fuzzy ordering," *Information Sciences*, vol. 3, pp. 177–200, 1971.

[4] L. A. Zadeh, "Is there a need for fuzzy logical," *Information Sciences*, vol. 178, pp. 2751–2779, 2008.

[5] A. Rosenfeld, *Fuzzy Graphs, Fuzzy Sets and Their Applications*, L. A. Zadeh, K. S. Fu, and M. Shimura, Eds., Academic Press, New York, 1975.

[6] P. Bhattacharya, "Some remarks on fuzzy graphs," *Pattern Recognition Letters*, vol. 6, no. 5, pp. 297–302, 1987.

[7] J. N. Mordeson and P. S. Nair, *Fuzzy Graph and Fuzzy Hypergraphs*, PhysicaVerlag, Heidebeg, Second edition, 2001.

[8] K. T. Atanassov, "Intuitionistic fuzzy sets," *International Journal Bioautomation*, vol. 20, pp. 87–96, 1986.

[9] K. T. Atanassov and G. Gargov, "Interval-valued intuitionistic fuzzy sets," *Fuzzy Sets and Systems*, vol. 31, no. 3, pp. 343–349, 1989.

[10] K. T. Atanassov, "Intuitionistic Fuzzy Sets," in *Theory, Applications, Studies in Fuzziness and Soft Computing*, Physica-Verl, Heidelberg, New York, 1999.

[11] M. Akram and B. Davvaz, "Strong intuitionistic fuzzy graphs," *Filomat*, vol. 26, no. 1, pp. 177–196, 2012.

[12] J. Hongmei and W. Lianhua, "Interval-valued fuzzy subsemigroups and subgroups associated by interval-valued fuzzy graphs," *2009 WRz Global Congress on Intelligent Systems*, vol. 1, pp. 484–487, 2009.

[13] M. G. Karunambigai, S. Sivasankar, and K. Palanivel, "Edge regular intuitionistic fuzzy graph," *Advances in Fuzzy Sets and Systems*, vol. 20, no. 1, pp. 25–46, 2015.

[14] S. N. Mishra and A. Pal, "Product of interval-valued intuitionistic fuzzy graph," *Annals of Pure and Applied Mathematics*, vol. 5, no. 1, pp. 37–46, 2013.

[15] A. Nagoorgani and K. Radha, "The degree of a vertex in some fuzzy graphs," *International Journal of Algorithms, Computing and Mathematics*, vol. 2, no. 3, pp. 107–116, 2009.

[16] A. Nagoorgani and K. Radha, "On regular fuzzy graphs," *Journal of Physical Sciences*, vol. 12, pp. 33–44, 2008.

[17] A. Nagoorgani and S. R. Latha, "On irregular fuzzy graphs," *Applied Mathematical Sciences*, vol. 6, no. 11, pp. 517–523, 2012.

[18] Z. Shao, S. Kosari, H. Rashmanlou, and M. Shoaib, "New concepts in intuitionistic fuzzy graph with application in water supplier systems," *Mathematics*, vol. 8, no. 8, p. 1241, 2020.

[19] S. P. Nandhini and E. Nandhini, "Strongly irregular fuzzy graphs," *International Journal of Mathematical Archive*, vol. 5, no. 5, pp. 110–114, 2014.

[20] N. R. Santhi Maheswari and C. Sekar, "On edge irregular fuzzy graphs," *International Journal of Mathematics and Soft Computing*, vol. 6, no. 2, pp. 131–143, 2016.

[21] N. R. Santhi Maheswari and C. Sekar, "On neighbourly edge irregular fuzzy graphs," *International Journal of Mathematical Archive*, vol. 6, no. 10, pp. 224–231, 2015.

[22] N. R. Santhi Maheswari and C. Sekar, "On strongly edge irregular fuzzy graphs," *Kragujevac Journal of Mathematics*, vol. 40, no. 1, pp. 125–135, 2016.

[23] S. Kosari, Y. Rao, H. Jiang, X. Liu, P. Wu, and Z. Shao, "Vague graph structure with application in medical diagnosis," *Symmetry*, vol. 12, no. 10, p. 1582, 2020.

[24] Y. Rao, S. Kosari, and Z. Shao, "Certain properties of vague graphs with a novel application," *Mathematics*, vol. 8, no. 10, p. 1647, 2020.

[25] Y. Rao, S. Kosari, Z. Shao, R. Cai, and L. Xinyue, "A study on domination in vague incidence graph and its application in medical sciences," *Symmetry*, vol. 12, no. 11, p. 1885, 2020.

[26] X. Shi and S. Kosari, "Certain properties of domination in product vague graphs with an application in medicine," *Frontiers of Physics*, vol. 9, article 680634, 2021.

[27] A. A. Talebi, M. Ghassemi, and H. Rashmanlou, "New concepts of irregular-intuitionistic fuzzy graphs with applications," *Annals of the University of Craiova-Mathematics and Computer Science Series*, vol. 47, no. 2, pp. 226–243, 2020.

[28] A. A. Talebi, M. Ghassemi, H. Rashmanlou, and S. Broumi, "Novel properties of edge irregular single valued neutrosophic graphs," *Neutrosophic Sets and Systems (NSS)*, vol. 43, pp. 255–279, 2021.

[29] A. A. Talebi, H. Rashmanlou, and M. Ghassemi, *New Concepts of Strongly Edge Irregular Interval-Valued Neutrosophic Graphs*, Nova Science Publishers, Inc., 2020.

[30] A. A. Talebi, H. Rashmanlou, and S. H. Sadati, "Interval-valued intuitionistic fuzzy competition graph," *Journal of Multiple-Valued Logic and Soft Computing*, vol. 34, pp. 335–364, 2020.

[31] Z. Kou, S. Kosari, and M. Akhoundi, "A novel description on vague graph with application in transportation systems," *Journal of Mathematics*, vol. 2021, Article ID 4800499, 11 pages, 2021.

[32] K. Kalaiarasi and L. Mahalakshmi, "Regular and irreguar m-polar fuzzy graphs," *Global Journal of Mathematical Sciences: Theory and Practical*, vol. 9, no. 2, pp. 139–152, 2017.

[33] S. Selvanayaki, "Strong and balanced irregular interval valued fuzzy graphs," *International Journal of Engineering, Science and Mathematics*, vol. 6, no. 2, pp. 28–37, 2017.

[34] H. Rashmanlou, G. Muhiuddin, S. K. Amanathulla, F. Mofidnakhaei, and M. Pal, "A study on cubic graphs with novel application," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 1, pp. 89–101, 2021.

[35] S. Poulik and G. Ghorai, "Detour g-interior nodes and detour g-boundary nodes in bipolar fuzzy graph with applications," *Hacettepe Journal of Mathematics and Statistics*, vol. 49, no. 1, pp. 106–119, 2020.

[36] S. Poulik and G. Ghorai, "Certain indices of graphs under bipolar fuzzy environment with applications," *Soft Computing*, vol. 24, no. 7, pp. 5119–5131, 2020.

[37] S. Poulik and G. Ghorai, "Applications of graph's complete degree with bipolar fuzzy information," in *Complex & Intelligent Systems*, Springer, 2021.

[38] T. Pramanik, G. Muhiuddin, A. M. Alanazi, and M. Pal, "An extension of fuzzy competition graph and its uses in manufacturing industries," *Mathematics*, vol. 8, no. 6, 2020.

[39] G. Muhiuddin, N. Sridharan, D. Al-Kadi, S. Amutha, and M. E. Elnair, "Reinforcement number of a graph with respect to half-domination," *Journal of Mathematics*, vol. 2021, Article ID 6689816, 7 pages, 2021.

[40] S. K. Amanathulla, G. Muhiuddin, D. Al-Kadi, and M. Pal, "Distance two surjective labelling of paths and interval graphs," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 9958077, 9 pages, 2021.

[41] C. Ramprasad, P. L. N. Varma, S. Satyanarayana, and N. Srinivasarao, "Morphism of m-polar fuzzy graph,"

Advances in Fuzzy Systems, vol. 2017, Article ID 4715421, 9 pages, 2017.

[42] I. Nazeer, T. Rashid, and A. Keikha, "An application of product of intuitionistic fuzzy incidence graphs in textile industry," *Complexity*, vol. 2021, Article ID 5541125, 16 pages, 2021.

[43] A. Bhattacharya and M. Pal, "Fuzzy covering problem of fuzzy graphs and its application to investigate the Indian economy in new normal," *Journal of Applied Mathematics and Computing*, vol. 68, no. 1, pp. 479–510, 2022.

[44] R. A. Borzooei, R. Almallah, Y. B. Jun, and H. Ghaznavi, "Inverse fuzzy graphs with applications," *New Mathematics and Natural Computation*, vol. 16, no. 2, pp. 397–418, 2020.