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Three Types of Fuzzy Group Topological Spaces and a Comparison Among Them

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Abstract

In this paper, we introduce three new structures of fuzzy group sets and three new structures of fuzzy group topological spaces and we study the relation among them

1 Introduction

In 1979, Foster [1] introduced the concept of fuzzy topological group using Lowen's definition of fuzzy topological spaces. Since then, several definitions and studies of fuzzy topological groups have been proposed. For instance, Hai [3] and Liang [4] presented definitions based on Chang's definition. In this paper, we introduce three new structures of fuzzy group sets using a different approach from previous definitions: element fuzzy group set, fuzzy

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group set, and dual fuzzy group set. We investigate the relationships among them based on the definition of crisp sets [2] and generate three new related structures of fuzzy group topologies: element fuzzy group topology, fuzzy group topology, and dual fuzzy group topology.

2 Element Fuzzy Group Topology

In this section, we introduce a new type of group topological space called Element Fuzzy Group Topology but before that we give the following definition and some remarks.

Definition 2.1. *A group G is called an element fuzzy group set, denoted by fgx-set, if for each element a in G associated to a membership function $M_G(a)$, where $M_G(a) : a \to [0,1]$ for all $a \in G$; i.e., fgx-set $\widetilde{U} = \{\tilde{a} : \tilde{a} = a_\lambda^{M_{G(a_\lambda)}}, forall \quad \lambda \in \omega\}$.*

Remark 2.2. *1- The universal fgx-set $\widetilde{U} = \{\tilde{a} : \tilde{a} = a_\lambda^{M_{G(a_\lambda)}}, M_G(a_\lambda) = 1, a_\lambda \in \mathbb{R}, forall \quad \lambda \in \omega\}$.*
2- The null f_gx-set $\widetilde{\phi} = \{\tilde{a} : \tilde{a} = a_\lambda^{M_{G(a_\lambda)}}, M_G(a_\lambda) = 0, a_\lambda = 0, forall \quad \lambda \in \omega\}$.
3- That $\tilde{a}$ is an fgx-element of fgx-set $\tilde{U}$ will be denoted by $\tilde{a}\tilde{\in}\tilde{U}$.
4- Two fgx-elements $\tilde{a} : \tilde{a} = a_\lambda^{M_{G(a_\lambda)}}$, $\tilde{e} : \tilde{e} = e_\lambda^{M_{G(e_\lambda)}}$ are fgx-equal if $a_\lambda = e_\lambda$ and $M_G(a_\lambda) = M_G(e_\lambda)$.
5- For fgx-sets $\tilde{A}$ and $\tilde{Y}$ generated by the same group G , $\tilde{A}$ is said to be fgx-subset of $\tilde{Y}$ ($\tilde{A}\tilde{\subseteq}\tilde{Y}$) if for every fgx–element $\tilde{a}\tilde{\in}\tilde{Y}$, we have $\tilde{a} \in \tilde{Y}$.
6- The fgx-union, fgx-intersection of two fgx-sets $\tilde{A}$,$\tilde{Y}$ generated by the same group G, where $\tilde{A} = \{\tilde{a}_\lambda : \tilde{a}_\lambda = a_\lambda^{M_{G(a_\lambda)}}, forall \quad \lambda \in \omega\}$, $\tilde{Y} = \{\tilde{a}_\sigma : \tilde{a}_\sigma = a_\sigma^{M_{G(a_\sigma)}}, for\ all \quad \sigma \in \omega\}$ are defined as follows:
$\tilde{N} = \tilde{A}\tilde{\cup}\tilde{Y} = \{\tilde{a}_\rho : \tilde{a}_\rho = a_\rho^{M_{G(a_\rho)}}, for\ all \quad \rho \in \omega\}$, $M_G(a_\rho) = max\{M_G(a_\lambda), M_G(a_\sigma)\}$, $a_\rho = max\{a_\lambda, a_\sigma\}$, $\tilde{N} = \tilde{A}\tilde{\cap}\tilde{Y} = \{\tilde{a}_\rho : \tilde{a}_\rho = a_\rho^{M_{G(a_\rho)}}, for\ all \quad \rho \in \omega\}$, $M_G(a_\rho) = min\{M_G(a_\lambda), M_G(a_\sigma)\}$, $a_\rho = min\{a_\lambda, a_\sigma\}$.

Example 2.3. *1- Consider the group $G = (G, .) = \{1, -1, i, -i\}$ Define $M_G(a) : a \to [0,1]$, and*

$$M_G(a) = \begin{cases} 0.2, & x = 1 \\ 0.4, & x = -1 \\ 0.5, & x = \pm i \end{cases}$$

Then $\tilde{A} = \{1^{0.2}, -1^{0.4}, i^{0.5}, -i^{0.5}\}$ *is* fgx*-set .*

2- Let $G = (\mathbb{Z}, +)$ *and* $M_G(a) : a \to [0, 1]$*, for all* $a \in G$ *defined as follows:* $M_G(a) = 0.0369$ *for all* $a \in G$*. Then the resulting set is* fgx*-set.*

Definition 2.4. *Let* G *be a group. Then* (G, τ_{fgx}) *is called an element fuzzy group topological space (simply* τ_{fgx}*-space) on* $\tilde{V}$ *(the maximum* fg_x*-set) if* τ_{fgx} *satisfies the following conditions:*

1. $\tilde{\phi}$*,* $\tilde{V}$ *are in* τ_{fgx}*,*

2. *The* fgx*-union of any members of* fgx*-set in* τ_{fgx} *belongs to* τ_{fgx}*,*

3. *The* fgx*-intersection of any two* fgx*-set in* τ_{fgx} *belong to* τ_{fgx} *.*

The fgx*-sets of* τ_{fgx} *are called* τ_{fgx}*-open sets, their complements are called* τ_{fgx}*-closed sets.*

Remark 2.5. *If* $\tilde{A}\tilde{\in}\tau_{fgx}$*, the complement of* fgx*-set* $\tilde{A} = \{\tilde{a} = a_\lambda^{(M_G(x_\lambda))}\}$ *is defined by:* $\tilde{A}^c = \{\tilde{a}^c : \tilde{a}^c = a_\lambda^{(1-(M_G(x_\lambda)))}, \lambda \in \omega\}$*.*

Definition 2.6. *An* fgx*-set* $\tilde{A}$ *in an* fgx*-topology* (G, τ_{fgx}) *is called* fgx*-neighborhood of* fgx*-point* $\tilde{a}$ *in* (G, τ_{fgx}) *if there is a* fgx*-set* $\tilde{V}$ *in* τ_{fgx} *such that* $\tilde{a}\tilde{\in}\tilde{V}\tilde{\subseteq}\tilde{A}$*.*

Definition 2.7. *Let* G *be a group,* (G, τ_{fgx}) *be a* fgx*-space and* $\tilde{A}\tilde{\in}\tau_{fgx}$*. Then the closure and interior of* $\tilde{A}$ *are defined by:*
$cl(\tilde{A}) = \tilde{\cap}\{\tilde{Y} : \tilde{Y} fgx-closed \quad set \quad in \quad \tau_{fgx}, \tilde{A}\tilde{\subseteq}\tilde{Y}\}$ *and*
$int(\tilde{A}) = \tilde{\cup}\{\tilde{Y} : \tilde{Y} fgx-open \quad set \quad in \quad \tau_{fgx}, \tilde{Y}\tilde{\subseteq}\tilde{A}\}$*.*

3 Fuzzy Group Topology

Definition 3.1. *Let* G *be a group. If each element* x *in* G *associated to a membership function* M_G *where* $M_G : G \to [0, 1]$*. Then the resulting set is said to be fuzzy group (denoted by* fg*-set).*

Remark 3.2. *1- For a group* G*, the* fg*-universal set* $\hat{G} = \{G^{M_G} : M_G(x) = 1\}$*.*
2- For a group G*, the* fg*-null set* $\hat{\phi} = \{G^{M_G} : M_G = 0\}$*.*
3- The fact that $\hat{a}$ *is an* fg*-element of* fg*-set* $\hat{A}$ *will be denoted by* $\hat{a}\hat{\in}\hat{A}$*.*
4- Two fg*–elements* $\hat{a} = a^{M_{G_1}}$ *,*$\hat{h} = h^{M_{G_2}}$ *are* fg*-equal if* $a = h$ *and* $M_{G_1} =$

M_{G_2}.
5- For fg-sets $\hat{E}$, $\hat{H}$ generated by the same group G , $\hat{E}$ is said to be fg-subset of $\hat{H}$ ($\hat{E}\hat{\subseteq}\hat{H}$) if every fg-element in $\hat{E}$ is in $\hat{H}$.
6- The fg-union, fg-intersection of two fg-sets $\hat{A}$, $\hat{E}$ generated by the same group are defined as follows:
$\hat{C} = \hat{A}\hat{\cup}\hat{E} = G^{M_{GA}}\hat{\cup}(G^{M_{GE}}) = C^{M_{G}c}, M_{G}c = max\{M_{GA}, M_{GE}\}$.
and $\hat{C} = \hat{A}\hat{\cap}\hat{E} = G^{M_{GA}}\hat{\cup}(G^{M_{GE}}) = C^{M_{G}c}, M_{G}c = min\{M_{GA}, M_{GE}\}$

Example 3.3. *Consider the group* $G = (G, .) = \{1, -1, i, -i\}$. *Define* $M_G : G \to [0, 1]$, $M_G = 0.2$, *then* $\hat{A} = \{1, -1, i, -i\}^{0.2}$ *is* fg-*set.*

Definition 3.4. *Let* G *be a group . Then* (G, τ_{fg}) *is called a fuzzy group topological space (simply* τ_{fg}*-space) on* $\hat{H}$ *(the maximum* fg*-set) if* τ_{fg}) *satisfies the following conditions :*
(1) $\hat{\phi}, \hat{H}$ *are in* τ_{fg},
(2) The fg*-union of any members of* fg*-sets in* τ_{fg} *belongs to* τ_{fg},
(3) The fg*-intersection of any two* fg*-sets in* τ_{fg} *belong to* τ_{fg},
The fg*- sets of* τ_{fg} *are called* τ_{fg}*-open sets and their complements are called* τ_{fg}*-closed sets.*

Remark 3.5. *If* $\hat{U}\hat{\in}\tau_{fg}$, *the complement of* fg*-set* $\hat{U} = \{G^{M_G} : M_G \in [0, 1]\}$ *is defined by:* $\hat{U}^c = \{G^{1-M_G} : M_G \in [0, 1]\}$.

Example 3.6. *Let* $G = \{1, -1\}$, $M_G : G \to [0, 1]$ *and* fg*-sets are defined as follows:* $\hat{A} = \{1, -1\}^1$, $\hat{C} = \{1, -1\}^{0.7}$, $\hat{H} = \{1, -1\}^{0.5}$. *Then* $\tau_{fg} = \{\hat{\phi}, \hat{A}, \hat{C}, \hat{H}\}$ *is an element fuzzy group topology over* $\hat{A}$, $\hat{A}^c = \{1, -1\}^0 = \hat{\phi}$.

Definition 3.7. *An* fg*-set* $\hat{E}$ *in* fg*–space* (G, τ_{fg}) *is called* fg*-neighborhood of* fg*-point* $\hat{a}$ *in* (G, τ_{fg}) *if there is a* fg*-set* $\hat{H}$ *in* τ_{fg} *such that* $\hat{a}\hat{\in}\hat{H}\hat{\subseteq}\hat{E}$.

Definition 3.8. *Let* (G, τ_{fg}) *be an* fg*-space and* $\hat{A}\hat{\in}\tau_{fg}$. *Then the closure and interior of* $\hat{A}$ *are defined by:*
$cl(\hat{A}) = \hat{\cap}\{\hat{E} : \hat{E}$ *be an fgx- closed set in*$\tau_{fg}, \hat{A}\hat{\subseteq}\hat{E}\}$ *and* $int(\hat{A}) = \hat{\cup}\{\hat{E} : \hat{E}$ *be an fg- open set in*$\tau_{fg}, \hat{E}\hat{\subseteq}\hat{A}\}$

4 Dual Fuzzy Group Topology

Definition 4.1. *Let* G *be a group if each element* a *in* G *associated to a membership function* $M_G(a)$ *where* $M_G(a) : a \to [0, 1]$, *and* G *associated to membership function* M_G *where* $M_G : G \to [0, 1]$. *Then the result set is said to be dual fuzzy group (denoted by* dfg*-set).*

Remark 4.2. *1- The dfg-universal set* $\check{U} = \{\check{a} : \check{a} = G_{\lambda}^{M_G(a_\lambda)} : M_G(a_\lambda) = 1, for\ all\ \lambda \in \omega, M_G = 1\}$.
2- The dfg-null set $\check{\phi} = \{\check{a} : \check{a} = G_{\lambda}^{M_G(a_\lambda)} : M_G(a_\lambda) = 0, for\ all \lambda \in \omega, M_G = 0\}$.
3- The fact that $\hat{a}$ *is an dfg-element of dfg-set* $\check{A}$ *will be denoted by* $\check{a} \check{\in} \check{A}$.
4- Two dfg–elements $\check{a} = a_{\lambda}^{M_G(a_\lambda)}$ *with* $M_G = \delta$ *and* $\check{v} = v_{\lambda}^{M_G(v_\lambda)}$ *with* $M_G = \gamma$ *are dfg-equal if* $a_\lambda = v_\lambda$ *and* $M_G(a_\lambda) = M_G(v_\lambda)$ *and* $\delta = \gamma$.
5- For dfg-sets $\check{A}$, $\check{N}$ *generated by the same group G ,*$\check{A}$ *is said to be dfg-subset of* $\check{N}$ $(\check{A} \check{\subseteq} \check{N})$ *if every dfg-element in* $\check{A}$ *is in* $\check{N}$.
6- The dfg-union, dfg-intersection of two dfg-sets $\check{A}$, $\check{B}$ *generated by the same group where* $\check{A} = \{\check{a}_\lambda : \check{a}_\lambda = a_{\lambda}^{M_A(a_\lambda)}, \lambda \in \omega, M_A = \delta\}$ *and* $\check{B} = \{\check{a}_\sigma : \check{a}_\sigma = a_{\sigma}^{M_B(a_\sigma)}, \sigma \in \omega, M_A = \gamma\}$ *are defined as follows:*
$\check{C} = \check{A}^{M_A} \check{\cup} \check{B}^{M_B} = \{\check{a}_\rho : \check{a}_\rho = a_{\rho}^{M_c(a_\rho)}, \rho \in \omega\}$ $M_c(a_\rho) = max\{M_G a_\lambda, M_G a_\sigma\}$, *and* $M_c = max\{M_A, M_B\}$.
$\check{C}^{M_C} = \check{A}^{M_A} \check{\cap} \check{B}^{M_B} = \{\check{a}_\rho : \check{a}_\rho = a_{\rho}^{M_c(a_\rho)}, \rho \in \omega\}$ $M_c(a_\rho) = min\{M_G a_\lambda, M_G a_\sigma\}$, *and* $M_c = min\{M_A, M_B\}$.

Example 4.3. *Consider the group* $G = (G, .) = \{1, -1, i, -i\}$. *Define* $M_G(x) : G \to [0, 1]$, *for all* $x \in G$, *and*

$$M_G(x) = \begin{cases} 0.2, & x = 1 \\ 0.4, & x = -1 \\ 0.5, & x = \pm i \end{cases}$$

and $M_G = 0.8$. *Then* $\check{G} = \{1^{0.2}, -1^{0.4}, i^{0.5}, -i^{0.5}\}^{0.8}$ *is dfg-set .*

Definition 4.4. *Let G be a group. Then* (G, τ_{dfg}) *is called a dual fuzzy group topological space (simply* $\tau_{dfg}-$*space) on* $\check{A}$ *(the maximum dfg-set) if* τ_{dfg} *satisfies the following conditions:*
(1)$\check{\phi}, \check{A}$ *are in* τ_{dfg},
(2) The dfg-union of any members of dfg-set in τ_{dfg} *belongs to* τ_{dfg},
(3) The dfg-intersection of any two dfg-set in τ_{dfg} *belong to* τ_{dfg},
The dfg-sets of τ_{dfg} *are called* τ_{dfg}*-open sets, their complements are called* τ_{dfg}*-closed sets .*

Remark 4.5. *If* $\check{U} \check{\in} \tau_{dfg}$, *the complement of dfg-set*
$\check{U} = \{\check{a} = a_{\lambda}^{M_G(a_\lambda)}$ *with* $M_G = \gamma\}$ *is defined by:*
$\check{U}^c = \{\check{a}^c : \check{a}^c = a_{\lambda}^{1-M_G(a_\lambda)}, \lambda \in \omega$ *with* $M_G = 1 - \gamma, \gamma \in [0, 1]\}$.

Example 4.6. *Let* $G = (G, .) = \{1, -1\}$ *and dfg-set are defined as follows:* $\check{U} = \{1^1, -1^1\}^1$, $\check{N} = \{1^{0.3}, -1^{0.5}\}^{0.4}$, $\check{E} = \{1^{0.6}, -10.7\}^{0.8}$ *Then* $\tau_{dfg} = \{\check{\phi}, \check{U}, \check{N}, \check{E}\}$ *is a dual fuzzy Group Topology over* $\check{U}$, $\check{N}^c = \{1^{0.7}, -1^{0.5}\}^{0.6}$.

Definition 4.7. *A dfg-set $\check{A}$ in dfg-topology (G, τ_{dfg}) is called dfg-neighborhood of dfg-point $\check{a}$ in (G, τ_{dfg}) if there is a dfg-set $\check{N}$ in τ_{dfg} such that $\check{a}\check{\in}\check{N}\check{\subseteq}\check{A}$.*

Definition 4.8 Let (G, τ_{dfg}) be a dfg-topological space and $\check{A}$ in τ_{dfg}, then the closure and interior of $\check{A}$ are defined by:
$cl(\check{A}) = \check{\cap}\{\check{N} : \check{N} \quad \text{be dfg-closed set in} \quad \tau_{dfg}, \check{A}\check{\subseteq}\check{N}\}$ and $int(\check{A}) = \check{\cup}\{\check{N} : \check{N} \quad \text{be dfg-open set in} \quad \tau_{dfg}, \check{N}\check{\subseteq}\check{A}\}$

5 Comparison between Types of Fuzzy Group Topologies

Definition 5.1 (2). *A crisp (or classical) set $V \subseteq A$ is a set characterized by the function $\chi_V : A \to 0, 1$ called the characteristic function and V is defined by $V = \{x \in A|\chi(x) = 0 \quad ifx \notin V, \chi(x) = 1 \quad ifx \in V\}$.*

Lemma 5.2. *Every fuzzy group set considered as a special case of the dual fuzzy group set.*

Proof. From the dual fuzzy group set definition. Let $\check{U}$ be dfg–set , define a group G, the group G associated to a membership function $M_G : G \to [0, 1]$, each element x in G associated to a membership function$M_G(x)$ where $M_G(x) : x \to [0, 1]$,for all $x \in G$. Suppose $M_G(x) = 1$ for all $x \in G$(as a special case) then the resulting set is fuzzy group set . □

Lemma 5.3. *Every element fuzzy group set considered as a special case of the dual fuzzy group set.*

Proof. From the dual fuzzy group set definition let $\check{A}$ be a dfg–set define a group G, each element x in G associated to a membership function $M_G(x)$ where $M_{x\in G} : x \to [0, 1]$, for all $x \in G$, the group G associated to a membership function $M_G : G \to [0, 1]$, suppose $M_G = 1$ (as a special case) then the resulting set is element fuzzy group set .

□

Remark 5.4. *1- Dual fuzzy group set is not necessary element fuzzy group set.*
2- Fuzzy group set is not necessary element fuzzy group set.
3- Element fuzzy group set is not necessary fuzzy group set.
4- Each element fuzzy group set is dual fuzzy group set.
5- Each fuzzy group set is dual fuzzy group set.
6- Dual fuzzy group set is not necessary fuzzy group set.

Example 5.5. *1- Let* $G = (G, .) = \{1, -1\}$*, and* $M_G = 0.7$*. Consider* dfg*-set* $\check{A} = \{1^{0.5}, -1^{0.2}\}^{0.7}$*. Then* $\check{A}$ *is not* fgx*–set since* $M_G \neq 1$ *.*
2- Consider $G = (\mathbb{C}, +)$ *be a commutative group with* $M_(G) : G \to [0, 1]$ *,* $M_G = 0.5$*. Then the result* fg*–set is not* fgx*–set since* $M_G \neq 1$*.*
3- Consider $G = (\mathbb{R}, +)$ *be a commutative group with* $M_(G)(x) : x \to [0, 1]$*,* $M_G(x) = 0.57$ *for all* $x \in G$*. Then the resulting* fgx*–set is not* fg*–set since* $M_G(x) \neq 1$ *for all* $x \in G$ *.*
4- Let $G = (G, .) = \{1, -1\}$*,* fgx*-set* $\tilde{A} = \{1^{0.5}, -1^{0.2}\}$ *. Then* $\tilde{A}$ *is* dfg*–set since the membership of* G *is 1.*
5- Let $G = (G, .) = \{1, -1\}$*,* fg*–set* $\hat{A} = \{1, -1\}^{0.023}$*. Then* $\hat{A}$ *is* dfg*–set since the member ship of each element in* G *is 1.*
6- From (1) $\check{A}$ *is* dfg*–set but not* fg*–set.*

Theorem 5.6. *Every element fuzzy group topological space is dual fuzzy group topological space.*

Proof. From Lemma 5.3. □

Dual fuzzy group topological space need not be element fuzzy group topological space, consider the following example.

Example 5.7. $G = (G, .) = \{1, -1\}$ *,*$dfgx$*–sets are defined as follows :* $\check{U} = \{1^1, -1^1\}^1$*,* $\check{N} = \{1^{0.5}, -1^{0.5}\}^{0.6}$ *,* $\check{E} = \{1^{0.7}, -1^{0.8}\}^{0.9}$ *,* $\tau_{dfg} = \{\check{\phi}, \check{U}, \check{N}, \check{E}\}$ *is a dual fuzzy group topology but not an element fuzzy group topological space since* $M_G \neq 1$*, for each* dfg*-open.*

Remark 5.8. *1- Fuzzy group topological space need not be element fuzzy group topological space.*
2- Element fuzzy group topological space need not be fuzzy group topological space.

Example 5.9. *1- Consider* $G = (\mathbb{C}, +)$ *be a commutative group with* $M_G : G \to [0, 1]$ *,* $M_G = 0.5$ *. Then the resulting fuzzy group set is not element fuzzy group set since* $M_G \neq 1$*.*
2- Consider $G = (\mathbb{R}, +)$ *be a commutative group with* $M_(G)(x) : x \to [0, 1]$ *,* $M_G(x) = 0.57$ *for all* $x \in G$*. Then the resulting element fuzzy group set is not fuzzy group set since* $M_G(x) \neq 1$ *, for all* $x \in G$*.*

Theorem 5.10. *Every fuzzy group topological space is dual fuzzy group topological space.*

Proof. The sesult follows since every fuzzy group set is a dual fuzzy group set. □

Remark 5.11. *Dual fuzzy group topological space need not be fuzzy group topological space*

Example 5.12. $G = (G, .) = \{1, -1\}$ *,$dfgx$–sets are defined as follows:* $\check{U} = \{1^1, -1^1\}^1$, $\check{N} = \{1^{0.5}, -1^{0.5}\}^{0.6}$, $\check{E} = \{1^{0.7}, -1^{0.8}\}^{0.9}$, $\tau_{dfg} = \{\check{\phi}, \check{U}, \check{N}, \check{E}\}$ *is a dual fuzzy group topology but not an element fuzzy group topological space since* $M_G \neq 1$ *for each dfg-open set in* τ_{dfg}.

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