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ON SOMEWHAT PAIRWISE FUZZY FAINTLY ω-CONTINUOUS FUNCTIONS

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Abstract

In this paper the concept of somewhat pairwise fuzzy faintly ω-continuous functions and somewhat pairwise fuzzy faintly ω-open functions are introduced. Some interesting properties of these functions are investigated besides giving some characterizations of these functions.

Keywords
Fuzzy ω-open set, fuzzy ω-continuous function, somewhat pairwise fuzzy faintly ω-continuous function, somewhat pairwise fuzzy faintly ω-open function, pairwise fuzzy ω-dense set, pairwise fuzzy θ^*-dense set.

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1. Introduction

The fuzzy concept has invaded almost all branches of Mathematics ever since the introduction of fuzzy sets by Zadeh [10]. Fuzzy sets have applications in many fields such as information [7] and control [8]. The theory of fuzzy topological spaces was introduced and developed by Chang [3] and since then various notions in classical topology have been extended to fuzzy topological spaces. The concept of somewhat continuous functions was introduced by Karl. R.Gentry and Hughes.B.Hoyle III in [5] . In 1989 Kandil
[4] introduced the concept of fuzzy bitopological spaces. Uma, Roja and Balasubramanian introduced the concept of somewhat pairwise fuzzy continuous functions [9]. Anjan Mukherjee introduced the concept of fuzzy faintly continuous functions in [1]. The concept of
ω-continuous mappings was introduced and studied by Sheik John in [6]. In this paper we introduce a new class of fuzzy set called fuzzy
ω-open set and a new form of fuzzy θ-open set labelled as fuzzy
θ^*-open set. Also we study some of its properties and characterizations with suitable examples.

2. Preliminaries

We recall the following definitions which we used in this paper.

Definition 2.1 [9]

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two bitopological spaces. A function $f : (X, T_1, T_2) \to (Y, S_1, S_2)$ is called pairwise* fuzzy continuous if for each S_1-fuzzy open set or S_2-fuzzy open set λ in (Y, S_1, S_2), the inverse image $f^{-1} (\lambda)$ is a T_1-fuzzy open or T_2-fuzzy open set in (X, T_1, T_2).

Definition 2.2 [9]

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two bitopological spaces. A function $f : (X, T_1, T_2) \to (Y, S_1, S_2)$ is called somewhat pairwise fuzzy continuous if $\lambda \in S_1$ or $\lambda \in S_2$ and $f^{-1} (\lambda) \neq 0 \Rightarrow$ there exists $\mu \in T_1$ or $\mu \in T_2$ such that $\mu \neq 0$ and $\mu \leq f^{-1} (\lambda)$.

Definition 2.3 [6]

Let $f : (X, T) \to (Y, S)$ be a function from the fuzzy topological space (X, T) to the fuzzy topological space (Y, S). f is called fuzzy faintly continuous if $f^{-1} (\lambda)$ is fuzzy open for every fuzzy θ-open set
λ in Y.

Definition 2.4 [1]

A subset A of a topological space (X, T) is called ω-closed in (X, T) if cl (A) $\subseteq$ U whenever A $\subseteq$ U and U is semi-open in (X, T).

A subset A is called ω-open in (X, T) if its complement, A^c is ω-closed.

Definition 2.5 [2]

Let (X, T) and (Y, S) be any two fuzzy topological spaces. For a mapping f : (X, T) $\rightarrow$ (Y, S), the graph g : X $\rightarrow$ X × Y of f is defined as
g (x) = (x, f (x)), for each $x \in$ X.

3.1 Somewhat pairwise fuzzy faintly ω-continuous functions

In this section we investigate some properties of Somewhat pairwise fuzzy faintly ω-continuous functions and we also obtain characterizations of these functions.

Definition 3.1.1

Let (X, T) be a fuzzy topological space. For a fuzzy set $\lambda \in I^X$, $int_\theta (\lambda)^*$ is defined as $int_\theta (\lambda)^* = \vee \{ \beta \in I^X / \beta \leq \mu \leq \lambda, \mu \in T, \mu + \beta > 1$ and $cl (\mu) \leq \lambda \}$. The fuzzy set λ is said to be fuzzy θ^*-open in (X, T) if
$int_\theta (\lambda)^* = \lambda$.

The complement of a fuzzy θ^*-open set is fuzzy θ^*-closed.

Definition 3.1.2

Let (X, T) be a fuzzy topological space. A fuzzy set $\lambda \in I^X$ is called fuzzy ω-open in (X, T) if int (λ) ≥ μ whenever λ ≥ μ and μ is fuzzy semi-closed in (X, T).

The complement of a fuzzy ω-open set is fuzzy ω-closed.

Definition 3.1.3

Let (X, T) and (Y, S) be any two fuzzy topological spaces. A map f : (X, T) $\rightarrow$ (Y, S) is called fuzzy ω-continuous if f^{-1} (λ) is fuzzy ω-open in (X, T) for every fuzzy open set λ in (Y, S).

Definition 3.1.4

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A function f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called pairwise fuzzy ω-continuous if for each $\lambda \in S_1$ or $\lambda \in S_2$ the inverse image f^{-1} (λ) is T_1-fuzzy ω-open or T_2-fuzzy ω-open in (X, T_1, T_2).

Definition 3.1.5

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A function f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called somewhat pairwise fuzzy ω-continuous if $\lambda \in S_1$ or $\lambda \in S_2$ and f^{-1} (λ) ≠ 0 implies that there exists a T_1-fuzzy ω-open or T_2-fuzzy ω-open set μ such that μ ≠ 0 and μ ≤ f^{-1} (λ).

Definition 3.1.6

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A function f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called pairwise fuzzy faintly continuous if f^{-1}(λ) $\in T_1$ or f^{-1}(λ) $\in T_2$ for every S_1-fuzzy θ^*-open or S_2-fuzzy θ^*-open set λ in (Y, S_1, S_2).

Definition 3.1.7

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A function f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called pairwise fuzzy faintly ω-continuous if for every S_1-fuzzy θ^*-open or S_2-fuzzy θ^*-open set λ the inverse image f^{-1} (λ) is T_1-fuzzy ω-open or T_2-fuzzy ω-open.

Definition 3.1.8

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A function f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called somewhat pairwise fuzzy faintly ω-continuous if for every S_1-fuzzy θ^*-open or S_2-fuzzy θ^*-open set λ with f^{-1} (λ)≠ 0 there exists a T_1-fuzzy ω-open or T_2-fuzzy ω-open set μ such that μ ≠ 0 and μ ≤ f^{-1} (λ).

Every pairwise fuzzy ω-continuous function is somewhat pairwise fuzzy ω-continuous, but the converse need not be true as the following example shows.

Example 3.1.1

Let X = { a, b }. Define T_1 = { 0, 1, δ_1, δ_2, δ_3 }, T_2 = { 0, 1, δ_2 },
S_1 = { 0, 1, γ_1, γ_2 }, S_2 = { 0, 1 } where δ_1, δ_2, δ_3, γ_1, γ_2 : X $\rightarrow$ [0, 1] are such that δ_1 (a) = 0.3, δ_1 (b) = 0.4, δ_2 (a) = 0.61, δ_2 (b) = 0.41,
δ_3 (a) = 0.7, δ_3 (b) = 0.6 and γ_1 (a) = 0.59, γ_1 (b) = 0.56,
γ_2 (a) = 0.41, γ_2 (b) = 0.44. Clearly, T_1, T_2, S_1 and S_2 are fuzzy topologies on X. Define f : (X, T_1, T_2)

$\rightarrow$ (X, S_1, S_2) as f (a) = b,
f (b) = a. Then, **f is not pairwise fuzzy faintly ω-continuous** since the inverse image $f^{-1}(\gamma_1)$ is not T_1-fuzzy ω-open or T_2-fuzzy ω-open. But **f is somewhat pairwise fuzzy faintly ω-continuous** since for the S_1-fuzzy θ*-open set γ_1 with $f^{-1}(\gamma_1) \neq 0$, $\delta_1 \neq 0$ is T_1-fuzzy ω-open and $\delta_1 \leq f^{-1}(\gamma_1)$.

Every pairwise fuzzy faintly continuous function is somewhat pairwise fuzzy faintly ω-continuous but the converse need not be true as the following example shows.

Example 3.1.2

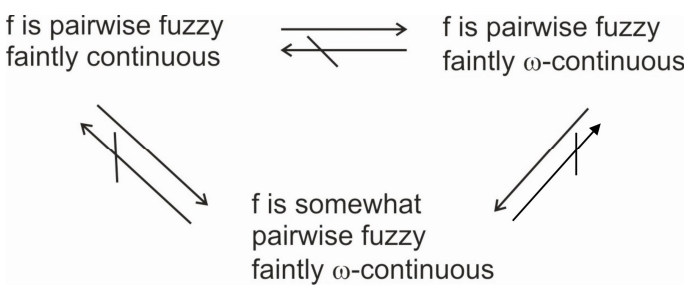
Let X = { a, b }. Define T_1 = { 0, 1, λ_1, λ_2 }, T_2 = { 0, 1},
S_1 = { 0, 1, μ_1, μ_2 }, S_2 = { 0, 1, μ_3 } where $\lambda_1, \lambda_2, \mu_1, \mu_2, \mu_3 : X \rightarrow [0, 1]$ are such that $\lambda_1(a) = 0.02$, $\lambda_1(b) = 0$, $\lambda_2(a) = 0.98$, $\lambda_2(b) = 1$,
$\mu_1(a) = 0.1$, $\mu_1(b) = 0.1$, $\mu_2(a) = 0.9$, $\mu_2(b) = 0.9$ and
$\mu_3(a) = 0.2$, $\mu_3(b) = 0.3$. Clearly, T_1, T_2, S_1 and S_2 are fuzzy topologies on X. Define g : (X, T_1, T_2) $\rightarrow$ (X, S_1, S_2) as g (a) = b,
g (b) = a. Since, $g^{-1}(\mu_2)$ is not T_1-fuzzy open or T_2-fuzzy open, **g is not pairwise fuzzy faintly continuous.** But **g is somewhat pairwise fuzzy faintly ω-continuous,** since the fuzzy set $\gamma : X \rightarrow [0, 1]$ defined as $\gamma(a) = 0.1$, $\gamma(b) = 0$ is T_1-fuzzy ω-open and $\gamma \leq g^{-1}(\mu_2)$, for the S_1-fuzzy θ^*-open set μ_2.

Every pairwise fuzzy faintly continuous mapping is pairwise fuzzy faintly ω-continuous, but the converse need not be true as the following example shows.

Example 3.1.3

In Example 7.3.2, g is not pairwise fuzzy faintly continuous. But g is pairwise fuzzy faintly ω-continuous, since for the S_1-fuzzy θ^*-open set μ_2, $g^{-1}(\mu_2)$ is T_1-fuzzy ω-open.

The following diagram gives the interrelations :



Definition 3.1.9

A fuzzy set λ in a fuzzy bitopological space (X, T_1, T_2) is called pairwise fuzzy ω-dense (resp.θ^*-dense) set if there exists no T_1-fuzzy ω-closed (resp.θ^*-closed) or T_2-fuzzy ω-closed (resp.θ^*-closed) set μ in (X, T_1, T_2) such that λ < μ < 1.

Example 3.1.4

Let X = { a, b, c }. Define T_1 = { 0, 1, δ }, T_2 = { 0, 1, γ } where
δ, γ : X → [0, 1] are such that as δ (a) = 0, δ (b) = 1/4, δ (c) = 1/3 and γ (a) = 1, γ (b) = 1/3, γ (c) = 1/3. Clearly T_1 and T_2 are fuzzy topologies on X. Define a fuzzy set λ : X → [0 , 1] such that λ (a) = 1, λ (b) = 3/4, λ (c) = 2/3. Clearly λ is a pairwise fuzzy ω-dense set.

Example 3.1.5

Let X= { a, b, c }. Define T_1 = { 0, 1, λ, μ }, T_2 = { 0, 1, γ } where
λ, μ, γ : X → [0, 1] are defined as λ (a) = 1/2, λ (b) = 3/4,
λ (c) = 2/3, μ (a) = 1/2, μ (b) = 1/4, μ (c) = 1/3 and γ (a) = 1/3,
γ (b) = 1/4, γ (c) = 1/3. Clearly T_1 and T_2 are fuzzy topologies on X. Let η : X → [0,1] be such that η (a) = 3/4, η (b) = 3/4,
η (c) = 2/3. Clearly η is a pairwise fuzzy θ^*-dense set.

Notation 3.1.1

(a) $\theta^*\text{-int}_{S_1}(\lambda)$ and $\theta^*\text{-int}_{S_2}(\lambda)$ denotes the S_1-fuzzy θ^*-interior and S_2-fuzzy θ^*-interior of a fuzzy set λ in a fuzzy bitopological space (X, S_1, S_2).

(b) $\theta^* - cl_{S_1}(\lambda)$ and $\theta^* - cl_{S_2}(\lambda)$ denotes the S_1-fuzzy θ^*-closure and S_2-fuzzy θ^*-closure of a fuzzy set λ in a fuzzy bitopological space (X, S_1, S_2).

Notation 3.1.2

(a) $\omega - int_{T_1}(\lambda)$ and $\omega - int_{T_2}(\lambda)$ denotes the T_1-fuzzy ω-interior and T_2-fuzzy ω-interior of a fuzzy set λ in a fuzzy bitopological space (X, T_1, T_2).

(b) $\omega - cl_{T_1}(\lambda)$ and $\omega - cl_{T_2}(\lambda)$ denotes the T_1-fuzzy ω-closure and T_2-fuzzy ω-closure of a fuzzy set λ in a fuzzy bitopological space (X, T_1, T_2).

Proposition 3.1.1

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. Let f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) be any function. Then the following conditions are equivalent:

(a) f is somewhat pairwise fuzzy faintly ω-continuous.

(b) If λ is S_1-fuzzy θ^*-closed or S_2-fuzzy θ^*-closed set such that $f^{-1}(\lambda) \neq 1$ then there exists a proper T_1-fuzzy ω-closed or T_2-fuzzy ω-closed set μ such that $\mu \geq f^{-1}(\lambda)$.

(c) If λ is a pairwise fuzzy ω-dense set in (X, T_1, T_2) then f (λ) is a pairwise fuzzy θ^*-dense set in (Y, S_1, S_2).

Proposition 3.1.2

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces and f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) be a somewhat pairwise fuzzy faintly ω-continuous function. Let A $\subset$ X be such that $\chi_A \wedge \mu \neq 0$ for all $0 \neq \mu \in T_1 \cup T_2$. Let T_1/A and T_2/A be the induced fuzzy topologies on A. Then f/A : (A, T_1/A, T_2/A) $\rightarrow$ (Y, S_1, S_2) is somewhat pairwise fuzzy faintly ω-continuous.

Proposition 3.1.3

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces and X = A $\cup$ B where A and B are subsets of X such that χ_A, $\chi_B \in T_1 \cap T_2$. Let f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) be such that f/A and f/B are somewhat pairwise fuzzy faintly ω-continuous. Then f is somewhat pairwise fuzzy faintly ω-continuous.

3.2 Somewhat pairwise fuzzy faintly ω-open functions

In this section we investigate some properties of Somewhat pairwise fuzzy faintly ω-open functions and we also obtain characterizations of these functions.

Definition 3.2.1

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A mapping f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called pairwise fuzzy ω-open if for every T_1-fuzzy ω-open or T_2-fuzzy ω-open set λ, the image f (λ) is S_1-fuzzy ω-open or S_2-fuzzy ω-open.

Definition 3.2.2

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A mapping f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called somewhat pairwise fuzzy ω-open if for every T_1-fuzzy ω-open or T_2-fuzzy ω-open set λ with $\lambda \neq 0$, there exists a S_1-fuzzy ω-open or S_2-fuzzy ω-open set μ such that $\mu \neq 0$ and $\mu \leq f(\lambda)$.

Definition 3.2.3

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. A mapping f : (X, T_1, T_2) $\rightarrow$ (Y, S_1, S_2) is called somewhat pairwise fuzzy faintly ω-open if for every T_1-fuzzy ω-open or T_2-fuzzy ω-open set λ with $\lambda \neq 0$, there exists a S_1-fuzzy θ^*-open or S_2-fuzzy θ^*-open set μ such that $\mu \neq 0$ and $\mu \leq f(\lambda)$. That is, $\theta^* - int_{S_1}(f(\lambda)) \neq 0$ or $\theta^* - int_{S_2}(f(\lambda)) \neq 0$.

Every pairwise fuzzy ω-open function is somewhat pairwise fuzzy ω-open, but the converse need not be true as shown in the following example.

Example 3.2.1

Let X = { a, b, c }. Define T_1 = { 0, 1, μ_1, μ_2 }, T_2 = { 0, 1 }, S_1 = { 0, 1, δ_1 }, S_2 = { 0,1, δ_2 } where $\mu_1, \mu_2, \delta_1, \delta_2 : X \to [0,1]$ are defined as $\mu_1(a) = 0.1$, $\mu_1(b) = 0.2$, $\mu_2(a) = 0.9$, $\mu_2(b) = 0.8$, $\delta_1(a) = 0.1$, $\delta_1(b) = 0.1$, $\delta_2(a) = 0.3$, $\delta_2(b) = 0.3$. Clearly T_1, T_2, S_1, and S_2 are fuzzy topologies on X. Let $f : (X, T_1, T_2) \to (X, S_1, S_2)$ be the identify function. Let $\lambda : X \to [0,1]$ be such that $\lambda(a) = 0.2$, $\lambda(b) = 0.2$. Now, λ is T_1-fuzzy ω-open but $\lambda = f(\lambda)$ is not S_1-fuzzy ω-open or S_2-fuzzy ω-open. **Therefore, f is not pairwise fuzzy ω-open.** Since λ is T_1-fuzzy ω-open and δ_1 is S_1-fuzzy ω-open such that $\delta_1 \neq 0$ and $\delta_1 \leq \lambda = f(\lambda)$. **f is somewhat pairwise fuzzy ω-open.**

Every pairwise fuzzy faintly ω-open function is somewhat pairwise fuzzy faintly ω-open but the converse need not be true as the following example shows.

Example 3.2.2

Let X = { a, b }. Define T_1 = { 0, 1, λ, γ }, T_2 = { 0, 1 }, S_1 = { 0, 1, μ_1, μ_2 }, S_2 = { 0, 1, δ } where $\lambda, \gamma, \mu_1, \mu_2, \delta : X \to [0, 1]$ are defined as $\lambda(a) = 0.02$, $\lambda(b) = 0$, $\gamma(a) = 0.98$, $\gamma(b) = 1$, $\mu_1(a) = 0.05$, $\mu_1(b) = 0$, $\mu_2(a) = 0.95$, $\mu_2(b) = 1$, and $\delta(a) = 0.5$, $\delta(b) = 0.5$. Clearly T_1, T_2, S_1, and S_2 are fuzzy topologies on X. Let $f : (X, T_1, T_2) \to (X, S_1, S_2)$ be the identity function. Let $\eta : X \to [0, 1]$ be such that $\eta(a) = 0.96$, $\eta(b) = 1$. Then, η is T_1-fuzzy ω-open but $f(\eta) = \eta$ is not S_1-fuzzy θ^*-open or S_2-fuzzy θ^*-open. **Therefore, f is not pairwise fuzzy faintly ω-open. Since** $\mu_2 \neq 0$ is S_1-fuzzy θ^*-open and $\mu_2 \leq f(\eta)$, **f is somewhat pairwise fuzzy faintly ω-open.**

Proposition 3.2.1

Let (X, T_1, T_2), (Y, S_1, S_2) and (Z, R_1, R_2) be any there fuzzy bitopological spaces If $f : (X, T_1, T_2) \to (Y, S_1, S_2)$ and $g : (Y, S_1, S_2) \to (Z, R_1, R_2)$ are somewhat pairwirse fuzzy faintly ω-open functions then $g \circ f : (X, T_1, T_2) \to (Z, R_1, R_2)$ is a somewhat pairwise fuzzy faintly ω-open function.

Proposition 3.2.2

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces and let $f : (X, T_1, T_2) \to (Y, S_1, S_2)$ be a one-to-one and onto function. Then the following conditions are equivalent :

(a) f is somewhat pariwise fuzzy faintly ω-open.

(b) If λ is a pairwise fuzzy θ^*-dense set in (Y, S_1, S_2), then $f^{-1}(\lambda)$ is a pairwise fuzzy ω-dense set in (X, T_1, T_2).

Proposition 3.2.3

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces and let $f : (X, T_1, T_2) \to (Y, S_1, S_2)$ be a one-to-one and onto function. Then the following conditions are equivalent :

(a) f is somewhat pariwise fuzzy faintly ω-open.

(b) If λ is a T_1-fuzzy ω-closed or T_2-fuzzy ω-closed set in (X, T_1, T_2) such that $f(\lambda) \neq 1$, then there exists a S_1-fuzzy θ^*-closed or S_2-fuzzy θ^*-closed set μ in (Y, S_1, S_2) such that $\mu \neq 1$ and $\mu > f(\lambda)$.

Definition 3.2.4

A fuzzy bitopological space (X, T_1, T_2) is called a pairwise fuzzy D-space if every non-zero fuzzy set $\lambda \in T_1$ or $\lambda \in T_2$ of (X, T_1, T_2) is dense in (X, T_1, T_2).

Definition 3.2.5

A fuzzy bitopological space (X, T_1, T_2) is called a pairwise fuzzy D_ω-space (resp. D_{θ^*}-space) if every non-zero fuzzy T_1-fuzzy ω-open (resp. θ^*-open) or T_2-fuzzy ω-open (resp. θ^*-open) set in (X, T_1, T_2) is pairwise fuzzy ω-dense (resp. θ^*-dense) in (X, T_1, T_2).

Proposition 3.2.4

Let f: (X, T_1, T_2) → (Y, S_1, S_2) be somewhat pairwise fuzzy faintly ω-continuous. Suppose (X, T_1, T_2) is a pairwise fuzzy
D_ω-space. Then (Y, S_1, S_2) is a pairwise fuzzy D_θ^*-space.

Proposition 3.2.5

Let (X, T_1, T_2) and (Y, S_1, S_2) be any two fuzzy bitopological spaces. Let X = A ∪ B where A and B are subsets of X and
f : (X, T_1, T_2) → (Y, S_1, S_2) is a function such that f/A and f/B are somewhat pairwise fuzzy faintly ω-open. Then f is somewhat pairwise fuzzy faintly ω-open.

Proposition 3.2.6

Let f : (X, T_1, T_2) → (Y, S_1, S_2) be any function from a
fuzzy bitopological space (X, T_1, T_2) to another fuzzy bitopological space (Y, S_1, S_2). If the graph g : X→ X × Y of f is somewhat pairwise fuzzy faintly ω-continuous then f is also somewhat pairwise fuzzy faintly ω-continuous.

Proposition 3.2.7

Let f : (X, T_1, T_2), (X_1, S_1, S_2) and (X_2, R_1, R_2) be any three fuzzy bitopological spaces. Let p_i : $X_1 \times X_2 \to X_i$ (i = 1, 2) be the projection mappings. If f : X→ $X_1 \times X_2$ is a somewhat pairwise fuzzy ω-continuous function then p_i o f is also somewhat pairwise fuzzy
ω-continuous function for i = 1,2.

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