A Type-2 Fuzzy Somewhere Dense Set In General Type-2 Fuzzy Topological Space

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Abstract
The multiplicity of connotations in any paper does not mean that there is no main objective for that paper and certainly one of these papers is our research the main objective is to introduce a new connotation which is type-2 fuzzy somewhere dense set in general type-2 fuzzy topological space and its relationship with open sets of the connotation type-2 fuzzy set in the same space topology and theories of this connotation.

Keywords: Type-2 Fuzzy Set, Type-2 Fuzzy Somewhere Dense Set, General Type-2 Fuzzy Topological Space, Type-2 Fuzzy Open Sets.

Introduction
The ability to provide suitable solutions to mathematical problems, including the conversion of nonlinear equations into linear equations, has made type-2 fuzzy set a wide field of scientific studies of the branches of mathematics because its appearance in the hands of L. Zadeh in 1975 [1] was not surprising after he introduced in 1965 fuzzy set [2] type-1 fuzzy set (fuzzy set), but this discovery became a necessary need to complete modern scientific research and the entry of fuzzy logic in its formulation. In 1976, Mizumoto and Tanaka introduced the properties of type-2 fuzzy set and the various methods of finding union and intersection [3]. Mendel and Karnik then introduced new methods in the formation of operation of type-2 fuzzy set [4] and then Mendel introduced an important connotation which is Interval type-2 fuzzy set [5] to become the study of type-2 fuzzy set into two parts the first part is interval type-2 fuzzy set and the second part general type-2 fuzzy set all these studies opened the way to study the topology spaces of each part, Zhang introduced the concept of interval type-2 fuzzy topology space [6] and Hussan and AL-Khafaji general type-2 fuzzy topology space[7]. This paper complements the topology construction path by introducing the connotation of type-2 fuzzy somewhere dense set in the general type-2 fuzzy topology space and its relationship to some type-2 fuzzy open sets.

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1. Preliminaries

Everything in this section is an important preamble of the main definitions and features that reflect the nature of type-2 fuzzy set work [1], [3], and [5]. We assume that \( X \neq \emptyset \) and \( I = [0,1] \) be closed unit interval.

**Definition 1.1**

A type-2 fuzzy set, denoted by \( \tilde{A} \) characterized by a type-2 membership function, where \( x \in X \neq \emptyset \) which is universal and \( \tilde{u} \in J_x \subseteq [0, 1] \)

\[
\tilde{A} = \{ ((x, \tilde{u}), \mu^\sim_A(x, \tilde{u})) : 0 \leq \mu^\sim_A(x, \tilde{u}) \leq 1 \text{, where } x \in X \neq \emptyset \text{, } \tilde{u} \in J_x \} \text{.........(1)}
\]

We can give a new wording to \( \tilde{A} \)

\[
\tilde{A} = \sum_{x \in X} \sum_{\tilde{u} \in J_x} \mu^\sim_A(x, \tilde{u}) / (x, \tilde{u}) \Rightarrow \tilde{A} = \sum_{x \in X} \sum_{\tilde{u} \in J_x} \mu^\sim_A(x, \tilde{u}) / \tilde{u} / x, \ J_x \subseteq [0,1] \text{.........(2)}
\]

Where \( \tilde{F}_x(\tilde{u}) = \mu^\sim_A(x, \tilde{u}) \) and \( \sum \) entones the union in discrete sets and \( \sum \) is replaced by \( \int \) is continuous universes are set.

The class of all type-2 fuzzy set of \( x \in X \neq \emptyset \) denoted by \( \tilde{F}_{T_2}(x) \).

**Remark 1.2** [3], [5]:

A type-2 fuzzy universes set, denoted by \( \tilde{X} \) such that \( \tilde{X} = \sum_{x \in X} \sum_{\tilde{u} \in [0,1]} 1 / \tilde{u} / \tilde{x} \) .........(3)

A type-2 fuzzy empty set, denoted by \( \emptyset \) such that \( \emptyset = \sum_{x \in X} \sum_{\tilde{u} \in [0,1]} 1 / \tilde{u} / \tilde{x} \) .........(4) .

**Definition 1.3** [5]:

When all the \( \mu^\sim_A(x, \tilde{u}) = 1 \) then type-2 fuzzy set is called interval type-2 fuzzy set.

**Definition 1.3** [3]:

A normal type-2 fuzzy set \( \tilde{A} \) is one for which \( \max_{x \in X} \mu^\sim_A(x, \tilde{u}) = 1 \).

**Operation of type-2 fuzzy set 1.3** [3]:

Consider \( \tilde{A} \) and \( \tilde{B} \) are two type-2 fuzzy sets and the membership grades of \( \tilde{A} \) and \( \tilde{B} \) respectively, we can represented by

\[
\tilde{\mu}^\sim_A(x) = \sum_{\tilde{w} \in J^w} \tilde{F}_x(\tilde{w}) / \tilde{w} \text{ and } \tilde{\mu}^\sim_B(x) = \sum_{\tilde{w} \in J^w} \tilde{K}_x(\tilde{w}) / \tilde{w}
\]

where \( \tilde{F}_x(\tilde{w}) \), \( \tilde{K}_x(\tilde{w}) \in I = [0,1] \) and \( x \in X \neq \emptyset \).

The union of two type-2 fuzzy sets is defined as

\[
\tilde{A} \cup \tilde{B} \iff \tilde{\mu}^\sim_{\tilde{A} \cup \tilde{B}}(x) = \sum_{\tilde{w} \in J^w} \tilde{F}_x(\tilde{w}) / \tilde{w} \wedge \tilde{K}_x(\tilde{w}) / \tilde{w} \wedge \tilde{w} \text{ .......(5)}
\]

The intersection of two type-2 fuzzy sets is defined as

\[
\tilde{A} \cap \tilde{B} \iff \tilde{\mu}^\sim_{\tilde{A} \cap \tilde{B}}(x) = \sum_{\tilde{w} \in J^w} \tilde{F}_x(\tilde{w}) / \tilde{w} \wedge \tilde{K}_x(\tilde{w}) / \tilde{w} \wedge \tilde{w} \text{ .......(6)}
\]

The containment type-2 fuzzy sets are defined as \( \tilde{A} \subseteq \tilde{B} \iff \tilde{\mu}^\sim_{\tilde{A} \subseteq \tilde{B}}(x) = \sum_{\tilde{w} \in J^w} \tilde{F}_x(\tilde{w}) / (1 - \tilde{u}) \text{ .......(7)}
\]

The complement of type-2 fuzzy set defined as \( \tilde{A} = \sum_{\tilde{u} \in J} \tilde{K}_x(\tilde{u}) / (1 - \tilde{u}) \text{ .......(8)} \)
General type-2 fuzzy topological space 1.4 [6]:

Let $\tilde{T}$ be the collection of type-2 fuzzy sets over $X \neq \emptyset$ then $\tilde{T}$ is called to be general type-2 fuzzy topology on $X \neq \emptyset$ if

1. $\tilde{X}, \tilde{\emptyset} \in \tilde{T}$
2. $\tilde{\Lambda} \cap \tilde{B} \in \tilde{T}$
3. $\bigcup_{i \in J} \tilde{A}_i \in \tilde{T}$ for $\tilde{A}_i \in \tilde{T}$ for all $i \in J$ (J is an arbitrary index set).

The pair $(X, \tilde{T})$ is said to type-2 fuzzy topological space over $X$ (Simply GT-2FTS) ; and the member of $\tilde{T}$ are said to be type-2 fuzzy open sets in $X$ and type-2 fuzzy set $\tilde{A}$ is said type-2 fuzzy closed sets in $X$, if its complement $\tilde{\Lambda} \in \tilde{T}$.

We must note that all the type-2 fuzzy sets is normal type-2 fuzzy sets so as to complete the topological construction and especially check identity law ($\tilde{\Lambda} \cap \tilde{\emptyset} = \tilde{\emptyset}$).

The type-2 fuzzy interior of $\tilde{A}$, denoted by $\tilde{\text{int}}(\tilde{A})$ is defined $\tilde{\text{int}}(\tilde{A}) = \bigcup \{ \tilde{R}_i : \tilde{R}_i$ type-2 fuzzy open set in $X, \tilde{R}_i \subseteq \tilde{A}, i \in J \}

**Theorem 1.4.(1):**

Let $(X, \tilde{T})$ be a general type-2 fuzzy topology space over $X$, and let $\tilde{A}, \tilde{B}$ are type-2 fuzzy sets in $X$, then

1. $\tilde{\text{int}}(\tilde{\emptyset}) = \tilde{\emptyset}$ and $\tilde{\text{int}}(X) = X$
2. $\tilde{\text{int}}(\tilde{A}) \subseteq \tilde{A}$
3. $\tilde{\text{int}}(\tilde{\text{int}}(\tilde{A})) = \tilde{A}$
4. $\tilde{A} \subseteq \tilde{B} \Rightarrow \tilde{\text{int}}(\tilde{A}) \subseteq \tilde{\text{int}}(\tilde{B})$
5. $\tilde{\text{int}}(\tilde{A} \cap \tilde{B}) = \tilde{\text{int}}(\tilde{A}) \cap \tilde{\text{int}}(\tilde{B})$

6. $\tilde{A}$ is a type-2 fuzzy open set if and only if $\tilde{\text{int}}(\tilde{A}) = \tilde{A}$

The type-2 fuzzy closure of $\tilde{A}$, denoted by $\tilde{\text{cl}}(\tilde{A})$ is defined $\tilde{\text{cl}}(\tilde{A}) = \bigcap \{ \tilde{N}_i : \tilde{N}_i$ type-2 fuzzy closed set in $X, \tilde{N}_i \subseteq \tilde{A}, i \in J \}$

**Theorem 1.4.(2):**

Let $(X, \tilde{T})$ be a general type-2 fuzzy topology space over $X$, and let $\tilde{A}, \tilde{B}$ are type-2 fuzzy sets in $X$, then

1. $\tilde{\text{cl}}(\tilde{\emptyset}) = \tilde{\emptyset}$ and $\tilde{\text{cl}}(X) = X$
2. $\tilde{A} \subseteq \tilde{\text{cl}}(\tilde{A})$
3. $\tilde{A}$ is a type-2 fuzzy closed set if and only if $\tilde{\text{cl}}(\tilde{A}) = \tilde{A}$
4. $\tilde{\text{cl}}(\tilde{\text{cl}}(\tilde{A})) = \tilde{\text{cl}}(\tilde{A})$
5. $\tilde{A} \subseteq \tilde{B} \Rightarrow \tilde{\text{cl}}(\tilde{A}) \subseteq \tilde{\text{cl}}(\tilde{B})$
6. $\tilde{\text{cl}}(\tilde{A} \cup \tilde{B}) = \tilde{\text{cl}}(\tilde{A}) \cup \tilde{\text{cl}}(\tilde{B})$

2. Some type-2 Fuzzy Open Sets in General type-2 fuzzy Topological Space.

In a concise manner all lines of this section include a presentation of open set for type-2 fuzzy set and how it was first formed in general type-2 fuzzy topological space.
Definition (1.2):
A subset type-2 fuzzy set \( \tilde{A} \) of a general type-2 fuzzy topological space is called:
1. Type-2 fuzzy preopen set if \( \tilde{A} \subseteq \text{int}(\text{cl}(A)) \) (Simply \( T - 2f \tilde{\varnothing} )
2. Type-2 fuzzy \( \tilde{\beta} \)-open set if \( A \subseteq \text{cl}(\text{int}(\text{cl}(A))) \) (Simply \( T - 2f \tilde{\beta} \))
3. Type-2 fuzzy semiopen set if \( A \subseteq \text{cl}(\text{int}(\text{cl}(A))) \) (Simply \( T - 2f \tilde{\alpha} \)).
4. Type-2 fuzzy \( \tilde{\alpha} \)-open set if \( A \subseteq \text{int}(\text{cl}(\text{int}(\text{cl}(A)))) \) (Simply \( T - 2f \tilde{\alpha} \)).

3. Type-2 fuzzy Somewhere Dense Set in General Type-2 Fuzzy Topological Space:
The display area of this section is wider than the previous one because it provides the full definition of
type-2 fuzzy somewhere dense set with the direct relationship to type-2 fuzzy open sets by theoretical
and examples.

Definition (1.3):
Let \((X, T)\) be a general type-2 fuzzy topology space over \(X\), a type-2 fuzzy set \(\tilde{A}\)
defined on \(X\) is called a type-2 fuzzy somewhere dense set if \(\text{int}(\text{cl}(A)) \neq \emptyset \) (short by \( T - 2f \tilde{SD} S \)).
We can give an equivalent definition for def (1.3).

Definition (2.3):
A subset type-2 fuzzy set \( \tilde{A} \) of a general type-2 fuzzy topological space \((X, T)\) is called type-2 fuzzy
somewhere dense set if there exists type-2 fuzzy set \( B \neq \emptyset \in T \) such that \( B \subseteq \text{cl}(A) \).

Definition (3.3):
The complement of type-2 fuzzy somewhere dense set subset \( \tilde{A} \) of a general type-2 fuzzy topological
space \((X, T)\) is called a type-2 fuzzy Co- somewhere dense set (short by \( \text{Co} - T - 2f \tilde{SD} S \)).

Remark (4.3):
We denote the collection of all type-2 fuzzy somewhere dense set in a general type-2 fuzzy topology
space \((X, T)\) by \( \text{SDT} - 2(T) \).

Theorem (5.3):
A non-empty \( T - 2f \tilde{\beta} \) is \( T - 2f \tilde{SD} S \)
Proof:
Let \( \tilde{A} \neq \tilde{\varnothing} \) is a \( T - 2f \tilde{\beta} \) then \( \tilde{A} \subseteq \text{cl}(\text{int}(\text{cl}(A))) \Rightarrow \tilde{A} \subseteq \text{cl}(\text{cl}(A)) = \text{cl}(A) \), hence the set
\( \text{int}(\text{cl}(A)) \neq \emptyset \in T \) and \( \text{int}(\text{cl}(A)) \subseteq \text{cl}(A) \) hence \( \tilde{A} \) is \( T - 2f \tilde{SD} S \).
The converse theorem (5.3) is not true.

Example (6.3):
Let \((X, T)\) be a general type-2 fuzzy topological space, \( X = \{x_1, x_2\} \) and \( T = \{X, \emptyset, \tilde{A}, \tilde{B}, \tilde{C}\} \),
\( \mu_{\tilde{X}}(x_1, \tilde{u}) = 1 \), \( \mu_{\tilde{X}}(x_2, \tilde{u}) = 1 \), \( \mu_{\tilde{\varnothing}}(x_1, \tilde{u}) = 1 \), \( \mu_{\tilde{\varnothing}}(x_2, \tilde{u}) = 0 \) and \( \tilde{A}, \tilde{B}, \tilde{C} \), are type-2 fuzzy sets
\( \mu_{\tilde{A}}(x_1, \tilde{u}) = \{0.9, \tilde{0.2}, \tilde{u} = 0.1\} \), \( \mu_{\tilde{A}}(x_2, \tilde{u}) = 0.2 \), \( \mu_{\tilde{B}}(x_1, \tilde{u}) = \{0.7, \tilde{0.07}, \tilde{u} = 0.8\} \),
\( \mu_{\tilde{B}}(x_2, \tilde{u}) = 0.2 \).
\[ \mu_C(x_1, \tilde{u}) = \{ 0.8, \tilde{u} = 0.1, 0.2 \}, \mu_C(x_2, \tilde{u}) = 0.2 \] and we have \( K \) is type-2 fuzzy set in \((X, T)\) such that
\[ \mu_K(x_1, \tilde{u}) = \{ 0.9, \tilde{u} = 0.8, 0.9 \}, \mu_K(x_2, \tilde{u}) = 0.8 \]
and \( K \) is \( T - 2f \) SDS and is not \( T - 2f \) S.

**Theorem (7.3):**
A non-empty \( T - 2f \) \( \alpha \) is \( T - 2f \) SDS.

**Proof:**
Let \( A = \emptyset \) is a \( T - 2f \) \( \alpha \) then \( A \subseteq \text{int}(\text{cl}(A))) \) and by definition \( T - 2f \) S we have
\[ \text{int}(\text{cl}(A))) \neq \emptyset \] suppose that \( \text{int}(\text{cl}(A))) = \emptyset \) such that
\[ A \subseteq \text{int}(\text{cl}(A))) \subseteq \text{int}(\text{cl}(A))) = \emptyset \] that is contradiction therefore \( A \) is \( T - 2f \) S.

**Example (8.3):**
Let \((X, T)\) be a general type-2 fuzzy topological space, \( X = \{ x_1, x_2 \} \) and \( T = \{ X, \emptyset, A \} , \mu^T_{X}(x_1, \tilde{u}) = 1, \mu^T_{X}(x_2, \tilde{u}) = 1, \mu^T_{\emptyset}(x_1, \tilde{u}) = 0, \) \( \mu^T_{A}(x_2, \tilde{u}) = 1 \) let \( A \) a type-2 fuzzy sets
\[ \mu^T_{A}(x_1, \tilde{u}) = \{ 0.8, \tilde{u} = 0.3, \tilde{u} = 0.2 \}, \mu^T_{B}(x_2, \tilde{u}) = 0.1 \] and \( B \) type-2 fuzzy set in \((X, T)\) such that
\[ \mu^T_{B}(x_1, \tilde{u}) = \{ 0.3, \tilde{u} = 0.7, \tilde{u} = 0.6 \} \] \( B \) is \( T - 2f \) S but not a \( T - 2f \) \( \alpha \).

**Theorem (9.3):**
A non-empty \( T - 2f \) \( \zeta \) is \( T - 2f \) S.

**Proof:**
Let \( A = \emptyset \) is a \( T - 2f \) \( \zeta \) then \( A \subseteq \text{cl}(\text{int}(A))) \), and by defined \( T - 2f \) S we have
\[ \text{int}(\text{cl}(A))) \neq \emptyset \] suppose that \( \text{int}(\text{cl}(A))) = \emptyset \) such that
\[ A \subseteq \text{cl}(\text{int}(A))) \subseteq \text{cl}(\text{int}(A))) \Rightarrow A \subseteq \emptyset \]
That is contradiction then \( A = \emptyset \) is a \( T - 2f \) S.

**Example (10.3):**
Let \((X, T)\) be a general type-2 fuzzy topological space, \( X = \{ x_1, x_2 \} \) and \( T = \{ X, \emptyset, W \} , \mu^T_{X}(x_1, \tilde{u}) = 1, \mu^T_{X}(x_2, \tilde{u}) = 1, \mu^T_{\emptyset}(x_1, \tilde{u}) = 0, \) \( \mu^T_{W}(x_2, \tilde{u}) = 1 \) let \( W \) a type-2 fuzzy set
\[ \mu^T_{W}(x_2, \tilde{u}) = \{ 0.7, \tilde{u} = 0.3, \tilde{u} = 0.1 \}, \mu^T_{W}(x_2, \tilde{u}) = 0.2 \] and \( \hat{L} \) a type-2 fuzzy set in \((X, T)\),
\[ \mu^T_{\hat{L}}(x_2, \tilde{u}) = \{ 0.8, \tilde{u} = 0.6, \tilde{u} = 0.9 \}, \mu^T_{\hat{L}}(x_1, \tilde{u}) = 0.7 \] \( \hat{L} \) is not \( T - 2f \) \( \zeta \) but is a \( T - 2f \) S.

**Theorem (11.3):**
A non-empty \( T - 2f \) \( \emptyset \) is \( T - 2f \) S.
Proof:

Let \( A \neq \emptyset \) is a \( T-2f \)-set and \( A \subseteq \text{int}(\text{cl}(A)) \), and by defined \( T-2f \) we have \( \text{int}(\text{cl}(A)) \neq \emptyset \). So, Suppose that \( \text{int}(\text{cl}(A)) = \emptyset \), such that \( A \subseteq \text{int}(\text{cl}(A)) = \emptyset \), that is contradiction therefore \( A \) is \( T-2f \)-set.

The converse theorem (11.3) is not true.

Example (12.3):

Let \((X,T)\) be a general type-2 fuzzy topological space, \( X = \{x_1, x_2\} \) and \( T = \{X, \emptyset, Y\} \),
\[
\begin{align*}
\mu_X(x_1, \overline{u} = 1), & \quad \mu_X(x_2, \overline{u} = 1), & \quad \mu_\varnothing(x_1, \overline{u} = 0), & \quad \mu_\varnothing(x_2, \overline{u} = 0) = 1,
\end{align*}
\]

\( Y \) type-2 fuzzy sets \( \mu_Y(x_1, \overline{u}) = \{0.4, \overline{u} = 0.4\}, \quad \mu_Y(x_2, \overline{u} = 0.1) = 1 \), and let \( N \) type-2 fuzzy set in \((X,T)\), \( \mu_N(x_2, \overline{u}) = \{0.3, \overline{u} = 0.8\}, \quad \mu_N(x_2, \overline{u} = 0.6) = 0.4 \). Therefore, \( N \) is not a \( T-2f \)-set but is a \( T-2f \)-set.

Theorem (13.3):

Every a type-2 fuzzy subset of a general type-2 fuzzy topology space is \( T-2f \)-set or \( C_0 = T-2f \)-set.

Proof:

Let \( A \neq \emptyset \) is a type-2 fuzzy subset of \( X \) and not \( T-2f \)-set, that is \( \text{int}(\text{cl}(A)) = \emptyset \), such that can not have \( \text{cl}(A) = X \), therefore \( \text{cl}(A) = \emptyset \) such that \( A \subseteq \text{cl}(A) \), \( \text{cl}(A) = T-2f \)-set and \( A \) is \( C_0 = T-2f \)-set.

Theorem (14.3):

Let \( \{A_k : k \in J\} \) be a class of a fuzzy subset of a general type-2 fuzzy topology space \((X,T)\) then \( \bigcup_{k \in J} A_k \) is \( T-2f \)-set if and only if \( \bigcup_{k \in J} \overline{A_k} \) is \( T-2f \)-set.

Proof:

Suppose that \( \bigcup_{k \in J} A_k \) is \( T-2f \)-set we must prove that \( \bigcup_{k \in J} \overline{A_k} \) is \( T-2f \)-set, we have \( \bigcup_{k \in J} A_k \) is \( T-2f \)-set such that \( \text{int}(\text{cl}\big(\bigcup_{k \in J} A_k\big)) \neq \emptyset \) and but by \( \overline{\big(\bigcup_{k \in J} A_k\big)} = \overline{\big(\bigcup_{k \in J} A_k\big)} \), such that
\[
\begin{align*}
\text{int}[\text{cl}(\overline{\big(\bigcup_{k \in J} A_k\big)})] & \neq \emptyset, \\
\text{int}[\text{cl}(\overline{\big(\bigcup_{k \in J} A_k\big)})] & \neq \emptyset, \\
\text{int}[\text{cl}(\big(\bigcup_{k \in J} A_k\big))] & \neq \emptyset.
\end{align*}
\]
therefore \( \bigcup_{k \in J} A_k \) is \( T-2fSD S \).

**Proposition (15.3):**

Let \( \{ K_r : r \in J \} \) be a family of \( T-2fSD S \) then \( \bigcup_{r \in J} K_r \) is \( T-2fSD S \).

**Proof:**

Let \( \{ K_r : r \in J \} \) be a family of \( T-2fSD S \) and by definition of \( T-2fSD S \) then there exist \( M_{t_0} \neq \emptyset \subseteq \text{cl}(K_{t_0}) \), but \( \text{cl}(K_{t_0}) \subseteq \text{cl} \left( \bigcup_{r \in J} K_r \right) \), therefore \( \bigcup_{r \in J} K_r \) is \( T-2fSD S \).

**Proposition (16.3):**

Let \( \{ B_r : r \in J \} \) be a family of \( Co-T-2fSD S \) then \( \bigcap_{r \in J} B_r \) is \( Co-T-2fSD S \).

**Proof:**

Let \( \{ B_r : r \in J \} \) be a family of \( Co-T-2fSD S \) and by proposition(15.3) \( \bigcup_{r \in J} -B_r \) is \( T-2fSD S \) therefore \( \bigcap_{r \in J} B_r \) is \( Co-T-2fSD S \).

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