Tikrit Journal of Pure Science 22 (2) 2017
ISSN: 1813 – 1662 (Print)
E-ISSN: 2415 – 1726 (On Line)

On Semi- regular T_1 and Semi- regular T_2 in Intuitionistic Fuzzy Topological Spaces

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Abstract

The purpose of this paper is to give the new definitions of semi-regular T_1 and semi-regular T_2 separation axioms in intuitionistic fuzzy topological spaces. Study the basic properties, characterizations and relationships of these new concepts in intuitionistic fuzzy topological spaces.

Key words: fuzzy set, intuitionistic fuzzy topology, semi-regular T_1, semi-regular T_2.

1. Introduction

After the introduction of fuzzy sets by Zadeh [1], Atanassov in 1983 [2,3] introduced the notion of "intuitionistic fuzzy set " (IFS for short). Using intuitionistic fuzzy sets, Coker [5] introduced the notion of "intuitionistic fuzzy topological spaces. In this paper, we introduce new notions of semi-regular T_1 and semi-regular T_2 separation axioms in intuitionistic fuzzy topological spaces.

2. Preliminaries

The concept of " intuitionistic fuzzy set " (IFS for short) was introduced by Atanassov as an object of the form $A=< x, A_1, A_2>$, where A_1 and A_2 are subset of a nonempty fixed set X, satisfying the following $A_1 \cap A_2 = \emptyset$. Every subset of a nonempty set of IFS having the form $< x , A, A^c >$. Some Boolean algebra operations on IFS is defined by Coker [5] as follows:-

Let A, B be IF'S where $A = <x , A_1, A_2>$, $B = < x, B_1, B_2 >$ belong to a non-empty set X and $\{A\acute{\imath} : \acute{\imath} \in J\}$ be an arbitrary family of IFS in X where $A\acute{\imath} = <x , \breve{A}_1, \breve{A}_2>$, then :-

$A \subseteq B \Leftrightarrow A_1 \subseteq B_1 \wedge A_2 \supseteq B_2$;

$A = B \Leftrightarrow A \subseteq B \wedge B \subseteq A$;

$A^c = < x, A_2, A_1 >$

$\bigcup A\acute{\imath} = < x, \bigcup \breve{A}_1, \cap \breve{A}_2 >$,

$\cap A\acute{\imath} = < x, \cap \breve{A}_1, \bigcup \breve{A}_2 >$.

$\tilde{\emptyset} = < x, \emptyset, X >$, $\tilde{X} = <x, X, \emptyset >$.

The an intuitionistic fuzzy topology (IFT for short) on a nonempty set X is a family $\mathcal{T}$ of IF's in X containing $\tilde{\emptyset}$, $\tilde{X}$ and closed under finite intersection and arbitrary union, in this case the pair $(X, \mathcal{T})$ is called an intuitionistic fuzzy topological space (IFTS for short).

Now let A be any IF'S in $(X, \mathcal{T})$, then A said to be intuitionistic fuzzy regular (semi) open set ((IFROS), IFSOS for short) if A=Int(ClA) ($A \subseteq CL$ (IntA)) and called intuitionistic fuzzy regular (semi)closed set (IFRCS), IFSCS for short) if A= Cl(IntA)($A \subseteq CL$ (IntA)), when the interior and closure of an IFS A are defined by ;

$$\text{Int } A = \bigcup \{ G : G \in \mathcal{T},\ G \subseteq A \}$$

$$\text{Cl } A = \cap \{ K : 1\text{-}K \in \mathcal{T},\ A \subseteq K \}$$

Any IF'S in $\mathcal{T}$ is known an intuitionistic fuzzy open set (IFOS for short) in X. The IF'S $\bar{p} = <x, p, \{P\}^c>$ is called intuitionistic fuzzy point in X. The IF'S $\bar{p}$ is said to be contained in A if ($P \in A_1$ and $P \notin A_2$, and the set $\bar{\bar{p}} = <x, \emptyset, \{P\}^c >$ is called vanishing Intuitionistic point in X (VIP for short).

2. Some Forms of Semi-regular T_1 Separation axioms:

In this section, we introduce some new form of the separation axioms namely semi-regular T_1 (SRT_1 for short) in IFTS, we give a definition of semi-regular and semi-regular T_1 and some of it's properties and relations with each other.

Definition 2.1: Let $(X, \mathcal{T})$ be an IFTS, A subset A of X is said to be semi-regular if A is both semi open and semi closed [5].

The set of all semi-regular sets of X is denoted by SR(X), the intersection of all semi-regular sets of X containing A is called the semi-regular closure of A and denoted by SRCL(A) and the union of all semi-regular sets of X contained in A is called the semi-regular interior of A and denoted by SRI(A).

Definition 2.2: Let $(X, \mathcal{T})$ be an IFTS, than $(X, \mathcal{T})$ is said to be :-

1. **SRT_1(í)** if for each x, y $\in$ X, $x \neq y$, $\exists$ U, V $\in$ SR(X) s.t $\bar{x} \in U$, $\bar{y} \notin U$ and $\bar{y} \in V$, $\bar{x} \notin V$.
2. **SRT_1 (íí)** if for each x, y $\in$ X, $x \neq y$, $\exists$ U ,V $\in$ SR(X) s.t $\bar{\bar{x}} \in U$, $\bar{\bar{y}} \notin U$ and $\bar{\bar{y}} \in V$, $\bar{\bar{x}} \notin$ $\bar{x} \in V$.
3. **SRT_1 (ííí)** if for each x, y $\in$ X, $x \neq y$, $\exists$ U, V$\in$ SR(X) s.t $\bar{x} \in U \subseteq \bar{y}^c$ and $\bar{y} \in V \subseteq \bar{x}^c$.
4. **SRT_1 (iv)** if for each x, y $\in$ X, $x \neq y$, $\exists$ U, V $\in$ SR(X) s.t $\bar{\bar{x}} \in U \subseteq \bar{\bar{y}}^c$ and $\bar{\bar{y}} \in V \subseteq \bar{\bar{x}}^c$.
5. **SRT_1(V)** if for each x, y $\in$ X, $x \neq y$, $\exists$U, V $\in$ SR(X) s.t y $\notin$V and $\bar{x} \notin$ V.
6. **SRT_1(Ví)** if for each x, y $\in$X, $x \neq y$, $\exists$ U, V $\in$SR(X) s.t $\bar{y}^c \notin$U and $\bar{\bar{x}} \notin$ V.

The following theorem appears in [4] for IFOS without proof, we generalize it for SR sets and give it here with proof.

Theorem 2.3 : Let (X, $\mathcal{T}$) be an IFTS, then the following implication are valid.

$SRT_1(V)$ ⟵ $SRT_1(Vi)$

↑ ↖

$SRT_1(i)$ ⟵ $SRT_1(i) + SRT_1(ii) \rightarrow SRT_1(ii)$

↕ ↓

$SRT_1(iii)$ $SRT_1(iv)$

Proof : To prove $SRT_1(vi) \rightarrow SRT_1(v)$:-

Let x, y $\in$X, x $\neq$ y, since SRT_1(v i) hold so there exists U ,V $\in$SR(X) s.t $\bar{\bar{y}} \notin$U and $\bar{\bar{x}} \notin$ V, this implies that y $\in u_2$ and x $\in V_2$, Since $u_1 \cap u_2 = \emptyset$ and $v_1 \cap v_2 = \emptyset$, we get y $\notin u_1$ and x $\notin V_1$, therefore $\bar{x} \notin$ V and $\bar{y} \notin$ U so $SRT_1(v)$ holds.

To prove $SRT_1(i) \rightarrow SRT_1(v)$:-

Let x, y $\in$ X. Since $SRT_1(i)$ hold, so there exists U , V $\in$ SR(X) s.t $\bar{x} \in$U, $\bar{y} \notin$U and y $\in$ V, x $\notin$ U, this implies that $\bar{x} \notin$U and $\bar{y} \in$V, $\bar{x} \notin$ V, x $\notin$ V and $\bar{y} \notin$ U, therefore $SRT_1(v)$ hold.

In order to prove $SRT_1(ii) \rightarrow SRT_1(vi)$, take x, y $\in$ X, x $\neq$ y. Since $SRT_1(ii)$ hold, so there exists U, V $\in$ SR(X) s.t $\bar{\bar{x}} \in$ U, $\bar{\bar{y}} \notin$ U and $\bar{\bar{y}} \in$ V, $\bar{\bar{x}} \notin \bar{x}, \in$ V . From this we have $\bar{x} \notin$ V and $\bar{\bar{y}} \notin$U, therefore $SRT_1(vi)$ hold.

$SRT_1(i) + SRT_1(ii) \longrightarrow SRT_1(i)$ and

$SRT_1(i) + SRT_1(ii) \longrightarrow SRT_1(ii)$ is direct.

To prove $SRT_1(i) + SRT_1(ii) \rightarrow SRT_1(iii)$:-

Let x, y $\in$ X, x$\neq$y . Since $SRT_1(i)$ & $SRT_1(ii)$ hold so $\exists$ U, V $\in$SR(X) s.t $\bar{x} \in$ U, $\bar{y} \in$V, $\bar{x} \notin$V and $\bar{y} \notin$U, so $\bar{\bar{x}} \in$ U, $\bar{\bar{y}} \notin$U and $\bar{\bar{y}} \in$V, $\bar{\bar{x}} \notin \bar{x} \in$V .

First we have to prove :-

$\bar{x} \in U \subseteq \bar{Y}^c$ and $\bar{y} \in V \subseteq \bar{X}^c$, we have from assumption $\bar{x} \in$U and $\bar{y} \in$V.

To prove U $\subseteq \bar{Y}^c$, let U = < x, u_1, u_2> and $\bar{Y}^c$ = <y, $\{y\}^c$, {y}>, since $\bar{y} \notin$U, so y$\in u_1$, therefore $u_1 \subseteq \{y\}^c$ and$\{y\} \subseteq u_2$, this implies that U $\subseteq \bar{Y}^c$. In a similar way, we can prove V$\subseteq \bar{X}^c$. Hence $SRT_1(iii)$ holds.

In order to prove $SRT_1(iii) \rightarrow SRT_1(i) + SRT_1(ii)$:-

First we have to prove $SRT_1(iii) \rightarrow SRT_1(i)$

Let x, y $\in$ X, x$\neq$y. Since $RT_1(iii)$ hold, so $\exists$ U, V $\in$ SR(X) s.t $\bar{x} \in U \subseteq \subseteq \bar{Y}^c$ and $\bar{y} \in V \subseteq \bar{X}^c$, we have to prove $\bar{x} \in$ U, $\bar{y} \notin$U and $\bar{y} \neg\in$ V, $\bar{x} \notin$V this implies that $\bar{x} \in$ U and Y $\subseteq$ U so $\bar{x} \in$ U, $\bar{y} \notin$U and since $\bar{y} \in V \subseteq \bar{X}^c$, so we get that $\bar{y} \in$ V, $\bar{x} \notin$V , therefore $SRT_1(i)$ holds.

Similarly, we can prove that $SRT_1(iii) \rightarrow SRT_1(ii)$.

The following implication all proved by transitivity :-

$SRT_1(ii) + SRT_1(i) \rightarrow SRT_1(vi)$,

$SRT_1(ii) + SRT_1(i) \rightarrow SRT_1(v)$

Remark 2.4: The converse of the last theorem are not true in general. The following counter example shows the cases.

Example 2.5 :

1. Let X = {1,2,3} and define $\mathcal{T}$ ={$\tilde{\emptyset}$, $\tilde{X}$, A, B, C, D, E, F} where A = < x, {1}, {2,3}> , B = < x,{2}, {1,3}>, C = < x, {1,2}, {3}> , D = < x, {1,3}, {2}> , E = < x, {2,3}, $\emptyset$>, F = < x, {1,3}, $\emptyset$> , so SR(X) = {$\tilde{\emptyset}$, $\tilde{X}$, B, D}, then (X, $\mathcal{T}$) is $SRT_1(i)$, but not $SRT_1(ii)$.
2. Let X = {1,2} and $\mathcal{T}$ = {$\tilde{\emptyset}$, $\tilde{X}$, A, B}, where A = < x, $\emptyset$, {1}> , B = < x, $\emptyset$, {2}> and SR(X) = {$\tilde{\emptyset}$, $\tilde{X}$, A, C, D} where C = < x, $\emptyset$, {1}> and D = < x, {2}, $\emptyset$>, then (X,$\mathcal{T}$) is $SRT_1(vi)$, but not $SRT_1(i)$.
3. Let X = {1,2,3} and define $\mathcal{T}$ = {$\tilde{\emptyset}$, $\tilde{X}$, A,B, C, D, E, F} on X where A = < x, $\emptyset$, {1,2}>, B = < x, {3}, {1,2}>, C = < x, $\emptyset$, {2,3}>, D= < x, {3}, {2}>, E = < x, {1,3}, {2}>, F = < x, $\emptyset$, {2}>, then (X, $\mathcal{T}$) is $SRT_1(vi)$, but not $SRT_1(i\ i)$ and not $SRT_1(iii)$.
4. Let X = {1,2,3} and $\mathcal{T}$ = {$\tilde{\emptyset}$, $\tilde{X}$, A, B, C, D, E, F, G, H, K} where A = < x, {1}, {3}>, B = < x, {2}, {1}>, C = < x, {1},{2,3}>, D = < x, $\emptyset$, {2}>, E = < x, {1,2}, $\emptyset$>, F= < x, $\emptyset$, {1,3}>, G = < x, $\emptyset$, {2,3}>, K = < x,{1}, $\emptyset$> So (X, $\mathcal{T}$) is $SRT_1(i)$ but not $SRT_1(iii)$.

3. Semi- regular T_2 in intuitionistic Fuzzy Topological Spaces :

The aim of this part is to introducing some new form of T_2 separation axioms namely semi-regular T_2 in IFTS and study properties and it's relations of each other.

Definition 3.1: Let (X, $\mathcal{T}$) be an IFTS. (X, $\mathcal{T}$) is said to be :-

1. $SRT_2(i)$ if for all x, y $\in$X, x$\neq$y, $\exists$U,V $\in$ SR(X) such that $\bar{x} \in$ U, $\bar{y} \in$ V and U $\cap$ V = $\tilde{\emptyset}$.
2. $SRT_2(ii)$ if for all x, y $\in$X, x$\neq$y, $\exists$U,V $\in$ SR(X) such that $\bar{\bar{x}} \in$U, $\bar{\bar{y}} \in$ V and U$\cap$V = $\tilde{\emptyset}$.

3. SRT_2(iii) if for all x, y $\in$X, x$\neq$y, $\exists$U,V$\in$ SR(X) such that $\bar{x} \in$ U, $\bar{y}$ $\in$V and U$\cap$V = $\tilde{\emptyset}$.
4. SRT_2(iv) if for all x, y$\in$X, x$\neq$y, $\exists$U,V $\in$ SR(X) such that $\bar{\bar{x}}$ $\in$V and U$\subseteq$V.
5. SRT_2(v) if for all x, y$\in$X, x$\neq$y,$\exists$U,V$\in$SR(X) such that $\bar{x}\in U\subseteq \bar{Y}^c, \bar{y}\in V \subseteq \bar{X}^c$ and U$\cap$V = $\tilde{\emptyset}$.
6. SRT_2(vi) if for all x, y $\in$X, x$\neq$y, $\exists$U,V $\in$ SR(X) such that $\bar{\bar{x}} \in U \subseteq \bar{Y}^c$, $\bar{y}^c \in V \subseteq \bar{\bar{X}}^c$ and U$\cap$V = $\tilde{\emptyset}$.

Theorem 3.2 : Let (X, $\mathcal{T}$) be an IFTS, then the following implications are valid.

$$\begin{array}{ccc} SRT_2(v) & \longrightarrow & SRT_2(vi) \\ \downarrow & & \downarrow \\ SRT_2(i) & \longrightarrow & SRT_2(ii) \\ \downarrow & & \downarrow \\ SRT_2(iii) & \longrightarrow & SRT_2(iv) \end{array}$$

Proof :-

1. Let (X, $\mathcal{T}$) be IFTS satisfy SRT_2(V), to prove that (X, $\mathcal{T}$) is satisfy SRT_2(vi) . Let x, y $\in$X, x$\neq$y. Since SRT_2(v) holes. Then $\exists$U,V $\in$SR(X) such that $\bar{x}\in$ U $\subseteq\bar{Y}^c$, $\bar{y}$ $\in$V $\subseteq\bar{X}^c$ and U $\cap$V = $\tilde{\emptyset}$, Since $\bar{x}$ $\in$U and $\bar{y}$ $\in$V then we can get easily that $\bar{\bar{x}}\in$U and $\bar{\bar{y}}$ $\in$V, therefore $\bar{\bar{x}}$ $\in$U, $\bar{\bar{y}}$ $\in$V , U $\subseteq\bar{Y}^c$, V $\subseteq$ $\bar{\bar{X}}^c$ and U $\cap$V =$\tilde{\emptyset}$ from hypotheses , so we get that (X, $\mathcal{T}$) is satisfies SRT_2(vi).
2. To prove SRT_2(i) $\rightarrow$ SRT_2(ii), let (X, $\mathcal{T}$) be IFTS satisfy SRT_2(i)and x, y $\in$X, x$\neq$y, so $\exists$U,V $\in$ SR(X) such that $\bar{x}$ $\in$ U, $\bar{y}$ $\in$V and U $\cap$V = $\tilde{\emptyset}$. Then we can get easily that $\bar{\bar{x}}$ $\in$U and $\bar{\bar{y}}$ $\in$V and U $\cap$V =$\tilde{\emptyset}$, therefore SRT_2(ii) holds.
3. Let (X, $\mathcal{T}$) be IFTS x, y $\in$X, x$\neq$y and SRT_2(i) holds, to prove SRT_2(iii) is satisfy, since SRT_2(i) holds so $\exists$U,V $\in$ SR(X) such that $\bar{x}$ $\in$ U, $\bar{y}$ $\in$V and U $\cap$V =$\tilde{\emptyset}$, since $\bar{x}$ $\in$ U and U $\cap$V = $\tilde{\emptyset}$ this implies that $\bar{x}\notin$ V, so $\bar{x}$ $\in$ V^c, this prove that for every x $\in$X , if $\bar{x}$ $\in$U, then $\bar{x}$ $\in$ V^c, $\bar{y}$ $\in$V, i.e. U$\subseteq$V , therefore SRT_2(iii) holds.
4. Suppose that SRT_2(ii) holds, to prove SRT_2(iv), let x, y $\in$X, x$\neq$y, since SRT_2(ii) is hold so
$\exists$U,V$\in$SR(X) such that $\bar{\bar{x}}\in$ $\bar{U}^c\subseteq\bar{\bar{y}}$ and U $\cap$V= $\tilde{\emptyset}$, since $\bar{\bar{x}}$ $\in$ U, then $\bar{x}$ $\notin$ V^c =$\emptyset$, so
$\bar{\bar{x}}\in$V, therefore u$\in$V, that is mean SRT_2(iv) holds.
5. In order to prove SRT_2(ii) satisfy when SRT_2(vi) holds. Let x, y $\in$X, x$\neq$y, so $\exists$ U, V $\in$SR(X) such that $\bar{\bar{x}} \in \bar{U}^c \subseteq^{\bar{\bar{Y}}}$, $\bar{\bar{y}} \in \bar{V}^c \subseteq$ X and U $\cap$V = $\tilde{\emptyset}$, from this we get directly that $\exists$U,V $\in$SR(X) such that $\bar{\bar{x}}$ $\in$ U, $\bar{\bar{y}}$ $\in$V and U $\cap$V =$\tilde{\emptyset}$, therefore SRT_2(ii) holds.
6. SRT_2(iv) $\rightarrow$ SRT_2(i) is clear.
7. To prove SRT_2(iv) satisfy when SRT_2(iii) holds, suppose that x, y $\in$ X, x$\neq$y so $\exists$ U,V $\in$ SR(X) such that $\bar{x}$ $\in$ U, $\bar{y}$$\in$V and U$\subseteq$$V^c$, so we get directly that $\bar{\bar{x}}$ $\in$U, $\bar{\bar{y}}$$\in$V and
U $\cap$V = $\tilde{\emptyset}$, therefore SRT_2(iv) holds.

Remark 3.3: In general the converse of the diagram appears in the theorem is not true in general. The following counter example shows the cases.

Example 3.4 :

(i) Let X= {1,2,3} and define $\mathcal{T}$= {$\tilde{\emptyset}$, $\tilde{X}$, A, B, C} on X where A= <x, {1}, {2,3}> , B = < x,{2}, {1,3}>, C = <x,{1,2}, {3}>, then SR(X) = {$\tilde{\emptyset}$,X,D,E} where D = < x, {1},{2}>, E = < x, {2}, {1}>, so the IFTS (X, $\mathcal{T}$) is SRT_2(ii) but not SRT_2(i) .

(ii) Let X = {1,2} and define $\mathcal{T}$= {$\tilde{\emptyset}$, $\tilde{X}$, A, B} on X where A = <x, $\emptyset$, {2}> , B = < x, $\emptyset$ {1}>, then the IFTS (X, $\mathcal{T}$) is SRT_2(ii), but not SRT_2(i).

(iii) Let X={1,2,3} and define $\mathcal{T}$= {$\tilde{\emptyset}$, $\tilde{X}$, A, B} on X where A = <x, $\emptyset$, {2,3}> , B = <x, $\emptyset$, {1,3}>, then the IFTS (X, $\mathcal{T}$) is SRT_2(vi), but not SRT_2(v).

Since every T_2 separation axiom is T_1 separation axiom in general topology, then we have the following corollary :-

Corollary 3.5: Let (X, $\mathcal{T}$) be IFTS, then if (X, $\mathcal{T}$) is satisfies SRT_2(n), then it satisfies SRT_1(n), where n$\in${i, ii, iii, iv, v, vi}, but the converse of the last corollary is not true in general and the following examples show the cases :-

Example 3.6 :

1. Let X={1,2,3} and define $\mathcal{T}$= {$\tilde{\emptyset}$, $\tilde{X}$, A, B, C, D, E, F} where A = < x, $\emptyset$, {1,2}> , B = <x, $\emptyset$, {2,3}>, C = <x,{3},{1,2} >, D = <x, {3},{2}>, E = < x, {1,3},{2}>, F = < x, $\emptyset$, {2}>, so SR(X) ={$\tilde{\emptyset}$,$\tilde{X}$, M, H} where M= <x,{3},$\emptyset$>, H = <x, $\emptyset$, {3}>, so (X, $\mathcal{T}$) is SRT1(vi), but not SRT2(vi).
2. In the example 3.4(1) we see (X, $\mathcal{T}$) is SRT_1(i) but not SRT_2(i) and in the (iii) of the example 3.4 we see (X, $\mathcal{T}$) is SRT_1(v) , but not SRT_2(v).

3. Let X = {1,2} and define $\mathcal{T}=\{\tilde{\emptyset},\tilde{X},A,B\}$ where A = <x, Ø, {1}> , B = < x, Ø, {2}>,so SR(X) = $\mathcal{T}$. Hence, (X, $\mathcal{T}$) is SRT_1(íí) , but not SRT_2(íí).

4. Take X = {1,2,3} and define $\mathcal{T}=\{\tilde{\emptyset},\tilde{X}$, A, B, C, D, E, F, G}, where A = <x,{1}, {2,3}> , B = <x,{2}, {1,3}>, C = <x,{1,2},{3} >, D = <x, {3},{1,2}>, E = <x {1,3},{2}>, F = <x, {2,3}, {1}>, so SR(X) = $\mathcal{T}$, then (X, $\mathcal{T}$) is SRT_1(ííí) , but not SRT_2(ííí).

Let X = {1,2,3} and define $\mathcal{T}=\{\tilde{\emptyset},\tilde{X}$, A, B, C, D, E, F, G, H, K} where A = <x,{1},{3}> , B = < x,{2}, Ø>, C = < x, {3}, Ø > , D = < x,{1,2}, Ø>, E = < x, {1,3}, Ø>, F = < x, {2,3}, Ø>, G = < x, Ø,{3}> , H = < x, Ø, Ø>, K= < x {1}, Ø>, then the IFS (X, $\mathcal{T}$) on X is SRT_1(ív), but not SRT_2(ív).

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حول الشبه المنتظم T_1 والشبه المنتظم T_2 في الفضاءات التبولوجية الحدسية

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الملخص

الهدف من هذا البحث هو إعطاء تعريف جديد لبديهيتي الفصل T_1 و T_2 في الفضاءات التبولوجية الحدسية وهي الفضاء الشبه المنتظم T_1 و الشبه المنتظم T_2 ودراسة بعض صفاتهما وتعميمها مع بعض التفاصيل والعلاقات التي تربط بينهما .