Fuzzy Quadrigeminal Sets: A New approach And Application

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ABSTRACT
This paper introduces a new concept " Fuzzy Quadrigeminal Sets", a new approach onassigning degree values to elements of a set. Set operations are defined over Fuzzy QuadrigeminalSets which are very useful while attempting to solve real life problems. Fuzzy Quadrigeminal sets help to reducerisk while attempting a solution on a uncertain situation. The concept of viabilityof a Fuzzy Quadrigeminal set is introduced for the purpose of finding which Fuzzy Quadrigeminalset has high percentage of optimal solution and which has low percentage of optimalsolution. The authors also proved that Fuzzy Quadrigeminal sets meet the condition of a topology and hence developed Fuzzy Quadrigeminal Topological Spaces. A real life application is explained.

Keywords: Fuzzy Set, Intuitionistic Fuzzy Set, Neutrosophic Set, Fuzzy Quadrigeminal Set, Viability, Fuzzy Quadrigeminal Topological Space.

1. INTRODUCTION

A. Zadeh gave the world the notion of assigning degree values to elements of a crisp set and hence introduced a new branch in mathematics called Fuzzy Sets in 1965. Fuzzy sets later extended by K. Atanassov by adding one more degree value to an element of a fuzzy setand hence developed the branch Intuitionistic Fuzzy Sets, whose elements are assigned two degree values, namely degree of membership and degree of non-membership. In 1998, F. Smarandache generalized the IFS by assigning 3 degree values, namely degree of truthness, degree of falsity and degree of indeterminacy and since then a new set " Neutrosophic Sets " given birth and opened a new door for many research ideas. The authors of this article introduce a new set called " Fuzzy Quadrigeminal Sets" whose elements are assigned with four degree values. The authors find that some uncertain situations occur in the field of Medical Diagnosis, Economics, Psychology and Finance can be addressed by Fuzzy Quadrigeminal Sets and hence bring feasible conclusions.
The authors developed the idea of assigning four degree values to elements of a set from the following situations.

Example : 1.1
A baby which is given birth before the 37th week is known as a premature or pre-term baby. It is possible for babies born between 23rd and 24th weeks to survive, but they are at a greater risk of health complications.
A premature baby may fall under one of the following categories.
(1). Die during delivery. (Weak)
(2). Survive for short and die out of health complications. (Moderate)
(3). Survive with health complications. (Very)
(4). Survive with good health. (Extreme)
A doctor may predict the condition of the premature baby and may explain how well the baby could survive with or without any health complications. He could categorize the baby as above.

Example:1.2
Hippocrates suggests that there are four fundamental personality types, San-guine, Choleric, Melancholic and Phlegmatic. We all have qualities from all the four temperaments. Hence, a person can be assigned membership degree values based on the above four temperaments.

2. Preliminaries

In this section we introduce the concept of Fuzzy Quadrigeminal Sets and define set operations over Fuzzy Quadrigeminal Sets.

Definition2.1

Let X be a non-empty set of objects. A Fuzzy Quadrigeminal set[FQs in short] Q in X is of the form
$Q = \{< q, ϒ_Q, Ω_Q, Ʊ_Q, \partial_Q> \ : \ q \in X\}$
where$ϒ_Q$: X → [0,1] is called the degree of extreme - belongingness to Q
$Ω_Q$: X→ [0,1] is called the degree of very - belongingness to Q
$Ʊ_Q$: X → [0,1] is called the degree of moderate – belongingness to Q
∂_Q: X→ [0,1] is called the degree of weak- belongingness to Q
such that $ϒ_Q+Ω_Q + Ʊ_Q + \partial_Q \leq 1$.

Example 2.1

Let Q = { a , b } be a universal set. A FQs Q_1 is of the form
Q_1 = { < a, 0.8,0.1,0.06,0.02 > , < b, 0.2,0.6,0.06,0.02 > }
Let Ƒ denotes the set of all FQs over Q.

Definitions 2.2

Empty set

The empty FQs may be defined as follows.

0_Q = { <q, 0,0,0,1 >}
0_Q = { <q, 0,0,1,0 >}
0_Q = { <q, 0,1,0,0 >}
0_Q = { <q, 0,0,1,1> }
0_Q = { <q, 0,1,0,1> }
0_Q = { <q, 0,1,1,0> }
0_Q = { <q, 0,1,1,1> }
0_Q = { <q, 0,0,0,0> }

Universal Set

In the same way, the set 1_Q may be defined as

1_Q = { <q, 1,0,0,0> }
1_Q = { <q, 1,1,0,0> }
1_Q = { <q, 1,1,1,0>}
1_Q = { <q, 1,0,1,0> }
1_Q = { <q, 1,0,1,1> }
1_Q = { <q, 1,1,0,1> }
1_Q = { <q, 1,0,0,1> }
1_Q= {< q, 1,1,1,1> }

Equality

Two Fuzzy Quadrigeminal Sets L and P are equal only if $ϒ_L = ϒ_P$, $Ω_L = Ω_P$,
$Ʊ_L = Ʊ_P$, $\partial_L = \partial_P$for all q in Q.

Complement

Let P = $\{< q, ϒ_P, Ω_P, Ʊ_P, \partial_P> : q \in Q\}$ be a FQs. The complement of P is denoted by c(P)and is defined by $c(P) = \{< q, \partial_P, Ʊ_P, Ω_P, ϒ_P> : q \in Q\}$

Example 2.2

Let A = {< q, 0.2, 0.6, 0.1, 0.03>}.
Then c(A) = {< q, 0.03, 0.1, 0.6, 0.2>}

Inclusion

Let L and P be two FQs in Ƒ. Then L⊆P if and only if
$ϒ_L \leq ϒ_P$, $Ω_L \leq Ω_P$, $Ʊ_L \leq Ʊ_P$, $\partial_L \geq \partial_P$

Union

Let P and R be two FQs in Ƒ. Then the union of P and R is defined as

PUR = {⟨q, Max(ϒ$_P$, ϒ$_R$), Min(Ω$_P$, Ω$_R$), Min(Ʊ$_P$, Ʊ$_R$), Min(∂_P, ∂_R)⟩}

Intersection
Let S and T be two QS in Ƒ. Then the intersection of S and T is defined as
S∩T = {<q, Min(ϒ$_S$, ϒ$_T$), Min(Ω$_S$, Ω$_T$), Min(Ʊ$_S$, Ʊ$_T$), Max(∂_S, ∂_T)>}

Example 2.3

Let Q = {q_1, q_2 } be a universe of discourse.
Let A = {< q_1, 0.2, 0.6, 0.1, 0.05 >, < q_2, 0.7, 0.15, 0.09, 0.03>}
Let B = {< q_1, 0.8, 0.1, 0.07, 0.02>, < q_2, 0.08, 0.1, 0.2, 0.6>}

Then,

A U B = {< q_1, 0.8, 0.1, 0.07, 0.02>,<q_2, 0.7, 0.1, 0.09, 0.03>} and
A∩ B = {<q_1, 0.2, 0.1, 0.07, 0.05>, <q_2, 0.08, 0.1, 0.09, 0.6>}

Remark1
One may note that the degree of indeterminacy
Π$_A$(q) = 1 − (ϒ$_A$ (q) + Ω$_A$(q) + Ʊ$_A$(q) + ∂_A(q)) is minimized in FQs.
Let A = { < a, 0.2,0.6,0.1,0.05> , < b, 0.7,0.15,0.09,0.03>}
Then,
Π$_A$(a) = 1-{0.2+0.6+0.1+0.05} = 0.05 and
Π$_A$(b) = 1-{0.7+0.15+0.09+0.03} = 0.03

Definitions 2.2
Extreme-belonging favourite
The extreme-belonging favourite of a FQ set A, denoted by ꭗA, is defined by
ꭗA = { < q, min(ϒ$_A$ (q) + $\frac{\Omega_A(q) + Ʊ_A(q)}{2}$, 1) ,0,0, $\partial_A(q)$ >}

Weak-belonging favourite
The weakly-belonging favourite of a FQ set A, denoted by ꭓA, is defined by
ꭓA= {< q, ϒ$_A$ (q) ,0,0,min($\frac{\Omega_A(q) + Ʊ_A(q)}{2}$ + $\partial_A(q)$, 1) >}

Theorem2.1 Let Q_1 , Q_2∈Ƒ. Then the followings hold.

i. Q_1∩ Q_1 = Q_1 and Q_1 U Q_1 = Q_1
ii. Q_1∩ Q_2 = Q_2∩ Q_1 and Q_1 U Q_2 = Q_2 U Q_1
iii. Q_1∩ 0_Q = 0_Q and Q_1 ∩ 1_Q = Q_1
iv. Q_1 U 0_Q = Q_1 and Q_1 U 1_Q = 1_Q
v. c(c(Q_1)) = Q_1

Proof: It is clear.

3. Viability Index
In this section we introduce the concept of viability of an element of a FQ set.
Definition 3.1
The viability index of an element in a FQ set A is defined as

$$I_v = \frac{ϒ_A + \Omega_A + Ʊ_A}{ϒ_A + \Omega_A + Ʊ_A + \partial_A}$$

Example 3.1
Let A = { < q, 0.2, 0.6,0.1,0.05> , < p, 0.03, 0.08, 0.14,0.7 > , < r, 0.06,0.3,0.5,0.1 >} be a FQ set in Ƒ. Then the viability index of q in A is

$$I_v(q) = \frac{0.2 + 0.6 + 0.1}{0.2 + 0.6 + 0.1 + 0.05} = \frac{0.9}{0.95} = 0.9473$$

Similarly, $I_v(p) = 0.2631$ and $I_v(r) = 0.895$

Remark 3.1 The viability index of an element tells us how certain that this element belongs to A.

4. Fuzzy Quadrigeminal Topological Space
In this section we define Fuzzy Quadrigeminal Topological Space and present their properties.

Definition 3.1
Let Ꞇ be a collection of sets from Ƒ. Then Ꞇ is called a topology on Q if
(i) $0_Q, 1_Q \in$ Ꞇ
(ii) $Q_1 \cap Q_2 \in$ Ꞇ , whenever $Q_1, Q_2 \in$ Ꞇ
(iii) $\bigcup_{i \in j} Q_i \in$ Ꞇ, if $Q_i \in$ Ꞇ
The pair (Q, Ꞇ) is called Fuzzy Quadrigeminal Topological space. In short we use FQTS for Fuzzy Quadrigeminal Topological Space .

Definition 3.2
The members of Ꞇ are called fuzzy quadrigeminal open sets in Q.
If $c(Q_1) \in$ Ꞇ, then $Q_1 \in$ Ƒ is said to be fuzzy quadrigeminal closed set in Q.

Example 3.1
Let $Q = \{ q_1 , q_2 \}$ be a universe of discourse.
Let Q_1, Q_2, Q_3 and Q_4 be FQ sets in X such that
$Q_1 = \{ < q_1 , 0.2, 0.6, 0.1, 0.05 > , < q_2 , 0.7, 0.15, 0.09, 0.03 > \}$
$Q_2 = \{ < q_1 , 0.05, 0.1, 0.7, 0.15 > , < q_2 , 0.08, 0.1, 0.2, 0.6 > \}$
$Q_3 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \}$
$Q_4 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \}$
Then ,
$Q_1 \cup Q_2 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \} = Q_3$
$Q_1 \cap Q_2 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \} = Q_4$
$Q_1 \cup Q_3 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \} = Q_3$
$Q_1 \cap Q_3 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \} = Q_3$
$Q_1 \cup Q_4 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \} = Q_3$
$Q_1 \cap Q_4 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \} = Q_4$
$Q_2 \cup Q_3 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \} = Q_3$
$Q_2 \cap Q_3 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \} = Q_4$
$Q_2 \cup Q_4 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \} = Q_4$
$Q_2 \cap Q_4 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \} = Q_4$
$Q_3 \cup Q_4 = \{ < q_1 , 0.2, 0.1, 0.1, 0.05 > , < q_2 , 0.7, 0.1, 0.09, 0.03 > \} = Q_3$
$Q_3 \cap Q_4 = \{ < q_1 , 0.05, 0.1, 0.1, 0.15 > , < q_2 , 0.08, 0.1, 0.09, 0.6 > \} = Q_4$
From the above, it is clear that
Ꞇ = $\{ 0_Q, 1_Q, Q_1, Q_2, Q_3, Q_4 \}$ forms a topology on Q and the pair (Q , Ꞇ) is a FQTS.

Theorem 3.1 Let (Q,Ꞇ) be a FQTS over Q. Then
(i). 0_Q and 1_Q are Fuzzy Quadrigeminal closed sets over Q.
(ii).The intersection of any number of FQ closed sets is a FQ closed set over Q.
(iii). The union of any two FQ closed set is a FQ closed set over Q.
Proof: Proof is clear.

Example3.2 Let $Q = \{ q_1 , q_2 \}$ be a universe of discourse and $Q_1 \in$ Ƒ such that
$Q_1 = \{ < q_1 , 0.2, 0.6, 0.1, 0.05 > , < q_2 , 0.7, 0.15, 0.09, 0.03 > \}$
Then, Ꞇ = $\{ 0_Q, 1_Q, Q_1 \}$ is a Fuzzy Quadrigeminal Topology on Q.

Theorem 3.2 Let (Q , $Ꞇ_1$) and (Q , $Ꞇ_2$) be two FQTS over Q. Then (Q , $Ꞇ_1 \cap Ꞇ_2$) is FQTS over Q.
Proof: Let (Q , $Ꞇ_1$) and (Q , $Ꞇ_2$) be two FQTS over Q. Clearly, $0_Q, 1_Q \in Ꞇ_1 \cap Ꞇ_2$.
If Q_1 and Q_2 are in $Ꞇ_1 \cap Ꞇ_2$, then $Q_1, Q_2 \in Ꞇ_1$ and $Q_1, Q_2 \in Ꞇ_2$.
It is given that $Q_1 \cap Q_2 \in Ꞇ_1$ and $Q_1 \cap Q_2 \in Ꞇ_2$. So, it is true that $Q_1 \cap Q_2 \in Ꞇ_1 \cap Ꞇ_2$.
Let $\{ Q_i : i \in I \}$ are in $Ꞇ_1 \cap Ꞇ_2$. Then, $Q_i \in Ꞇ_1 \cap Ꞇ_2$ for all $i \in I$. Thus, $Q_i \in Ꞇ_1$ and $Q_i \in Ꞇ_2$ for all $i \in I$. S0, we get $\bigcup_{i \in j} Q_i \in Ꞇ_1 \cap Ꞇ_2$.

Corollary 3.1 Let $\{ (Q, Ꞇ_i) : i \in I \}$ be a family of FQTS over Q. Then, $\{ Q, \cap_i Ꞇ_i \}$ is a FQTS.
Proof: It can be proved in similar way of the above theorem.

Example 3.3 Let $Q = \{ q_1 , q_2 \}$
$Q_1 = \{ < q_1 , 0.2, 0.6, 0.1, 0.05 > , < q_2 , 0.7, 0.15, 0.09, 0.03 > \}$
$Q_2 = \{ < q_1 , 0.05, 0.1, 0.7, 0.15 > , < q_2 , 0.08, 0.1, 0.2, 0.6 > \}$

Then, $Ͳ_1$ = { 0_Q , 1_Q , Q_1 } and $Ͳ_2$ = { 0_Q , 1_Q , Q_2 }is a Fuzzy Quadrigeminal Topology on Q.
But, $Ͳ_1 \cup Ͳ_2$ = { 0_Q , 1_Q , Q_1, Q_2 } is not a Fuzzy Quadrigeminal Toplogy on Q.

Definition 3.3 Let { Q, Ͳ } be a FQTS over Q and $Q_1 \in Ƒ$. Then, the FQ interior of Q_1denoted by int(Q_1) is the union of all FQ open subsets of Q_1.

Theorem 3.3 Let { Q, Ͳ } be a FQTS over Q and Q_1,$Q_2 \in Ƒ$. Then,
(i) int(0_Q) = 0_Q and int(1_Q) = 1_Q.
(ii) int (Q_1) ⊆ Q_1
(iii) Q_1 is a FQ open set if and only if Q_1 = int(Q_1)
(iv) int(int(Q_1) = int(Q_1)
(v) $Q_1 \subseteq Q_2$ implies int(Q_1) ⊆ int (Q_2)
(vi) int (Q_1) U int (Q_2) ⊆ int($Q_1 \cup Q_2$)
(vii) int($Q_1 \cap Q_2$) = int(Q_1) ∩ int(Q_2)
Proof: (i) and (ii) are obvious.
(iii) If Q_1 is a FQ open set over Q, then Q_1 itself a FQ open set over Q which contains Q_1. So, Q_1 is the largest FQ open set contained in Q_1 and int(Q_1) = Q_1.
Conversely, suppose that int(Q_1) = Q_1, then $Q_1 \in Ͳ$.
(iv) Let int(Q_1) = Q_2 . Then, int(Q_2) = Q_2 from (iii). So, int(int(Q_1) = int(Q_1)
(v) Suppose, $Q_1 \subseteq Q_2$. Since, int(Q_1) ⊆ $Q_1 \subseteq Q_2$, int(Q_1) is the FQ open subset of Q_2. But, int(Q_2) is the biggest FQ open set contained in Q_2.
Thus, int(Q_1) ⊆ int (Q_2)
(vi) Since, $Q_1 \subseteq Q_1 \cup Q_2$ and $Q_2 \subseteq Q_1 \cup Q_2$ we have int(Q_1) ⊆$Q_1 \cup Q_2$ and int(Q_2) ⊆ $Q_1 \cup Q_2$. Thus, int (Q_1) U int (Q_2) ⊆ int($Q_1 \cup Q_2$) is true.
(vii) Since, int($Q_1 \cap Q_2$) ⊆ int(Q_1) and int($Q_1 \cap Q_2$) ⊆ int(Q_2) , we have
int($Q_1 \cap Q_2$) ⊆ int(Q_1) ∩ int(Q_2).
Also, from int(Q_1) ⊆Q_1 and int Q_2) ⊆Q_2 , we have
int(Q_1)∩ int(Q_2) ⊆$Q_1 \cap Q_2$.
These, imply that int($Q_1 \cap Q_2$) = int(Q_1) ∩ int(Q_2)

5.Application of Fuzzy Quadrigeminal Sets in Psychological Investigation
In this section we present an application of FQ sets in the field of Psychology.
A personality disorder is a type of mental health condition that disturbs one's thoughts, feelings and behaviors, leading to difficulties in relationships, work and daily life.
We use FQ set tools to investigate psychological behavior of a set of students. The normalized Euclidean distance formula is applied for the investigation.

Definition 5.1 The Normalized Euclidean Distance

$$\mathbf{d_{n-E}(A,B)} = \sqrt{\frac{1}{4n}\sum_{i=1}^{n}(\Upsilon_A(x_i)-\Upsilon_B(x_i))^2+(\Omega_A(x_i)-\Omega_B(x_i))^2+(\mho_A(x_i)-\mho_B(x_i))^2+(\partial_A(x_i)-\partial_B(x_i))^2}$$

Let S = { S_1,S_2,} be a set of students and let T = { Personality difficulty, Mild personality disorder, Moderate personal disorder, Severe personal disorder } be the severity level of Personal disorder. Let U = { Negative affectivity, Detachment, Dissociality, Disinhibition, Anankastia } be the set of traits domain of students.
The table below depicts severity level with respect to traits.

Table 1. Severity vs Traits

Severity /Traits	Negative affectivity	Detachment	Dissociality	Disinhibition	Anankastia
Personality difficulty	< 0.03,0.09,0.15,0.8>	<0.8,0.1,0.04,0.01>	<0.05,0.2,0.3,0.45>	<0.02,0.15,0.2,0.6>	<0.4,0.3,0.15,0.05>
Mild PD	<0.06,0.1,0.5,0.2>	<0.6,0.15,0.06,0.02>	<0.5,0.3,0.05,0.02>	<0.1,0.2,0.5,0.1>	<0.8,0.15,0.03,0.01>
Moderate PD	<0.2,0.6,0.1,0.05>	<0.1,0.15,0.6,0.15>	<0.8,0.1,0.05,0.01>	<0.2,0.4,0.25,0.1>	<0.4,0.25,0.1,0.15>
Severe	<0.9,0.1,0.02,0>	<0.03,0.1,0.15,0.5	<0.4,0.3,0.1,0.05	<0.7,0.1,0.04,0.1	<0.02,0.1,0.15,0.7

PD		>	>	>	>

The table below shows students and their personal disorder

Table 2. Students vs PD

Students/ PD	Negative affectivity	Detachment	Dissociality	Disinhibition	Anankastia
S_1	<0.1,0.6,0.07,0.02>	<0.7,0.2,0.05,0.01>	<0.03,0.1,0.15,0.6>	<0.8,0.1,0.03,0>	<0.05,0.15,0.6,0.02>
S_2	<0.75,0.15,0.02,0>	<0.1,0.65,0.15,0.04>	<0.03,0.1,0.2,0.65>	<0.02,0.15,0.8,0.02>	<0.1,0.65,0.2,0.02>

The table below shows the distance obtained between each student and each severity level of PD using Normalized Euclidean Distance Formula.

Table 3. Students vs Severity

Students/ Severity	Personality difficulty	Mild PD	Moderate PD	Severe PD
S_1	0.3394	0.3678	0.3562	0.3687
S_2	0.3764	0.3749	0.3803	0.3815

From the above table of values, the minimum value gives the severity level of Personality Disorder of a student. S_1 scored 0.3394 which is the minimum under the trait Personality difficulty and hence S_1 is having personality difficulty.
Likewise, S_2 has Mild PD.

CONCLUSION

In this paper the authors defined a set called Fuzzy Quadrigeminal Sets by assigning four degree values to each element of a set and set operations on the set are explained. Viability indexis defined over elements of a FQ set to show its positive belongingness to the set. An application from the field of Psychology is explained.

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