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ABSTRACTS

STUDY ON BLOCKCHAIN TECHNOLOGY

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A blockchain is a public ledger to which everyone has access but without a central authority having control. It is an enabling technology for individuals and companies to collaborate with trust and transparency. One of the best know applications of blockchains are the cryptographic currencies such as Bitcoin and others are possible. Blockchain technology is considered to be the driving force of the next fundamental revolution in information technology. Many implementations of blockchain technology are widely available today, each having its particular strength for a specific application domain. This provides theory base exploration of possible business cases. Even though Blockchain holds a promising scope of development in the online transaction system, it is prone to several security and vulnerability issues. In this paper, blockchain methodology, its applications are discussed. Some of the security issues and solutions are also covered. This intended to discuss key security attacks and the enhancements that will help develop a better blockchain systems.

Keywords: Blockchain, Bitcoin, Cryptographic currency.

PARALLEL ALGORITHM FOR FINDING ALL PATHS OF A BINARY TREE USING MULTI-CORE PROCESSORS

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Searching techniques are pervasive in Artificial intelligence and Scientific problems. Exploiting parallelism in searching algorithm will be the effective utilization of resources available in the Multi-core systems and considerably reduces the running time. In this paper a parallel search algorithm is developed for finding all paths in a Tree. The proposed parallel algorithm is compared with the existing sequential algorithm. Considerable amount of time is reduced in the parallel algorithm. This paper proves in minimizing the time in various types of Binary trees and their results using the proposed parallel algorithm.

Keywords: Parallel processing, Searching Algorithms, Binary Tree

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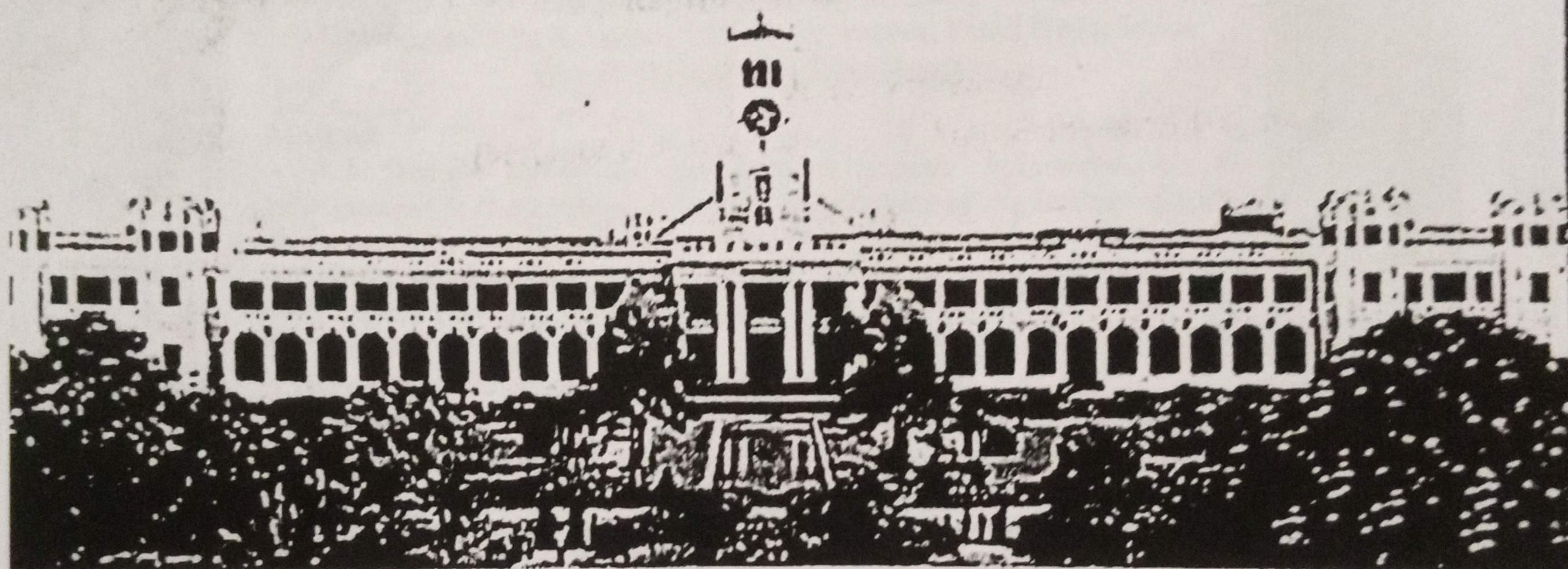

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An automated software failure prediction technique using hybrid machine learning algorithms

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ABSTRACT

Many sophisticated applications have been emerged in various industries due to the rapid growth of software technologies. Especially, the business organizations utilize the services of software-based applications to provide a state-of-the-art service. However, fault prediction in a software is a biggest challenge that needs to be addressed by the industries to improve the growth of their business. Therefore, there is a need for new techniques to perform fault prediction at an early stage of software life cycle so that software defects can be avoided in later stage. To overcome the issues in manual prediction, many prediction techniques are available that can predict the defects automatically. All of the available techniques are based on the pattern learning that finds the fault in the software based on the previously learned similar patterns. Even though many fault findings techniques are available, still there are some challenges to achieve the desired effect in its performance. To overcome the issues in currently available prediction techniques, this paper introduces an efficient software failure prediction technique using hybrid machine learning algorithms. First part of the work performs feature selection with an improved fitness function by utilizing genetic algorithm (GA) to optimize the features in the data set. After selecting the better features, Decision Tree algorithm is used as a classification technique for processing that features. The work compares the GA-DT based hybrid model with the currently available machine learning model such as RCSOLDA-RIR and WPA-PSO for the prediction of software failure. The outcome of the experimental analysis shows that the proposed model achieves better accuracy than the currently available model.

Introduction

The quality of Industrial applications has been improved greatly due to the rapid development of software technology. This ever-expanding technology improves the growth of the organization with the help of fault free software. Software defect prediction [5] is necessary for the developers to improve the quality of the software. Even a single defect in software can creates a major problem that leads to loss of the business life. Even though manual software testing is utilized in the industries, they are very complex in nature and requires manpower to perform software testing. However, algorithms such as Software failure prediction is recently performed by many automated prediction schemes [15]. They are useful in selecting appropriate prediction models and other necessary techniques automatically to predict the number of defects in the software module. However, there should be an appropriate model for a specific data set since the number of parameters in each data set is different (Herbold et.al 2018). Similarly, selecting a preprocessing technique for a particular data set is difficult since many numbers of preprocessing schemes are available. Therefore, it is very difficult to select an appropriate prediction model from the number of available models. At present, ensemble-based learning methods are popular for improving the prediction accuracy [10]. Many machine learning models are available such as random forest, decision tree, SVM, Bayesian and neural networks. Among these algorithms, neural network-based algorithms support processing of high dimensional data. In this paper, we propose a hybrid machine learning technique for the prediction of software defects. This paper is the extended version of our previous work where we utilized Ruzchika indexive regression (RCSOLDA-RIR) technique for improvising software quality. The previous works are focusing only on the better prediction of software failures but the time characteristics such as response time are not considered properly. Only few works are existed [6,7,16] by considering the importance of time factor. To overcome these problems, the proposed work introduces an improved cuckoo search algorithm

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OPTIMAL FEATURE EXTRACTION TECHNIQUES TO IDENTIFY PRINCIPAL LEARNERS' ACTIVITIES FOR PERSONALIZED LEARNING OUTCOME IN E-LEARNING

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Abstract

In recent years, the pedagogy is greatly influenced by the advancement in E-Learning. Academic performance of the learner depends on the teaching and learning activities. E-learning, in contrast to traditional education, places a greater emphasis on student-centered learning and is built around learning activities. The most effective E-Learning activities for the creation of any virtual course are continually being developed by researchers. However, adapting to online activities and achieving the desired learning outcome varies from learner to learner. It is generally observed that the learners attain the learning outcome much faster if guided with their preferred learning activities. Identifying the most preferred learning activities of a learner will ensure quicker learning capacities. The focus of this work is to employ feature extraction techniques such as Principal Components Analysis (PCA), Independent Component Analysis (ICA), and Linear Discriminant Analysis (LDA) to recognize the principal learning activities for personalized learning outcome.

Keywords: Learning Activities, Personalization, E-Learning, Principal Components Analysis (PCA), Independent Component Analysis (ICA), Linear Discriminant Analysis (LDA)

I. INTRODUCTION

There are significant developments and advancements in information and communication technology, and the modern educational system is becoming more and more technology-driven (ICT). It has created a thirst for introducing novelty and enhancement in pedagogy and the advancement, enhancement, novelty in the teaching and learning process are essential [1]. The goal of the eLearning system is to recognise the desire and requirements of various participants in the educational process, including students, teachers, and the tutors. The efforts made by eLearning systems to recognise the suitable learning activities are constantly emerging and still getting matured.

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INTUITIONISTIC FUZZY RELATION OF SECOND TYPE

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ABSTRACT

In this paper, we define the Intuitionistic Fuzzy Relation of Second Type defined on a crisp set or Intuitionistic Fuzzy Set or Intuitionistic Fuzzy Sets of Second type. Intuitionistic fuzzy relations of second type is an important concept in fuzzy mathematics because of its wide applications in real world, such as pattern recognition, machine learning, decision making and market prediction.

Key Words: Intuitionistic Fuzzy Set, Intuitionistic Fuzzy Sets of Second Type, Intuitionistic Fuzzy Relation.

Subject Classification: 03B20, 03D45, 03E72, 03F55.

1. INTRODUCTION

A crisp set partitions the universal set into two subsets members and non-members so, a crisp set has a sharp boundary, which partitions all elements inside and outside of it. Consequently, a crisp set cannot admit partial membership which is not the case in some real life situations. A Fuzzy binary relation (FBR)[4] is considered as a fuzzy subset A*B where A and B are two crisp sets. Intuitionistic Fuzzy Sets defined by K. Atanassov [1], helps us to model uncertainty with an additional degree. An Intuitionistic Relation is Intuitionistic fuzzy set in a Cartesian product of universes. Here an attempt is made to define the Intuitionistic Fuzzy Relation of Second Type between two Intuitionistic Fuzzy Sets of Second Type.

In 1976, Elie Sanchez [4] introduce the resolution of composite fuzzy relation equations and M. K. Chakraborty and Mili Das [3] studied fuzzy relations over fuzzy subsets in 1983 after P. Burillo and H. Bustince [2] further extend the concepts of intuitionistic fuzzy relations in 1995 further M. Panigrahi and S. Nanda [5] introduce the concept of intuitionistic fuzzy relations over intuitionistic fuzzy sets in 2007.

2. PRELIMINARIES

In this section, we give some basic definitions.

Definition 2.1[1] Let X be a non-empty set. An intuitionistic fuzzy set (IFS) A in X is defined as

$$A = \{< x,\ \mu_A(x),\ \nu_A(x) > \mid x \in X\}$$

Where $\mu_A: X \to [0,1]$ and $\nu_A: X \to [0,1]$ denote the degree of membership and non-membership respectively with the conditions that

$$0 \leq \mu_A(x) + \nu_A(x) \leq 1, \text{ for all } x \in X.$$

Definition 2.2[2] Let X be any non-empty set and A, B be IFS in X given by the membership function μ_A and μ_B respectively and non-membership functions ν_A and ν_B respectively, where $\mu_A, \mu_B, \nu_A, \nu_B : X \to [0,1]$. Then, A×B is an IFS in X × X defined by

$$\mu_{A \times B}(x, y) = \min\{\mu_A(x), \mu_B(y)\}$$
$$\nu_{A \times B}(x, y) = \max\{\nu_A(x), \nu_B(y)\}, \text{ for all } x, y \in X.$$

If $R \subseteq A \times B$ such that,

$$\mu_R(x,y) \le \mu_{A\times B}(x,y) \text{ and } \nu_R(x,y) \ge \nu_{A\times B}(x,y)$$

with the condition that $0 \le \mu_R(x,y) + \nu_R(x,y) \le 1$. Then R is an IFR from A to B.

Definition 2.3[1] Let X be a non-empty set. An intuitionistic fuzzy sets of second Type (IFSST) A in X is defined as

$$A = \{< x, \mu_A(x), \nu_A(x) > \mid x \in X\}$$

Where $\mu_A: X \to [0,1]$ and $\nu_A: X \to [0,1]$ denote the membership and non-membership functions of A respectively and $0 \le \mu_A{}^2(x) + \nu_A{}^2(x) \le 1$, for each $x \in X$.

Definition 2.4[1] The degree of uncertainty or the Hesitancy grade or the indeterminacy grade of X is defined as

$$\Pi_A(\boldsymbol{x}) = \sqrt{1 - (\mu_A{}^2(x) + \nu_A{}^2(x))}$$

Definition 2.5[1] Let X be a non-empty set. Let A and B be two IFSST such that

$$A = \{< x, \mu_A(x), \nu_A(x) > \mid x \in X\}$$
$$B = \{< x, \mu_B(x), \nu_B(x) > \mid x \in X\}$$

Then

i. $A \subset B$ iff, $\mu_A(x) \le \mu_B(x)$, and $\nu_A(x) \ge \nu_B(x)$, $\forall x \in X$.
ii. $A \supset B$ iff, $\mu_A(x) \ge \mu_B(x)$, and $\nu_A(x) \le \nu_B(x)$, $\forall x \in X$.
iii. $A = B$ iff, $\mu_A(x) = \mu_B(x)$, and $\nu_A(x) = \nu_B(x)$, $\forall x \in X$.
iv. $A \cup B = \{< x, \max(\mu_A(x), \mu_B(x)), \min(\nu_A(x), \nu_B(x)) | x \in X\}$
v. $A \cap B = \{< x, \min(\mu_A(x), \mu_B(x)), \max(\nu_A(x), \nu_B(x)) | x \in X\}$

3. RELATIONS ON INTUITIONISTIC FUZZY SETS OF SECOND TYPE

Definition 3.1 Let X and Y be two sets. An Intuitionistic Fuzzy Relation of Second Type from X to Y is an IFRST on X × Y is defined by

$$R = \{< (x,y), \mu_R(x,y), \nu_R(x,y) > \mid x \in X, y \in Y\}$$

Where $\mu_R: X \times Y \to [0,1]$ and $\nu_R: X \times Y \to [0,1]$ denote the membership and non-membership functions of R respectively, and $\mu_R{}^2(x,y) + \nu_R{}^2(x,y) \le 1$, for every $(x,y) \in X \times Y$.

Example 3.2 Let X={x_1, x_2, x_3} and Y= {y_1, y_2}. Then the following relation R is an *IFSST* from X to Y

R = {< (x_1, y_1), 0.4, 0.4 >, < (x_1, y_2), 0.2, 0.5 >,
< (x_2, y_1), 0.7, 0.2 >, < (x_2, y_2), 0.5, 0.3 >,
< (x_3, y_1), 0.4, 0.3 >, < (x_3, y_2), 0.6, 0.2 >}

We can represent the above IFRST as

R	y_1	y_2
x_1	(0.4, 0.4)	(0.2, 0.5)
x_2	(0.7, 0.2)	(0.5, 0.3)
x_3	(0.4, 0.3)	(0.6, 0.2)

Definition 3.3 Let X be non-empty set and A, B be IFRST in X and Y given by the membership

function μ_A and μ_B respectively and non-membership functions ν_A and ν_B respectively, where

$$\mu_A, \mu_B, \nu_A, \nu_B : X \times Y \to [0,1]$$

Then, A × B is an IFS in X × Y defined by

$$\mu_{A\times B}(x,y) = \min\{\mu_A(x), \mu_B(y)\}$$
$$\nu_{A\times B}(x,y) = \max\{\nu_A(x), \nu_B(y)\}, \text{ for all } (x,y) \in X \times Y.$$

Let $R \subseteq A \times B$ such that

$$\mu_R(x,y) \le \mu_{A\times B}(x,y)$$
$$\nu_R(x,y) \ge \nu_{A\times B}(x,y)$$

with the condition that $0 \le \mu^2_R(x,y) + \nu^2_R(x,y) \le 1$, then R is an IFRST from A to B.

Definition 3.4 Let P and R be two IFRST from X to Y. Then,

i. $P \le R$ iff, $\mu_P(x,y) \le \mu_R(x,y)$, and $\nu_P(x,y) \ge \nu_R(x,y)$, $\forall\, x \in P, y \in R$
ii. $P \cup R = \{< (x,y), \max(\mu_P(x,y), \mu_R(x,y)), \min(\nu_P(x,y), \nu_R(x,y)) | x \in P, y \in R\}$
iii. $P \cap R = \{< (x,y), \min(\mu_P(x,y), \mu_R(x,y)), \max(\nu_P(x,y), \nu_R(x,y)) \,|\, x \in P, y \in R\}$
iv. $\overline{R} = \{< (x,y), \overline{\mu_R}(x,y), \overline{\nu_R}(x,y) > | (x,y) \in X \times Y\}$

$$\text{where } \overline{\mu_R}(x,y) = \nu_R(x,y) \text{ and } \overline{\nu_R}(x,y) = \mu_R(x,y)$$

Definition 3.5 Let R, R_1, R_2 be IFRSTs from A to B. Then the operators $R_1 \cup R_2$ and $R_1 \cap R_2$ are defined as

i. $\mu_{R_1\cup R_2}(x,y) = \max\{\mu_{R_1}(x,y), \mu_{R_2}(x,y)\}$
$\nu_{R_1\cup R_2}(x,y) = \min\{\nu_{R_1}(x,y), \nu_{R_2}(x,y)\}$
ii. $\mu_{R_1\cap R_2}(x,y) = \min\{\mu_{R_1}(x,y), \mu_{R_2}(x,y)\}$
$\nu_{R_1\cap R_2}(x,y) = \max\{\nu_{R_1}(x,y), \nu_{R_2}(x,y)\}$

Definition 3.6 Given a binary IFRST from X to Y we can define the inverse relation R^{-1} from X to Y is

$$\mu_{R^{-1}}(x,y) = \mu_R(y,x)$$
$$\nu_{R^{-1}}(x,y) = \nu_R(y,x)$$

Definition 3.7 An IFRST R on IFSST A is symmetric if

$$\mu_R(x,y) = \mu_R(y,x) \text{ and } \nu_R(x,y) = \nu_R(y,x), \forall\, x, y \in X.$$

Definition 3.8 An IFRST R on IFSST A is reflexive of order (α, β) if

$$\mu_R(x,x) = \alpha \text{ and } \nu_R(x,x) = \beta, \forall\, x, y \in X.$$

such that $\mu_A(x) \ne 0, \nu_A(x) \ne 1$, Clearly,

$$0 \le \alpha + \beta \le 1.$$

Theorem 3.9 *if R is symmetric then so is* R^{-1}

Proof: $\mu_{R^{-1}}(x,y) \Leftrightarrow \mu_R(y,x)$
$\Leftrightarrow \mu_R(x,y)$
$\Leftrightarrow \mu_{R^{-1}}(y,x)$
$\nu_{R^{-1}}(x,y) \Leftrightarrow \nu_R(y,x)$
$\Leftrightarrow \nu_R(x,y)$
$\Leftrightarrow \nu_{R^{-1}}(y,x), \forall\, x, y \in X.$

Theorem 3.10 *If R is reflexive, then so is* R^{-1}

Proof: $\mu_{R^{-1}}(x,x) = \mu_R(x,x) = \alpha$

$\nu_{R^{-1}}(x,x) = \nu_R(x,x) = \beta, \forall\, x \in \mathrm{X}$

So, R^{-1} is reflexive of order (α, β)

Proposition: 3.11 *Let P and R be IFRST from X to Y. Then*

i. $P \leq R \Rightarrow P^{-1} \leq R^{-1}$

ii. $(P \cup R)^{-1} \Rightarrow P^{-1} \cup R^{-1}$

iii. $(P \cap R)^{-1} \Rightarrow P^{-1} \cap R^{-1}$

iv. $(P^{-1})^{-1} = P$

Proof:

(i) Since P ≤ R, $\mu_{P^{-1}}(x,y) = \mu_{\mathrm{P}}(y,x) \leq \mu_{\mathrm{R}}(y,x) = \mu_{R^{-1}}(x,y)$ and $\nu_{P^{-1}}(x,y) = \nu_{\mathrm{P}}(y,x) \geq \nu_{\mathrm{R}}(y,x) = \nu_{R^{-1}}(y,x)$. So, $\mu_{P^{-1}}(x,y) \leq \mu_{R^{-1}}(x,y)$and $\nu_{P^{-1}}(x,y) \geq \nu_{R^{-1}}(x,y)$. Thus, $P^{-1} \leq R^{-1}$

(ii) $\mathrm{P} \cup R = \{< (x,y), \max\big(\mu_{\mathrm{P}}(x,y), \mu_{\mathrm{R}}(x,y)\big), \min\big(\nu_{\mathrm{P}}(x,y), \nu_{\mathrm{R}}(x,y)\big) > |(x,y) \in X \times Y\}$

$(\mathrm{P} \cup R)^{-1} = \{< (x,y), \max\big(\mu_{P^{-1}}(x,y), \mu_{R^{-1}}(x,y)\big),$
$\min\big(\nu_{P^{-1}}(x,y), \nu_{R^{-1}}(x,y)\big) > |(x,y) \in X \times Y\}$

$P^{-1} = \{< (x,y), \mu_{P^{-1}}(x,y), \nu_{P^{-1}}(x,y) > |\ (x,y) \in X \times Y\}$

$R^{-1} = \{< (x,y), \mu_{R^{-1}}(x,y), \nu_{R^{-1}}(x,y) > |\ (x,y) \in X \times Y\}$

$P^{-1} \cup R^{-1} = \{< (x,y), \max\big(\mu_{P^{-1}}(x,y), \mu_{R^{-1}}(x,y)\big),$
$\mathrm{Min}\big(\nu_{P^{-1}}(x,y), \nu_{R^{-1}}(x,y)\big) > |(x,y) \in X \times Y\}$

(iii) $\mathrm{P} \cap R = \{< (x,y), \min\big(\mu_{\mathrm{P}}(x,y), \mu_{\mathrm{R}}(x,y)\big), \max(\nu_{\mathrm{P}}(x,y), \nu_{\mathrm{R}}(x,y))|(x,y) \in X \times Y\}$

$(\mathrm{P} \cap R)^{-1} = \{< (x,y), \min\big(\mu_{P^{-1}}(x,y), \mu_{R^{-1}}(x,y)\big),$
$\max\big(\nu_{P^{-1}}(x,y), \nu_{R^{-1}}(x,y)\big) > |(x,y) \in X \times Y\}$
$= P^{-1} \cap R^{-1}$

(iv) $P^{-1} = \{< (x,y), \mu_{P^{-1}}(x,y), \nu_{P^{-1}}(x,y) > |\ (x,y) \in X \times Y\}$

$(P^{-1})^{-1} = \left\{< (x,y), \mu_{(P^{-1})^{-1}}(x,y), \nu_{(P^{-1})^{-1}}(x,y) > |\ (x,y) \in X \times Y\right\}$

$= \{< (x,y), \mu_{\mathrm{P}}(x,y), \nu_P(x,y) > |\ (x,y) \in X \times Y\} = \mathrm{P}$

Proposition 3.12 *Let P, Q and R be three IFRST from X to Y and* P^{-1},Q^{-1}*and* R^{-1}*are its inverses respectively, then*

i. $P \cup R = R \cup P$

ii. $P \cap (Q \cap R) = (P \cap Q) \cap R$

iii. $P^{-1} \cup R^{-1} = R^{-1} \cup P^{-1}$

iv. $P^{-1} \cap (Q^{-1} \cap R^{-1}) = (P^{-1} \cap Q^{-1}) \cap R^{-1}$

Proof:

(i) $\mathrm{P} \cup R = \{< (x,y), \max\big(\mu_{\mathrm{P}}(x,y), \mu_{\mathrm{R}}(x,y)\big), \min(\nu_{\mathrm{P}}(x,y), \nu_{\mathrm{R}}(x,y))|(x,y) \in X \times Y\}$
$= \{< (x,y), \max\big(\mu_{\mathrm{R}}(x,y), \mu_{\mathrm{P}}(x,y)\big), \min(\nu_{\mathrm{R}}(x,y), \nu_{\mathrm{P}}(x,y))|(x,y) \in X \times Y\}$
$= R \cup P$

(ii) $Q \cap R = \{< (x,y), \min\left(\mu_{\mathrm{Q}}(x,y), \mu_{\mathrm{R}}(x,y)\right), \max(\nu_{\mathrm{Q}}(x,y), \nu_{\mathrm{R}}(x,y))|(x,y) \in X \times Y\}$

$P \cap (Q \cap R) = P \cap \{< (x,y), \min\left(\mu_{\mathrm{Q}}(x,y), \mu_{\mathrm{R}}(x,y)\right),$
$\max(\nu_{\mathrm{Q}}(x,y), \nu_{\mathrm{R}}(x,y))|(x,y) \in X \times Y\}$

$$= \{< (x,y), \min\left(\mu_P(x,y), \min\left(\mu_Q(x,y), \mu_R(x,y)\right)\right),$$
$$\max\left(\nu_P(x,y), \max\left(\nu_Q(x,y), \nu_R(x,y)\right)\right) | (x,y) \in X \times Y\}$$
$$= \{< (x,y), \min\left(\mu_P(x,y), \mu_Q(x,y), \mu_R(x,y)\right),$$
$$\max\left(\nu_P(x,y), \nu_Q(x,y), \nu_R(x,y)\right) | (x,y) \in X \times Y\}$$
$$= \{< (x,y), \min\left(\min(\mu_P(x,y), \mu_Q(x,y)), \mu_R(x,y)\right),$$
$$\max\left(\max(\nu_P(x,y), \nu_Q(x,y)), \nu_R(x,y)\right) | (x,y) \in X \times Y\}$$
$$= \left\{< (x,y), \min\left(\mu_P(x,y), \mu_Q(x,y)\right), \max\left(\nu_P(x,y), \nu_Q(x,y)\right) \middle| (x,y) \in X \text{ x } Y\right\} \cap R$$
$$= (P \cap Q) \cap R$$

(iii) $P^{-1} \cup R^{-1} = \{< (x,y), \max(\mu_{P^{-1}}(x,y), \mu_{R^{-1}}(x,y)),$
$$\min(\nu_{P^{-1}}(x,y), \nu_{R^{-1}}(x,y)) | (x,y) \in X \times Y\}$$
$$= \{< (x,y), \max(\mu_{R^{-1}}(x,y), \mu_{P^{-1}}(x,y)),$$
$$\min(\nu_{R^{-1}}(x,y), \nu_{P^{-1}}(x,y)) | (x,y) \in X \times Y\}$$
$$= R^{-1} \cup P^{-1}$$

(iv) $P^{-1} \cap (Q^{-1} \cap R^{-1})$
$$= P^{-1} \cap \{< (x,y), \min\left(\mu_{Q^{-1}}(x,y), \mu_{R^{-1}}(x,y)\right),$$
$$\max(\nu_{Q^{-1}}(x,y), \nu_{R^{-1}}(x,y)) | (x,y) \in X \times Y\}$$
$$= \{< (x,y), \min\left(\mu_{P^{-1}}(x,y), \min\left(\mu_{Q^{-1}}(x,y), \mu_{R^{-1}}(x,y)\right)\right),$$
$$\max\ (\nu_{P^{-1}}(x,y), \max\left(\nu_{Q^{-1}}(x,y), \nu_{R^{-1}}(x,y)\right)) | (x,y) \in X \times Y\}$$
$$= \{< (x,y), \min\left(\mu_{P^{-1}}(x,y), \mu_{Q^{-1}}(x,y), \mu_{R^{-1}}(x,y)\right),$$
$$\max(\nu_{P^{-1}}(x,y), \nu_{Q^{-1}}(x,y), \nu_{R^{-1}}(x,y)) | (x,y) \in X \times Y\}$$
$$= \{< (x,y), \min\left(\min(\mu_{P^{-1}}(x,y), \mu_{Q^{-1}}(x,y)), \mu_{R^{-1}}(x,y)\right),$$
$$\max(\max(\nu_{P^{-1}}(x,y), \nu_{Q^{-1}}(x,y)), \nu_{R^{-1}}(x,y)) | (x,y) \in X \times Y\}$$
$$= \left\{< (x,y), \min(\mu_{P^{-1}}(x,y), \mu_{Q^{-1}}(x,y)\right),$$
$$\max(\nu_{P^{-1}}(x,y), \nu_{Q^{-1}}(x,y)) | (x,y) \in X \text{ x } Y\} \cup R^{-1}$$
$$= (P^{-1} \cap Q^{-1}) \cap R^{-1}$$

4. CONCLUSION

We have defined a new extension of IFR, namely, IFRST and studied the various basic operations like union, intersection, subset and complement. It is still open to check whether there exist a IFRST in case of the operators already defined on an IFR. Intuitionistic fuzzy relations of second type is an important concept in fuzzy mathematics because of its wide applications in real world, such as pattern recognition, machine learning, decision making and market prediction.

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A Study on Interval Valued Temporal Neutrosophic Fuzzy Sets

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Abstract

In this research, we introduce the Interval Valued Temporal Neutrosophic Fuzzy Sets (IVTNFS) and some of its basic operations. Also, examine some of their properties. The Neutrosophic Fuzzy Sets of membership and non-membership values are not always possible up to our satisfaction, but the IVTNFS part has a more important role here, because the time movement with an interval in NFS gave the best solution to making a decision, deciding their careers in our real-life situation.

Keywords: Intuitionistic Fuzzy Sets; Temporal Intuitionistic Fuzzy Sets; Neutrosophic Fuzzy Sets; Interval Valued Neutrosophic Fuzzy Sets and Interval Valued Intuitionistic Fuzzy Sets.

Subject Classification: 03E72, 03B20, 03D45, 03F55.

1. Introduction

Zadeh L has introduced fuzzy subset idea in the beginning instance, many authors have lately explained fuzzy subset directions, encompassing soft set, hazy set, rough set, etc. whereas the interval-valued fuzzy sets [6] were expanded the IVFS and IVFSs. The idea of IVFS was proposed by Pal and Shyamal with interval-valued fuzzy matrices and demonstrated several properties of it. Intuitionistic fuzzy sets (IFSs) [1] were first described by Atanassov K. T, which are fuzzy subsets as well as a superior simplification of fuzzy sets. Since the initiation of IFS, plentiful researchers have shown their interest in the theory and utilized it in several domains, including model detection, apparatus learning, likeness processing, decision building and others. Lots of authors illustrate numerous consequences utilizing this intuitionistic fuzzy sets concept. Atanassov K.T. introduced the latest

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operations that were defined on intuitionistic fuzzy sets. Supriya Kumar De, Ranjit Biswas along with Akhil Ranjan Roy [7] suggested certain operations over intuitionistic fuzzy sets, proposed medical diagnostics via intuitionistic fuzzy sets (IFS). The Temporal intuitionistic fuzzy sets orginated by Attanassov K. T [5].
Further, the notion of Interval-Valued Intuitionistic Fuzzy Sets [IVIFS] was first introduced by George Gargov and Krassimir T Atanasov, which is an oversimplification of the equality of IFS as well as IVFS. With the subsequent advance of IVIFS, many researchers expressed their attention to the theory and also used it in a diversity of domains. Later Krassimir T Atanassov introduced the operators over interval-valued intuitionistic fuzzy sets in 1994 [4]. Florentin Smarandache and Broumi, proposed a new operation of interval-valued intuitionistic hesitant fuzzy sets. Power harmonic weighted aggregation operator on single-valued trapezoidal neutrosophic numbers and interval-valued neutrosophic sets introduced by Janani [8], Integrals by Reduction Formula in the neutrosophic studied by Manshath [9]. Interval-Valued Fermatean Neutrosophic Shortest Path Problem via Score Function studied, all these above are associated with temparal neutrosophic sets.
Florentin Smarandache [12-13] introduced Neutrosophic Set (NS) and their extensions like, Neutrosophic probability, Neutrosophic set, Neutrosophic logic, the Multi-Moora method, Single valued neutrosophic sets and Bipolar neutrosophic sets. The NS uses hesitancy as an independent measure of the membership and non-membership information. Hence the concept of NS is considered as a generalization of FS, IFS, and interval-valued sets. Interval Valued Neutrosophic Fuzzy Set was introduced by Florentin Smarandache, where the fuzzy membership grade of each part is connected with neutrosophic components, i.e., truth, indeterminacy, and falsity membership grades. The assimilation of neutrosophic components to FS is required to manage the real life information which is both uncertain and unpredictable in the environment. Certain level operators over temporal intuitionistic fuzzy sets [11] and also established some of their properties. Solving shortest path problems using an ant colony algorithm with triangular neutrosophic arc weights [3], Complex fermatean neutrosophic graph and application to decision making. Decision Making [2] explained by Broumi.
The neutrosophic fuzzy sets where proposed the fuzzy membership grade of each element is associated with neutrosophic mechanism, i.e., truth, indeterminacy, and falsity membership grades. The incorporation of neutrosophic components to Fuzzy Sets is necessary to handle the real life in turn which are both uncertain and inconsistent in nature. In various real life troubles, the membership degree of a FS cannot be totally assured due to the inaccurate and conflicting characteristic of human accomplishment. Therefore, it is more rational to engage neutrosophic fuzzy components to delegate the membership degree. From this view point, the authors propose the interval valued temporal neutrosophic fuzzy set (IVTNFS), in additional; the membership position of the neutrosophic components can also be expressed with IVNFS. The Interval Valued Neutrosophic Fuzzy Sets of membership and non-membership values are not always possible up to our satisfaction, but the IVTNFS part has a more important role here, because the time moment of IVNFS gives the best solution to finding the shortest distance in making a decision, decide their careers and so on. Particularly in the case of medical diagnosis, there is a fair chance of the existence of a non-zero hesitation part at each moment of evaluation by using this concept.
The rest of the paper is designed as follows: Section 2 gives some basic definition’s. In Section 3, we define the Interval Valued Temporal Neutrosophic Fuzzy Sets. Also, we establish some relationships among the existing sets. This paper is concluded in section 4.

2. Preliminaries

Neutrosophic Fuzzy Sets is important in real life situation and its most important in decision making like career determination, image processing, medical diagnosis, etc. In our reality, we find things that cannot be precisely defined and that contain an indeterminacy part. This is the reason for studying neutrosophic fuzzy sets and their extensions.

Definition 2.1[29] Let G be a non-empty set. A Fuzzy Set A in G is characterized by its membership function and $\mu_A(r)$ is interpreted as the degree of membership of the element G in fuzzy set A, for each $r \in G$. It is clear that A is completely determined by the set of tuples

$$A = \{< r, \mu_A(r) > | \, r \in G\}$$

Definition 2.2[1] Let G be a non-empty set. An intuitionistic fuzzy set (IFS) A in G is defined as an object of the following form.

$$A = \{< x, \mu_A(x), \nu_A(x) > | \, x \in X\}$$

where the functions $\mu_A: G \to [0,1]$ and $\nu_A: G \to [0,1]$ denote the degree of membership and the degree of non-membership of the element $r \in G$, respectively, and for every $r \in G$.

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$$0 \leq \mu_A(x) + \nu_A(x) \leq 1$$

Definition 2.3[9] Let G be a non-empty set and A Temporal Intuitionistic Fuzzy Sets (TIFS) is defined as the following object of the form.

$$A = \{< r, \mu_A(r,t), \nu_A(r,t) > \mid < r,t > \in G \times T\}$$

where

i) $A \subset G$ is a fixed set.

ii) $\mu_A(r,t) + \nu_A(r,t) \leq 1$ For every $< r,t > \in G \times T$.

$\mu_A(r,t)$ and $\nu_A(r,t)$ are the degree of membership and the degree of non-membership of the element $r \in G$, respectively, and the time – moment $t \in T$.

Definition 2.4[4] An Interval Valued Intuitionistic Fuzzy Set (IVIFS) A in G is given by

$$A = \{< r, M_A(r,t), N_A(r,t) > |r \in G\}$$

where M_A: G → [0,1], N_A: G → [0,1]. The intervals $M_A(r,t)$ and $N_A(r,t)$ denote the degree of membership and the degree of non-membership of the element G to the set A, where $M_A(r,t) = [M_{AL}(r,t), M_{AU}(r,t)]$ and $N_A(r,t) = [N_{AL}(r,t), N_{AU}(r,t)]$ with the condition that $M_{AU}(r,t) + N_{AU}(r,t) \leq 1$ for all $r \in G$.

Definition 2.5[19] Let G be a universal set and $r \in G$. A Neutrosophic Sets (NS) A in G is characterized by a truth, indeterminacy, and falsity membership function which are, respectively denoted as T_A, I_A and F_A and it is denoted as the following form

$$A = \{< r, T_A(r), I_A(r), F_A(r) >| r \in G\}$$

The functions $T_A(r), I_A(r)$ and $F_A(r)$ are real standard or non-standard subsets of $]0^-, 1^+[$, .i.e., $T_A(r) : G \to]0^-, 1^+[, I_A(r) : G \to]0^-, 1^+[$ and $F_A(r) : G \to]0^-, 1^+[$ No restriction is applied on the sum of $T_A(r), I_A(r)$ and $F_A(r)$, so

$$0^- \leq \sup T_A(r) + \sup I_A(r) + \sup F_A(r) \leq 3^+$$

For a fixed $r \in G$. $T_A(r), I_A(r)$ and $F_A(r)$ is called neutrosophic number.

Definition 2.6[22] Let G be a set of objects and $A = \{r,\ \mu_A(r) \mid r \in G\}$, where $\mu_A(r) : G \to [0,1]$ be a fuzzy set. Then a Neutrosophic Fuzzy Sets (NFS) A in G defined by

$$A = \{< r, \mu_A(r), T_A(r,\mu), I_A(r,\mu), F_A(r) >| r \in G\}$$

where each membership value is expressed by a truth, indeterminacy, and falsity membership function which are respectively denoted as $T_A(r,\mu), I_A(r,\mu)$ and $F_A(r,\mu)$. Moreover T_A, I_A and F_A are real standard or non-standard subsets of $]0^-, 1^+[$, i.e., $T_A(r) : G \to]0^-, 1^+[, I_A(r) : G \to]0^-, 1^+[$ and $F_A(r) : G \to]0^-, 1^+[$ No restriction is applied on the sum of $T_A(r), I_A(r)$ and $F_A(r)$, so

$$0^- \leq \sup T_A(r) + \sup I_A(r) + \sup F_A(r) \leq 3^+$$

For a fixed $r \in G$. $\mu_A(r), T_A(r), I_A(r)$ and $F_A(r)$ is called neutrosophic fuzzy number(NFN).

Definition 2.7[26] Let G be a non empty set. Then an Interval Valued Neutrosophic Sets (IVNS) A is an object of the following form

$$A = \{< r, [\inf T_A(r), \sup T_A(r)], [\inf I_A(r), \sup I_A(r)], [\inf F_A(r), \sup F_A(r)] >| r \in G\}$$

where the functions $T_A(r), I_A(r)$ & $F_A(r) : G \to]0^-, 1^+[$ and $0 \leq \sup T_A(r) + \sup I_A(r) + \sup F_A(r) \leq 3$

We denote the class of all interval valued neutrosophic sets on G by IVNSG.

Definition 2.8[6] Let A, B be two interval valued neutrosophic sets on G. Then

(i) A is called a subset of B, denoted by $A \subseteq B$ if

$$\inf T_A(r) \leq \inf T_B(r), \sup T_A(r) \leq \sup T_B(r), \inf I_A(r) \leq \inf I_B(r), \sup I_A(r) \leq \sup I_B(r),$$
$$\inf F_A(r) \leq \inf F_B(r), \sup F_A(r) \leq \sup F_B(r)\ \forall\, r \in G$$

(ii) The intersection of A and B is denoted by $A \cap B$ and is defined by

$$A \cap B = \{r, < [\min[\inf T_A(r), \inf T_B(r)], \min[\sup T_A(r), \sup T_B(r)]],$$
$$[\max[\inf I_A(r), \inf I_B(r)], \max[\sup I_A(r), \sup I_B(r)]],$$
$$[\max[\inf F_A(r), \inf F_B(r)], \max[\sup F_A(r), \sup F_B(r)]] > |r \in G\}$$

(iii) The union of A and B is denoted by $A \cup B$ and is defined by

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$$A \cup B = \{r, < [\max[\inf T_A(r), \inf T_B(r)], \max[\sup T_A(r), \sup T_B(r)]], [\min[\inf I_A(r), \inf I_B(r)], \min[\sup I_A(r), \sup I_B(r)]], [\min[\inf F_A(r), \inf F_B(r)], \min[\sup F_A(r), \sup F_B(r)]] > | r \in G \}$$

(iv) The complement of A is denoted by A^c and is defined by

$$A^c = \{ < [\inf F_A(r), \sup F_A(r)], [1 - \sup I_A(r), 1 - \inf I_A(r)], [\inf T_A(r), \sup T_A(r)] > | r \in G\}$$

3. Interval Valued Temporal Neutrosophic Fuzzy Sets

In this section, we define the Interval Valued Temporal Neutrosophic Fuzzy Sets and its fundamental operations in addition that, we establish some relation along with the existing sets.

Definition 3.1 Let G be a non- empty set, then the Interval Valued Temporal Neutrosophic Fuzzy Sets (IVNFS) A in G is define in the following form

$$A = \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > | (r,t) \in G \times T\}$$

where the functions $\mu_A(r,t), T_A(r,t), I_A(r,t)$ & $F_A(r,t) : G \rightarrow]0^-, 1^+[$ and

$$0 \le \sup \mu_A(r,t) + \sup T_A(r,t) + \sup I_A(r,t) + \sup F_A(r,t) \le 3$$

Definition 3.2 Let A, B be two interval valued temporal neutrosophic fuzzy sets on G. Then A is called a subset of B, denoted by $A \subseteq B$ if

$$\inf T_A(r,t) \le \inf T_B(r,t), \sup T_A(r,t) \le \sup T_B(r,t), \inf I_A(r,t) \le \inf I_B(r,t), \sup I_A(r,t) \le \sup I_B(r,t), \inf F_A(r,t) \le \inf F_B(r,t), \sup F_A(r,t) \le \sup F_B(r,t) \ \forall \ (r,t) \in G \times T$$

Definition 3.3 Let A, B be two interval valued temporal neutrosophic fuzzy sets on G. Then A is called the intersection of A and B is denoted by $A \cap B$ and the union of A and B is denoted by $A \cup B$ respectively and it is define by the following form

$$A \cap B = \{(r,t), < [\min[\inf T_A(r,t), \inf T_B(r,t)], \min[\sup T_A(r,t), \sup T_B(r,t)]], [\max[\inf I_A(r,t), \inf I_B(r,t)], \max[\sup I_A(r,t), \sup I_B(r,t)]], [\max[\inf F_A(r,t), \inf F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > | (r,t) \in G \times T\}$$

$$A \cup B = \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]], [\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]], [\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > | (r,t) \in G \times T\}$$

Definition 3.4 Let A, B be two interval valued temporal neutrosophic fuzzy sets on G. Then A is called the complement of A is denoted by A^c and it is define by the following form

$$A^c = \{(r,t), < [\inf F_A(r,t), \sup F_A(r,t)], [1 - \sup I_A(r,t), 1 - \inf I_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)] > | (r,t) \in G \times T\}$$

Proposition 3.5 *Let A, B and C be two interval valued temporal neutrosophic fuzzy sets on G. Then for every IVTNFSs, we have the following*

i. $A \cup B = B \cup A$
ii. $A \cap B = B \cap A$
iii. $(A \cup B) \cup C = A \cup (B \cup C)$
iv. $(A \cap B) \cap C = A \cap (B \cap C)$
v. $\overline{(\bar{A} \cup \bar{B})} = A \cap B$
vi. $\overline{(\bar{A} \cap \bar{B})} = A \cup B$

Proof: Let

$$A = \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > | (r,t) \in G \times T\}$$

and

$$B = \{ < (r,t), [\inf \mu_B(r,t), \sup \mu_B(r,t)], [\inf T_B(r,t), \sup T_B(r,t)], [\inf I_B(r,t), \sup I_B(r,t)], [\inf F_B(r,t), \sup F_B(r,t)] > | (r,t) \in G \times T\}$$

Then by the definition of union,

$$A \cup B = \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]],$$

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$$[\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]],$$
$$[\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\}$$
$$= \{(r,t), < [\max[\inf T_B(r,t), \inf T_A(r,t)], \max[\sup T_B(r,t), \sup T_A(r,t)]],$$
$$[\min[\inf I_B(r,t), \inf I_A(r,t)], \min[\sup I_B(r,t), \sup I_A(r,t)]],$$
$$[\min[\inf F_B(r,t), \inf F_A(r,t)], \min[\sup F_B(r,t), \sup F_A(r,t)]] > |(r,t) \in G \times T\}$$
$$= B \cup A$$

Which is proved (i). by the definition of intersection,

$$A \cap B = \{(r,t), < [\min[\inf T_A(r,t), \inf T_B(r,t)], \min[\text{supe}\, T_A(r,t), \sup T_B(r,t)]],$$
$$[\max[\inf I_A(r,t), \inf I_B(r,t)], \max[\sup Ih_A(r,t), \sup I_B(r,t)]],$$
$$[\max[\inf F_A(r,t), \inf F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\}$$
$$= \{(r,t), < [\min[\inf T_B(r,t), \inf T_A(r,t)], \min[\sup T_B(r,t), \sup T_A(r,t)]],$$
$$[\max[\inf I_B(r,t), \inf I_A(r,t)], \max[\sup I_B(r,t), \sup I_A(r,t)]],$$
$$[\max[\inf F_B(r,t), \inf F_A(r,t)], \max[\sup F_B(r,t), \sup F_A(r,t)]] > |(r,t) \in G \times T\}$$
$$= B \cap A$$

hence its proved the part (ii) and the third part of the proof as follows

$$(A \cup B) \cup C = \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]],$$
$$[\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]],$$
$$[\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\} \cup C$$
$$= \{(r,t),$$
$$< [\max[\max[\inf T_A(r,t), \inf T_B(r,t)], \inf T_C(r,t)], \max[\max[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$$
$$[\min[\min[\inf I_A(r,t), \inf I_B(r,t)], \inf I_C(r,t)], \min[\min[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$$
$$[\min[\min[\inf F_A(r,t), \inf F_B(r,t)], \inf F_C(r,t)], \min[\min[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)]$$
$$>\}$$
$$= \{(r,t), < [\max[\inf \mathrm{T_A(r,t)}, \max[\inf T_B(r,t), \inf T_C(r,t)]], \max[\sup T_A(r,t), \max[\sup T_B(r,t), \sup T_C(r,t)]],$$
$$[\min[\inf \mathrm{I_A(r,t)}, \min[\inf I_B(r,t), \inf I_C(r,t)]], \min[\sup I_A(r,t), \min[\sup I_B(r,t), \sup I_C(r,t)]],$$
$$[\min[\inf \mathrm{F_A(r,t)}, \min[\inf F_B(r,t), \inf F_C(r,t)]], \min[\sup F_A(r,t), \min[\sup F_B(r,t), \sup F_C(r,t)]] >\}$$
$$= A \cup \{(r,t), < [\max[\inf T_B(r,t), \inf T_C(r,t)], \max[\sup T_B(r,t), \sup T_C(r,t)]],$$
$$[\min[\inf I_B(r,t), \inf I_C(r,t)], \min[\sup I_B(r,t), \sup I_C(r,t)]],$$
$$[\min[\inf F_B(r,t), \inf F_C(r,t)], \min[\sup F_B(r,t), \sup F_C(r,t)]] > |(r,t) \in G \times T\}$$
$$= A \cup (B \cup C)$$

hence its proved the part (iii) and the fourth part of the proof as follows

$$(A \cap B) \cap C = \{(r,t), < [\min[\inf T_A(r,t), \inf T_B(r,t)], \min[\sup T_A(r,t), \sup T_B(r,t)]],$$
$$[\max[\inf I_A(r,t), \inf I_B(r,t)], \max[\sup I_A(r,t), \sup I_B(r,t)]],$$
$$[\max[\inf F_A(r,t), \inf F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\} \cup C$$
$$= \{(r,t), < [\min[\min[\inf T_A(r,t), \inf T_B(r,t)], \inf T_C(r,t)], \min[\min[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$$
$$[\max[\max[\inf I_A(r,t), \inf I_B(r,t)], \inf I_C(r,t)], \max[\max[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$$
$$[\max[\max[\inf F_A(r,t), \inf F_B(r,t)], \inf F_C(r,t)], \max[\max[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)]$$
$$>\}$$
$$= \{(r,t), < [\min[\inf \mathrm{T_A(r,t)}, \min[\inf T_B(r,t), \inf T_C(r,t)]], \min[\sup T_A(r,t), \min[\sup T_B(r,t), \sup T_C(r,t)]],$$
$$[\max[\inf \mathrm{I_A(r,t)}, \max[\inf I_B(r,t), \inf I_C(r,t)]], \max[\sup I_A(r,t), \max[\sup I_B(r,t), \sup I_C(r,t)]],$$
$$[\max[\inf \mathrm{F_A(r,t)}, \max[\inf F_B(r,t), \inf F_C(r,t)]], \max[\sup F_A(r,t), \max[\sup F_B(r,t), \sup F_C(r,t)]] >\}$$
$$= A \cap \{(r,t), < [\min[\inf T_B(r,t), \inf T_C(r,t)], \min[\sup T_B(r,t), \sup T_C(r,t)]],$$
$$[\max[\inf I_B(r,t), \inf I_C(r,t)], \max[\sup I_B(r,t), \sup I_C(r,t)]],$$
$$[\max[\inf F_B(r,t), \inf F_C(r,t)], \max[\sup F_B(r,t), \sup F_C(r,t)]] > |(r,t) \in G \times T\}$$
$$= A \cap (B \cap C)$$

Which is proved (iv). by the definition of complement,

$$\bar{A} = \{(r,t), < [\inf F_A(r,t), \sup F_A(r,t)], [1 - \sup I_A(r,t), 1 - \inf I_A(r,t)],$$
$$[\inf T_A(r,t), \sup T_A(r,t)] > |(r,t) \in G \times T\}$$

And

$$\bar{B} = \{(r,t), < [\inf F_B(r,t), \sup F_B(r,t)], [1 - \sup I_B(r,t), 1 - \inf I_B(r,t)],$$
$$[\inf T_B(r,t), \sup T_B(r,t)] > |(r,t) \in G \times T\}$$

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Take the union operation, we have

$$\bar{A} \cup \bar{B} = \{(r,t), < [\inf F_A(r,t), \sup F_A(r,t)], [1 - \sup I_A(r,t), 1 - \inf I_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)] > |(r,t) \in G \times T\} \cup \{(r,t), < [\inf F_B(r,t), \sup F_B(r,t)], [1 - \sup I_B(r,t), 1 - \inf I_B(r,t)], [\inf T_B(r,t), \sup T_B(r,t)] > |(r,t) \in G \times T\}$$
$$= \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]], [\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]], [\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\}$$
$$\overline{(\bar{A} \cup \bar{B})} = \{(r,t), < [\min[\inf T_A(r,t), \inf T_B(r,t)], \min[\sup T_A(r,t), \sup T_B(r,t)]], [\max[\inf I_A(r,t), \inf I_B(r,t)], \max[\sup I_A(r,t), \sup I_B(r,t)]], [\max[\inf F_A(r,t), \inf F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\}$$
$$= A \cap B$$

Hence proved (v). Appl the intersection operation, we have

$$\bar{A} \cap \bar{B} = \{(r,t), < [\inf F_A(r,t), \sup F_A(r,t)], [1 - \sup I_A(r,t), 1 - \inf I_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)] > |(r,t) \in G \times T\} \cap \{(r,t), < [\inf F_B(r,t), \sup F_B(r,t)], [1 - \sup I_B(r,t), 1 - \inf I_B(r,t)], [\inf T_B(r,t), \sup T_B(r,t)] > |(r,t) \in G \times T\}$$
$$= \{(r,t), < [\min[\inf T_A(r,t), \inf T_B(r,t)], \min[\sup T_A(r,t), \sup T_B(r,t)]], [\max[\inf I_A(r,t), \inf I_B(r,t)], \max[\sup I_A(r,t), \sup I_B(r,t)]], [\max[\inf F_A(r,t), \inf F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\}$$
$$\overline{(\bar{A} \cap \bar{B})} = \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]], [\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]], [\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\}$$
$$= A \cup B$$

Hence, this completes the proofs of the proposition.

Proposition 3.6 *The following law holds good for every IVTNFS A:*

i. $A \cup A = A$

ii. $A \cap A = A$

Proof: Let

$$A = \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\}$$

Take the union operation for the same set A, we have

$$= \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\} \cup \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\}$$
$$= \{(r,t), < [\max[\inf T_A(r,t), \inf T_A(r,t)], \max[\sup T_A(r,t), \sup T_A(r,t)]], [\min[\inf I_A(r,t), \inf I_A(r,t)], \min[\sup I_A(r,t), \sup I_A(r,t)]], [\min[\inf F_A(r,t), \inf F_A(r,t)], \min[\sup F_A(r,t), \sup F_A(r,t)]] > |(r,t) \in G \times T\}$$
$$= \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\}$$
$$= A$$

Take the intersection operation for the same set A, we have

$$= \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\} \cap \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\}$$
$$= \{(r,t), < [\min[\inf T_A(r,t), \inf T_A(r,t)], \min[\sup T_A(r,t), \sup T_A(r,t)]], [\max[\inf I_A(r,t), \inf I_A(r,t)], \max[\sup I_A(r,t), \sup I_A(r,t)]], [\max[\inf F_A(r,t), \inf F_A(r,t)], \max[\sup F_A(r,t), \sup F_A(r,t)]] > |(r,t) \in G \times T\}$$
$$= \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > |(r,t) \in G \times T\}$$
$$= A.$$

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This completes the proposition.

Proposition 3.7 *Let A, B and C be the interval valued temporal neutrosophic fuzzy sets on G. Then for every IVTNFS, we have the following*

i. $(A \cup B) \cap C = (A \cap C) \cup (B \cap C)$

ii. $(A \cap B) \cup C = (A \cup C) \cap (B \cup C)$

Proof: Let

$A = \{ < (r,t), [\inf \mu_A(r,t), \sup \mu_A(r,t)], [\inf T_A(r,t), \sup T_A(r,t)], [\inf I_A(r,t), \sup I_A(r,t)], [\inf F_A(r,t), \sup F_A(r,t)] > | (r,t) \in G \times T\}$

and

$B = \{ < (r,t), [\inf \mu_B(r,t), \sup \mu_B(r,t)], [\inf T_B(r,t), \sup T_B(r,t)], [\inf I_B(r,t), \sup I_B(r,t)], [\inf F_B(r,t), \sup F_B(r,t)] > | (r,t) \in G \times T\}$

By the definition of union,

$$A \cup B = \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]], [\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]], [\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > | (r,t) \in G \times T\}$$

By the definition of intersection,

$$A \cap B = \{(r,t), < [\min[\inf T_A(r,t), \inf T_B(r,t)], \min[\text{supe}\, T_A(r,t), \sup T_B(r,t)]], [\max[\inf I_A(r,t), \inf I_B(r,t)], \max[\sup Ih_A(r,t), \sup I_B(r,t)]], [\max[\inf F_A(r,t), \inf F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > | (r,t) \in G \times T\}$$

i. LHS: $(A \cup B) \cap C$

$= \{(r,t), < [\max[\inf T_A(r,t), \inf T_B(r,t)], \max[\sup T_A(r,t), \sup T_B(r,t)]], [\min[\inf I_A(r,t), \inf I_B(r,t)], \min[\sup I_A(r,t), \sup I_B(r,t)]], [\min[\inf F_A(r,t), \inf F_B(r,t)], \min[\sup F_A(r,t), \sup F_B(r,t)]] > | (r,t) \in G \times T\} \cap C$

$= \{(r,t),$
$< [\min[\max[\inf T_A(r,t), \inf T_B(r,t)], \inf T_C(r,t)], \min[\max[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$
$[\max[\min[\inf I_A(r,t), \inf I_B(r,t)], \inf I_C(r,t)], \max[\min[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$
$[\max[\min[\inf F_A(r,t), \inf F_B(r,t)], \inf F_C(r,t)], \max[\min[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)] >\}$

$= \{(r,t),$
$< [\max[\min[\inf T_A(r,t), \inf T_B(r,t)], \inf T_C(r,t)], \max[\min[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$
$[\min[\max[\inf I_A(r,t), \inf I_B(r,t)], \inf I_C(r,t)], \min[\max[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$
$[\min[\max[\inf F_A(r,t), \inf F_B(r,t)], \inf F_C(r,t)], \min[\max[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)] >\}$

Now,

$A \cap C = \{(r,t), < [\min[\inf T_A(r,t), \inf T_C(r,t)], \min[\sup T_A(r,t), \sup T_C(r,t)]], [\max[\inf I_A(r,t), \inf I_C(r,t)], \max[\sup I_A(r,t), \sup I_C(r,t)]], [\max[\inf F_A(r,t), \inf F_C(r,t)], \max[\sup F_A(r,t), \sup F_C(r,t)]] > | (r,t) \in G \times T\}$

$B \cap C = \{(r,t), < [\min[\inf T_B(r,t), \inf T_C(r,t)], \min[\sup T_B(r,t), \sup T_C(r,t)]], [\max[\inf I_B(r,t), \inf I_C(r,t)], \max[\sup I_B(r,t), \sup I_C(r,t)]], [\max[\inf F_B(r,t), \inf F_C(r,t)], \max[\sup F_B(r,t), \sup F_C(r,t)]] > | (r,t) \in G \times T\}$

RHS: $(A \cap C) \cup (B \cap C)$

$= \{(r,t), < [\min[\inf T_A(r,t), \inf T_C(r,t)], \min[\sup T_A(r,t), \sup T_C(r,t)]], [\max[\inf I_A(r,t), \inf I_C(r,t)], \max[\sup I_A(r,t), \sup I_C(r,t)]], [\max[\inf F_A(r,t), \inf F_C(r,t)], \max[\sup F_A(r,t), \sup F_C(r,t)]] > | (r,t) \in G \times T\} \cup$
$\{(r,t), < [\min[\inf T_B(r,t), \inf T_C(r,t)], \min[\sup T_B(r,t), \sup T_C(r,t)]], [\max[\inf I_B(r,t), \inf I_C(r,t)], \max[\sup I_B(r,t), \sup I_C(r,t)]], [\max[\inf F_B(r,t), \inf F_C(r,t)], \max[\sup F_B(r,t), \sup F_C(r,t)]] > | (r,t) \in G \times T\}$

$= \{(r,t),$
$< [\max[\min[\inf T_A(r,t), \inf T_B(r,t)], \inf T_C(r,t)], \max[\min[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$

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$[\min[\max[\inf\ I_A(r,t), \inf\ I_B(r,t)], \inf I_C(r,t)], \min[\max[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$
$[\min[\max[\inf\ F_A(r,t), \inf\ F_B(r,t)], \inf F_C(r,t)], \min[\max[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)]$
$>\}$

Hence, $(A \cup B) \cap C = (A \cap C) \cup (B \cap C)$.

ii. LHS: $(A \cap B) \cup C$
$= \{(r,t), < [\min[\inf\ T_A(r,t), \inf\ T_B(r,t)], \min[\sup T_A(r,t), \sup T_B(r,t)]],$
$[\max[\inf I_A(r,t), \inf\ I_B(r,t)], \max[\sup I_A(r,t), \sup I_B(r,t)]],$
$[\max[\inf F_A(r,t), \inf\ F_B(r,t)], \max[\sup F_A(r,t), \sup F_B(r,t)]] > |(r,t) \in G \times T\} \cup C$

$= \{(r,t),$
$< [\max[\min[\inf\ T_A(r,t), \inf\ T_B(r,t)], \inf T_C(r,t)], \max[\min[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$
$[\min[\max[\inf\ I_A(r,t), \inf\ I_B(r,t)], \inf I_C(r,t)], \min[\max[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$
$[\min[\max[\inf\ F_A(r,t), \inf\ F_B(r,t)], \inf F_C(r,t)], \min[\max[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)]$
$>\}$

Now,
$A \cup C = \{(r,t), < [\max[\inf\ T_A(r,t), \inf\ T_C(r,t)], \max[\sup T_A(r,t), \sup T_C(r,t)]],$
$[\min[\inf I_A(r,t), \inf\ I_C(r,t)], \min[\sup I_A(r,t), \sup I_C(r,t)]],$
$[\min[\inf F_A(r,t), \inf\ F_C(r,t)], \min[\sup F_A(r,t), \sup F_C(r,t)]] > |(r,t) \in G \times T\}$

$B \cup C = \{(r,t), < [\max[\inf\ T_B(r,t), \inf\ T_C(r,t)], \max[\sup T_B(r,t), \sup T_C(r,t)]],$
$[\min[\inf I_B(r,t), \inf\ I_C(r,t)], \min[\sup I_B(r,t), \sup I_C(r,t)]],$
$[\min[\inf F_B(r,t), \inf\ F_C(r,t)], \min[\sup F_B(r,t), \sup F_C(r,t)]] > |(r,t) \in G \times T\}$

RHS: (A ∪ C) ∩ (B ∪ C)
$= \{(r,t), < [\max[\inf\ T_A(r,t), \inf\ T_C(r,t)], \max[\sup T_A(r,t), \sup T_C(r,t)]],$
$[\min[\inf I_A(r,t), \inf\ I_C(r,t)], \min[\sup I_A(r,t), \sup I_C(r,t)]],$
$[\min[\inf F_A(r,t), \inf\ F_C(r,t)], \min[\sup F_A(r,t), \sup F_C(r,t)]] > |(r,t) \in G \times T\} \cap$
$\{(r,t), < [\max[\inf\ T_B(r,t), \inf\ T_C(r,t)], \max[\sup T_B(r,t), \sup T_C(r,t)]],$
$[\min[\inf I_B(r,t), \inf\ I_C(r,t)], \min[\sup I_B(r,t), \sup I_C(r,t)]],$
$[\min[\inf F_B(r,t), \inf\ F_C(r,t)], \min[\sup F_B(r,t), \sup F_C(r,t)]] > |(r,t) \in G \times T\}$

$= \{(r,t),$
$< [\min[\max[\inf\ T_A(r,t), \inf\ T_B(r,t)], \inf T_C(r,t)], \min[\max[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$
$[\max[\min[\inf\ I_A(r,t), \inf\ I_B(r,t)], \inf I_C(r,t)], \max[\min[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$
$[\max[\min[\inf\ F_A(r,t), \inf\ F_B(r,t)], \inf F_C(r,t)], \max[\min[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)]$
$>\}$

$= \{(r,t),$
$< [\max[\min[\inf\ T_A(r,t), \inf\ T_B(r,t)], \inf T_C(r,t)], \max[\min[\sup T_A(r,t), \sup T_B(r,t)], \sup T_C(r,t)],$
$[\min[\max[\inf\ I_A(r,t), \inf\ I_B(r,t)], \inf I_C(r,t)], \min[\max[\sup I_A(r,t), \sup I_B(r,t)], \sup I_C(r,t)],$
$[\min[\max[\inf\ F_A(r,t), \inf\ F_B(r,t)], \inf F_C(r,t)], \min[\max[\sup F_A(r,t), \sup F_B(r,t)], \sup F_C(r,t)]$
$>\}$

Hence, (A ∩ B) ∪ C = (A ∪ C) ∩ (B ∪ C).

4. Conclusion

We have defined a new extension of Intuitionistic Fuzzy Sets, namely, Interval Valued Temporal Intuitionistic Fuzzy Sets and studied various basic operations like combination, connection, separation and complement. We have proved the commutatively and Associative of union and intersections and the distributive law of one over the other. Also, we have proved the idempotence law and demorgan's law. The defined IVTIFS is useful in many applications. It is open to check the newly defined IVTIFS in the real time applications such as medical diagnosis, electrol system, career determination and pattern recognition and so on.

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