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Post-symptomatic detection of COVID-2019 grade based mediative fuzzy projection☆

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ABSTRACT
The concept of fuzzy set, intuitionistic set, and mediative fuzzy set as a generalization of a crisp set have been introduced in many real-life applications. The concept of crisp relation between elements of sets can be extended to fuzzy relations. Extended relations will be considered as relations on fuzzy sets. In this work, we developed the concept of mediative fuzzy relation and mediative fuzzy projection in the context of fuzzy relation and fuzzy projection. We extended the basic operations of fuzzy projection into intuitionistic fuzzy projection and then in the mediative fuzzy projection. We have shown the credibility and impact of mediative index factor involves in the mediative fuzzy projection in context of prediction work in relation to the proposed model. Further, we applied the mediative fuzzy projection in the medical diagnosis in post-COVID-19 patients. The obtained results have also been discussed with their geometrical representation.

1. Introduction

L. A. Zadeh [1] introduced the concept of fuzzy set theory. Researchers are continuously working on the extension of classical set theory into the form of fuzzy set Logic and their extensions. Fuzzy logic is a mathematical tool to design a computer-based machine that is capable of solving problems involving imprecision. The fundamental notions in pure and applied mathematics are the concept of a relation. In the same manner fuzzy relation [2] generalized the concept of relationships as fuzzy set generalizes the concept of classical set. Fuzzy relation has also been in eigen fuzzy sets and their mathematical analysis. Montiel et al. [3] gave a new method that can handle contrary information and provided a logical solution known as the mediative solution. Mediative fuzzy logic is a novel approach for the management of contradictory knowledge by generalizing the concept of an intuitionistic fuzzy set [4]. The concept of mediative fuzzy logic has widely been used in disease diagnosis [5]; Multi-Criteria Decision Support System [6]; in COVID-19 pandemic [7] and many more. Almost every content of the mathematical problems involves imprecision. To deal with such a type
of imprecision and contradictory concept, the existing methods of fuzzy set and intuitionistic fuzzy set theory are insufficient to deal with the existing uncertainty and these concepts need to be extended to another mathematical tool. The mediative fuzzy logic tool is one of the concepts to overcome the contradiction. A fuzzy relation is a mathematical concept where the certain elements of fuzzy sets are related to another under some membership grade-based rule. Fuzzy relations have been applied in many fields such as clustering with a covariance matrix, L1-norm based clustering, clustering with partial supervision, controlling a dynamic plant, mathematical programming and reasoning including mathematical modeling. In real-life applications, there exist some situations that cannot be dealt with the mathematical aspect of uncertainty. In such a situation intuitionistic fuzzy relation comes under the picture. To introduce the concept of intuitionistic fuzzy relation, Cartesian products of intuitionistic fuzzy sets have been defined. The properties of intuitionistic fuzzy relation have also been studied in the existing literature. Later on, the effects of Atanassov’s operators on the properties of intuitionistic fuzzy relation have also been studied. Intuitionistic fuzzy sets have many applications in the medical field including diagnosis and medicine. Fuzzy relations can be defined in universes of different dimensions. Sometimes there is a need to increase or decrease the dimensions of one of the fuzzy relations. For this purpose, projection and its operations were defined in the existing literature, including analytic and geometric methods of map projections, datum and map projections, album of map projections, map projection transformation, improved projection for multidimensional spaces, cylindrical map projection. In this proposed work we introduce the concept of projection in a mediative fuzzy environment. In the contrast to classic sets, this concept allows for the partial membership of objects. Mediative fuzzy logic is the best mathematically proven logic to represent contradictory expressions. We will also discuss the mediative extension principle, which allows for the extension of traditional mathematical functions to mediative fuzzy sets, followed by the idea of a mediative fuzzy relation. The interpretation of mediative fuzzy projection has also been discussed in the medical field. The diagnosis of the disease involves several levels of imprecision and uncertainty, and it is essential in the medical field. In real-life situations, a single disease may exhibit itself in a contrary fashion, depending upon the patient, and with the different severity level. More precisely one single symptom may associate with a different type of disease. The purpose of the proposed mediative fuzzy projection is to present a generalized idea (mediated solution) of the present applications of fuzzy logic in the medical field. We particularly review the medical literature using fuzzy logic, intuitionistic fuzzy logic, and mediative fuzzy logic. We then recall the geometrical interpretation of mediative fuzzy sets with the help of mediative fuzzy logic and present the illustrations through medicine.

1.1. COVID-19

Coronavirus disease is caused by a novel discovered coronavirus. COVID-19 spreads through droplets discharged from the nose while the infected person sneezes and makes contact with the infected patient. Many mathematical researches have been conducted to respond to the COVID-19 in diagnosis, breakdown speed, and mathematical serve. A contradictory management prediction model in COVID-19 pandemic using mediative fuzzy logic mathematical model has been given in the existing model. In this work, the mediative fuzzy correlation technique provides the relation between the increments of the COVID-19 positive patients with respect to time. The peaks of infected cases in connection with the other condition are estimated from the available data. It is a highly infectious disease and spreads from people to people. Most people of the world have experienced mild-to-moderate respiratory illness. Some people are recovering without any special treatment of COVID-19. But those people who are underlying some medical problems like, diabetes, cancer, chronic respiratory disease are more likely to develop some serious illness issue. The best way to protect you from COVID-19 disease is to keep yourself in some isolated circumferences and washing hands with an alcohol-based sanitizer. Due to COVID-19 disease, hospitalization is a major concern for the government. The hospitalized patient may have post-traumatic stress disorder which involves long-term illness problems and after a patient returns to home it may remain in the patient.

1.2. Post COVID-19

In the case of a COVID-19 patient cure, there is a chance that the patient may get recovered in few days. Out of these infected patients, some have experienced post-COVID-19 effects. Post-COVID-19 condition is related to the long-term health effects associated with the novel coronavirus. Post-COVID-19 effects may occur due to returning COVID-19 or novel health problems. These novels or returning problems may remain present in the patient for a month after first being infected. Infact, non-symptomatic infected patients may have a post-COVID-19 situation. The effects of the post-COVID-19 patient may vary from patient to patient for a different time. There are various kinds of post-COVID-19 conditions which involve;

Novel or ongoing symptomatic problems: This condition occurs in patients who had severe health issues or sometimes these can happen in less or mild severe conditions in COVID-19 infected patients. Tiredness or headache: Patients who had COVID-19 problems may face headache and tiredness problems after being recovered from the COVID-19 disease, due to the post-COVID-19 effects. Various post-COVID-19 problems are as follows:

Mental illness: Post – COVID-19 conditions affect the mental fitness of most of the patients after been recovered from the COVID-19 disease.
Breathing difficulty: In some cases of COVID-19 recovered patients, people may face shortness of breath.
Insomnia: Post-COVID-19 situation may affect the sleep disorder of the recovered patients. These people have difficulty while sleeping. People with insomnia may lead to fatigue, mood change, lack of concentration, and many more problems.
The main objectives of this study are;
a) To define an intuitionistic fuzzy relation between the set of patients and the set of diseases and extension of this concept over mediative fuzzy logic.
b) To develop an intuitionistic fuzzy projection technique and its extension in the mediative fuzzy logic environment to form the mediative fuzzy projection technique.
c) The numerical illustration of the proposed mediative fuzzy logic projection technique in the medical field to diagnose the disease in the patients amongst the set of various diseases.
d) In this study, a study has been conducted based on data of post-COVID-19 patients collected from various hospitals in India.
e) We will show the impact and credibility of mediative factor in context of prediction work in relation to the proposed model.

The present research work has been divided into eight sections. The second section discusses the concepts of crisp relation, fuzzy relation, intuitionistic fuzzy relation, and mediative fuzzy relation and their extensions; the third section is dedicated to projections associated with fuzzy sets and intuitionistic fuzzy sets. Subsequent sections describe projection in a mediative fuzzy logic. The numerical illustration of the proposed mediative fuzzy logic projection technique in the medical field to diagnose the disease in the patients amongst the set of various diseases.

2. Basic concepts

In this section, we discussed the concept of crisp relation, fuzzy relation, intuitionistic fuzzy relation, and mediative fuzzy relation and their extensions;

2.1. Crisp relation

Let P and Q be two sets, then a set of order pairs (p, q) where p ∈ P & q ∈ Q is called a relation R on given sets.

\[ R = \{(p, q) : p \in P \& q \in Q\} \]  

If \((p, q) \in R\) then we say p is related to q.

2.2. Fuzzy relation

Fuzzy relation has a degree of membership lies between \([0, 1]\) i.e., \(\mu_R : P \times Q \rightarrow [0, 1]\) called the membership value and fuzzy relation is denoted by:

\[ R = \{((p, q), \mu_R(p, q)) : p \in P, q \in Q \& 0 \leq \mu_R(p, q) \leq 1\} \]  

Example: Let \(A = ((a, 0.2), (b, 0.4), (c, 0.5))\), \(B = ((d, 0.5), (e, 0.1), (f, 0.7))\)

\[ R = \{((a, d) 0.2), ((a, e) 0.1), ((a, f) 0.2), ((b, d) 0.4), ((b, e) 0.1), ((b, f) 0.5), ((c, d) 0.1), ((c, e) 0.5), ((c, f) 0.5)\} \]

or

\[
\begin{bmatrix}
a & 0.2 & 0.1 & 0.2 \\
b & 0.4 & 0.1 & 0.5 \\
c & 0.1 & 0.5 & 0.5 \\
\end{bmatrix}
\]

Here, a, b, c, d, e, f, denote rows and d, e, f, denote columns. The concept of fuzzy relation can be extended over n-dimensional space. Let \(A_1, A_2, A_3, ..., A_n\) be fuzzy sets defined on the universe of discourse \(X_1, X_2, X_3, ..., X_n\) respectively. A fuzzy relation \(R \subseteq A_1 \times A_2 \times A_3 \times ... \times A_n\) can be defined as;

\[ R = \{(a, \mu_R(a)) : \forall a = (x_1, x_2, ..., x_n) \in X_1 \times X_2 \times X_3 \times ... \times X_n\} \]  

2.3. Intuitionistic fuzzy relation

For two-dimensional space, let \(A, B\) be two intuitionistic fuzzy sets defined on the universe of discourse \(X, Y\) respectively. An intuitionistic fuzzy relation \(R \subseteq A \times B\) can be defined as,

\[ R = \{(a, \mu_R(a), \nu_R(a)) : \forall a = (x, y) \in X \times Y\} \]  

For n-dimensional space, let \(A_1, A_2, A_3, ..., A_n\) be intuitionistic fuzzy sets defined on the universe of discourse \(X_1, X_2, X_3, ..., X_n\)
respectively. A fuzzy relation \( R \subseteq A_1 \times A_2 \times A_3 \ldots \times A_n \) can be defined as,

\[
R = \{ (a, \mu_R(a), \nu_R(a)) : \forall a = (x_1, x_2, \ldots, x_n) \in X_1 \times X_2 \times X_3 \ldots \times X_n \}
\]  

(5)

Example:

Let \( A = \{(a, 0.2, 0.7), (b, 0.4, 0.6), (c, 0.5, 0.3)\} \)

\[
B = \{(d, 0.5, 0.2), (e, 0.1, 0.6), (f, 0.7, 0.2)\}
\]

\[
R = \{((a, d) 0.2, 0.7), ((a, e) 0.1, 0.7), ((a, f) 0.2, 0.7), ((b, d) 0.4, 0.6), ((b, e) 0.1, 0.6),
((b, f) 0.4, 0.6), ((c, d) 0.1, 0.3), ((c, e) 0.5, 0.6), ((c, f) 0.5, 0.3)\}
\]

or

\[
\begin{align*}
a & \begin{bmatrix} 0.2 & 0.7 \end{bmatrix} \begin{bmatrix} 0.1 & 0.7 \end{bmatrix} \begin{bmatrix} 0.2 & 0.7 \end{bmatrix} \\
b & \begin{bmatrix} 0.4 & 0.6 \end{bmatrix} \begin{bmatrix} 0.1 & 0.6 \end{bmatrix} \begin{bmatrix} 0.4 & 0.6 \end{bmatrix} \\
c & \begin{bmatrix} 0.1 & 0.3 \end{bmatrix} \begin{bmatrix} 0.1 & 0.6 \end{bmatrix} \begin{bmatrix} 0.5 & 0.3 \end{bmatrix}
\end{align*}
\]

2.4. Extension for intuitionistic fuzzy sets

Let \( X = I_1 \times I_2 \times \ldots \times I_n \) where \( I_i, i = 1, 2, \ldots, n \) are intuitionistic fuzzy sets and let \( Y \) be another set. Let \( f: X \rightarrow Y \) such that \( y = f(x) = f(x_1, x_2, \ldots, x_n) \); \( x_i \in I_i \) and \( x = (x_1, x_2, \ldots, x_n) \in X \), then the extension \( \hat{f} \) defines another intuitionistic fuzzy set \( B \) in \( Y \) as:

\[
B = \{(y, \mu_B(y), \nu_B(y)) : f(x) = y \text{ and } x \in X \}
\]

where \( \hat{f}^{-1}(y) \) is the inverse image of \( y \) under \( f \).

2.5. Mediative fuzzy relation

Mediative fuzzy relation has a degree of membership as well as non-membership lies between \([0, 1]\) i.e., \( \mu_R, \nu_R : P \times Q \rightarrow [0, 1] \) and denoted by

\[
R = \{((p, q), \xi_R(p, q)) : p \in P, q \in Q \land 0 \leq \xi_R(p, q) = \min \{\mu_R(p, q), \nu_R(p, q)\} \leq 1 \}
\]  

(6)

2.6. Extension for mediative fuzzy sets

Let \( X = I_1 \times I_2 \times \ldots \times I_n \) where \( I_i, i = 1, 2, \ldots, n \), the mediative fuzzy sets [4] are and let \( Y \) be another set. Let \( f: X \rightarrow Y \) such that \( y = f(x) = f(x_1, x_2, \ldots, x_n) \); \( x_i \in I_i \) and \( x = (x_1, x_2, \ldots, x_n) \in X \). Then the extension \( \hat{f} \) defines another mediative fuzzy set \( B \) in \( Y \) as:

\[
B = \{(y, \mu_B(y), \nu_B(y)) : f(x) = y \text{ and } x \in X \}
\]

with contradictory value \( \xi_R(y) \) defined as;

\[
\xi_R(y) = \begin{cases} \\text{Sup} \min \{\xi_R(x)\}, & \text{iff } \hat{f}^{-1}(y) \neq \emptyset \\
0, & \text{else}
\end{cases}
\]

where \( \xi_R(x) = \min \{\mu_R(x), \nu_R(x)\} \)

3. Fuzzy projection and intuitionistic fuzzy projection

In this section, we discuss the concept fuzzy projection and intuitionistic fuzzy projection in two and there in \( n \)-dimensional spaces;

3.1. Fuzzy projection

For two-dimensional space, let projection of relation \( R \) on \( A \) is denoted by \( R_A \) and their membership value is defined as (see the example of section II);
3.2. Intuitionistic fuzzy projection

For two-dimensional space, projection of relation \( R \) on \( A \) is denoted by \( \mathcal{R}_A \) with their membership and non-membership values are defined as:

\[
\mu_{\mathcal{R}_A}(x) = \max_y \mu_{\mathcal{R}}(\alpha) \quad (7a)
\]
\[
\nu_{\mathcal{R}_A}(x) = \min_y \nu_{\mathcal{R}}(\alpha) \quad (10)
\]

For n-dimensional space, let \( A_1, A_2, A_3, \ldots, A_n \) be n fuzzy sets defined on \( X_1, X_2, X_3, \ldots, X_n \) then the projection of relation \( R \) on \( A_1, A_2, A_3, \ldots, A_n \) is denoted by \( \mathcal{R}_{A_1, A_2, A_3, \ldots, A_n} \) and their membership value is defined as:

\[
\mu_{\mathcal{R}_{A_1, A_2, A_3, \ldots, A_n}}(x_1, x_2, x_3, \ldots, x_k) = \max_{x_1, x_2, x_3, \ldots, x_n} \mu_{\mathcal{R}}(\alpha), \quad \text{where} \ k + m = n \quad (9)
\]

The geometrical representation of fuzzy projection is given by Fig. 1.

### 3.2. Intuitionistic fuzzy projection

For two-dimensional space, projection of relation \( R \) on \( A \) is denoted by \( \mathcal{R}_A \) with their membership and non-membership values are defined as:

\[
\mu_{\mathcal{R}_A}(x) = \max_y \mu_{\mathcal{R}}(\alpha) \quad (7a)
\]
\[
\nu_{\mathcal{R}_A}(x) = \min_y \nu_{\mathcal{R}}(\alpha) \quad (11)
\]

\[
\begin{align*}
R &= \{(\mathbf{a}, 0.2), (\mathbf{b}, 0.4), (\mathbf{c}, 0.5)\} \\
\mathcal{R}_A &= \{(d, 0.4), (e, 0.1), (f, 0.5)\}
\end{align*}
\]

Projection of relation \( R \) on \( B \) is denoted by \( \mathcal{R}_B \) with their membership and non-membership values are defined as,

\[
\mu_{\mathcal{R}_B}(y) = \max_x \mu_{\mathcal{R}}(\alpha) \quad (7b)
\]
\[
\nu_{\mathcal{R}_B}(y) = \min_x \nu_{\mathcal{R}}(\alpha) \quad (12)
\]

\[
\begin{align*}
R &= \{(\mathbf{a}, 0.2, 0.7), (\mathbf{b}, 0.4, 0.6), (\mathbf{c}, 0.5, 0.3)\} \\
\mathcal{R}_B &= \{(d, 0.4, 0.3), (e, 0.1, 0.6), (f, 0.5, 0.3)\}
\end{align*}
\]

For, n-dimensional based space, \( A_1, A_2, A_3, \ldots, A_n \) be n intuitionistic fuzzy sets defined on \( X_1, X_2, X_3, \ldots, X_n \) then the projection of relation \( R \) on \( A_1, A_2, A_3, \ldots, A_n \) is denoted by \( \mathcal{R}_{A_1, A_2, A_3, \ldots, A_n} \) and their membership value and non-membership values are defined as:

\[
\mu_{\mathcal{R}_{A_1, A_2, A_3, \ldots, A_n}}(x_1, x_2, x_3, \ldots, x_k) = \max_{x_1, x_2, x_3, \ldots, x_n} \mu_{\mathcal{R}}(\alpha). \quad (14)
\]
\[ \nu_{R_1, \ldots, R_k}(x_1, x_2, \ldots, x_n) = \min_{x_1, x_2, \ldots, x_n} \nu_R(\alpha), \text{ where } k + m = n \] (15)

4. Mediative fuzzy projection: a mediative fuzzy logic approach

In this section, we discuss the concept of relation, projection in the respect of mediative fuzzy set, which is described as follows;

4.1. Mediative fuzzy projection

For two-dimensional space, the projection of relation \( R \) on \( A \) is denoted by \( R_A \) and their mediative index is defined as;

\[ \lambda_{R_A}(x) = \max_{\alpha} \lambda_{R_A}(\alpha) \] (16)

Where \( \lambda_{R_A} = [1 - \left( \pi_{R_A} + \frac{\tau_2}{2} \right) \mu_{R_A} + \left( \pi_{R_A} + \frac{\tau_2}{2} \right) \nu_{R_A}] \).

The projection of relation \( R \) on \( B \) is denoted by \( R_B \) and their mediative index value is defined as;

\[ \lambda_{R_B}(y) = \max_{\alpha} \lambda_{R_B}(\alpha) \] (17)

For \( n \)-dimensional based space, \( A_1, A_2, A_3, \ldots, A_n \) be \( n \) intuitionistic fuzzy sets defined on \( X_1, X_2, X_3, \ldots, X_n \) then the projection of relation \( R \) on \( A_1, A_2, A_3, \ldots, A_k \) and their mediative index value is defined as;

\[ \lambda_{R_{A_1, A_2, \ldots, A_k}}(x_1, x_2, x_3, \ldots, x_n) = \max_{x_1, x_2, x_3, \ldots, x_n} \lambda_R(\alpha), \] (18)

where \( k + m = n \)

5. Algorithm of the proposed work

In this section, we proposed an algorithm, given algorithm contains eight steps, and the various steps of the algorithm are defined in a systematic manner as follows;

Step 1: Let us consider the mediative fuzzy set for the set of ‘n’ patients \( P = \{p_1, p_2, \ldots, p_n\} \)

and set of ‘m’ disease \( D = \{d_1, d_2, d_3, \ldots, d_m\} \) associated with the set of ‘k’ symptoms

\[ S = (s_1, s_2, \ldots, s_k) \] of the patient denoted as;

\[ p_i = \{ (s_1, \mu_{s_1}, \nu_{s_1}), (s_2, \mu_{s_2}, \nu_{s_2}), \ldots, (s_k, \mu_{s_k}, \nu_{s_k}) \}, \quad 1 \leq i \leq n \]

\[ d_j = \{ (s_1, \mu_{s_1}, \nu_{s_1}), (s_2, \mu_{s_2}, \nu_{s_2}), \ldots, (s_k, \mu_{s_k}, \nu_{s_k}) \} \]

\[ d_2 = \{ (s_1, \mu_{s_1}, \nu_{s_1}), (s_2, \mu_{s_2}, \nu_{s_2}), \ldots, (s_k, \mu_{s_k}, \nu_{s_k}) \} \]

\[ d_3 = \{ (s_1, \mu_{s_1}, \nu_{s_1}), (s_2, \mu_{s_2}, \nu_{s_2}), \ldots, (s_k, \mu_{s_k}, \nu_{s_k}) \} \]

\[ d_4 = \{ (s_1, \mu_{s_1}, \nu_{s_1}), (s_2, \mu_{s_2}, \nu_{s_2}), \ldots, (s_k, \mu_{s_k}, \nu_{s_k}) \} \]

\[ d_m = \{ (s_1, \mu_{s_1}, \nu_{s_1}), (s_2, \mu_{s_2}, \nu_{s_2}), \ldots, (s_k, \mu_{s_k}, \nu_{s_k}) \} \]

Step 2: Define an intuitionistic fuzzy relation \( R \) between the patients \( P \) and diseases \( D \) defined as, \( R = \{(s_i, s_j), \mu_R(s_i, s_j), \nu_R(s_i, s_j); (s_i, s_j) \in P \times D, 1 \leq i, j \leq k\} \)

where \( \mu_R(s_i, s_j) = \min(\mu_{s_i}, \mu_{s_j}) \) and \( \nu_R(s_i, s_j) = \max(\nu_{s_i}, \nu_{s_j}) \).

Step 3: Define an intuitionistic fuzzy projection of \( R \) on the set of patients \( P \) defined as,

\[ R_P = \{ (s_i, \mu_{R_P}(s_i), \nu_{R_P}(s_i)) \} \]

where; \( \mu_{R_P}(s_i) = \max_{s_j} \mu_R(s_i, s_j) \) and \( \nu_{R_P}(s_i) = \min_{s_j} \nu_R(s_i, s_j) ; (s_i, s_j) \in P \times D \).

Step 4: Define an intuitionistic fuzzy projection of \( R \) on the set of disease \( D \) defined as,
\[ R_D = \{ (s_i, \mu_{R_D}(s_i), \nu_{R_D}(s_i)) \} \]

where; \( \mu_{R_D}(s_i) = \max_h \mu_R(s_i, s_j) \) and \( \nu_{R_D}(s_i) = \min_h \nu_R(s_i, s_j) \).

**Step 5:** Now, find the mediative fuzzy projection of relation \( R \) on mediative fuzzy set \( P \) denoted by \( \lambda_{R_P} \) and defined as; \( \lambda_{R_P} = \max_h \lambda_R(s_i)(\text{for each } P = \{ p_i | 1 \leq i \leq n \}) \)

where \( \lambda_R = [1 - (\pi_R + \frac{\zeta_R}{2})] \mu_R + [\pi_R + \frac{\zeta_R}{2}] \nu_R \).

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### Table 1

Collected data for post-COVID 19 patients.

| Patients ID | HRCT Thorax | Blood Test | Chest X-Ray | U.G.C. Whole Abdomen Function Test | Kidney Function Test | Liver Function Test | COVID-19 RT PCR |
|-------------|-------------|------------|-------------|-------------------------------------|---------------------|--------------------|-----------------|
| P-I         | Cardiothoracic ratio increased | Total leucocyte counts increased | Rt. Lung field is hazy and no focal parenchymal lesion seen | Moderate ++ He patomegaly and Moderate Splenomegaly | Blood urea is 51.20mg/L, serum sodium is 134.40 mmol/L | SGPT/ALT IS 175.4 IU/L, CRP IS 103.2mg/L |
| P-II        | Mild bilateral pleural effusion noted, minimal pericardial effusion noted and suggestive of infective etiology | Haemoglobin is 9.7 gm/dl and monocyte are 0% with platelet count 0.34 lakhs/Cmm m | II-defined in homogenous patchy opiates seen in both lung field | Moderate ++ He pato-Splenomegaly, small ascites, small rt. Pleural effusion, B/L kidney stones. |
| P-III       | Features are typical of COVID-19 infection CO-RADS-5, CT severity score 10/25 and there is evidence of 40% lung correlation | Haemoglobin is 10.9, TLC is 17700/ cumm, lymphocytes are 0%, segmented neutrophils is 78%, absolute neutrophils 13806/cumm with P.C.V./haematocrit value 31.2% and MCHC (mean crop hbccon) 34.9g/dl | Small pneumothorax with infiltration seen in the Lt. lung |
| P-IV        | Multiple patchy areas of ground glassing with septal thickening noted in bilateral lung field infective etiology and consolidation with air bronchogram noted in posterior segment of bilateral upper and lower lobes | Total leucocyte count is 134400Cu Cmm. Blood ures is 105 mg/dl and serum creatinine are 4.8 mg/dl | Fatty infiltration of liver, left kidney is small in size with renal internal echoes with reduced corticomediullary differentiation and bowel loops are gas filled |
| P-V         | Cotton wool shadows are seen in both lung fields | Total blood count is 19500 Cu. Cmm, monocytes 0% |
| P-VI        | Multiple patchy areas of ground glassing with segment thickness noted in bilateral lung fields | TLC-12900 CuGmm. Monocytes 0% and CRP-turbilatex is 58.5 mg/l |
| P-VII       | CT severity index is 12 suggestive of moderate disease | S. Ferritin is 656-50 ng/ml. L D H is 437-0 U/L and D. Dimer is e 1120mg/ml | Thrombus is seen in right common iliac, right external iliac, right common femoral, superficial femoral, femoral, popliteal, anterior tibial, posterior tibial and dorsalis pedis arteries with no flow |

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Now, we fixed the patient $p_i$ (for some $1 \leq i \leq n$) in the set $P$ and evaluate the mediative fuzzy projection of relation $R$ on $p_i$, i.e., $\lambda_{R_{p_i}}$.

**Step 6**: Now, find the mediative fuzzy projection of relation $R$ mediative fuzzy set $D$ defined as $\lambda_{R_D} = \max_s \lambda_{R_D}(s_j)$ (for $D = \{d_j, 1 \leq j \leq m\}$),

Where, $\lambda_R = [1 - (\pi_{R_{d_j}} + \zeta_{R_{d_j}})] \mu_{R_{d_j}} + [\pi_{R_{d_j}} + \zeta_{R_{d_j}}] \nu_{R_{d_j}}$. In this step, we evaluate the projection of mediative fuzzy set $R$ on each $d_j$, foreach $1 \leq j \leq m$.

**Step 7**: We now change the disease $d_j$ and repeat the process from steps 2 to 6. Now, we will check whether the mediative fuzzy projection gives the highest value or not i.e., that if the mediative fuzzy projection of $R$ gives the highest value for some $d_j, 1 \leq j \leq m$. Then the patient $p_i$ (for some fixed $i$) will be suffering from the disease $d_j$.

**Step 8**: After step 7, we change the patient $p_i$, for some fixed $1 \leq i \leq n$ and repeat the steps 5 & 7. In this manner, we can easily find out that the set of the patient $P$ will be suffering from a particular disease in the set of diseases $D$.

### 6. Data collection

In this section, we describe the data for post-COVID-19 patients with their HRCT thorax, blood report, chest X-ray, U.S.G. report, kidney & liver function test and RT PCR reports as shown in Table 1, the data for post COVID-19 patients has been collected from Yug hospital, Meerut, India. In this segment, we have given the data of seven post-covid-19 patients, the proposed methodology can easily be applicable over more available infected patients data.

The block diagram of the proposed algorithm is given in Fig. 2. As;

### 7. Numerical computations

In this section, we now present an example of the use of the mediative fuzzy projection in a medical field in which we discuss the projection of relation on COVID-19, pneumonia, and viral fever. CT Scan, X-Ray, Blood report and U.S.G. Whole abdomen factors have been taken for the diagnostic process of the patient. We have also taken a set of three diseases; COVID-19, pneumonia, and viral fever. On behalf of these diseases, we will diagnose the disease in the patients with the help of mediative fuzzy projection. We divide the levels of severity in two three categories with certain ranges based on the medical experts (physician or doctor) recommendations;
a) High-resolution CT (HRCT) of the chest, also referred to as HRCT of the lungs, refers to a CT technique in which thin-slice chest images are obtained and post-processed in a high-spatial-frequency reconstruction algorithm. CT scan reports have been divided into three linguistic categories as shown in Table 2.

a) A fully computerized lab report with auto analyzer and Elisa reader for the blood test (which includes hemoglobin count, total leucocyte count, differential leucocyte count, absolute leucocyte count, P.C.V./haematocrit value, mean crop volume, mean crop Hb, and mean crop Hb Conc) of the patient has also been taken in this study. Further, based on the blood report the severity of the patient is also divided into three categories as shown in Table 3;

a) The severity level of X-ray (includes Rt. Lung fields, focal parenchymal lesion, cardiac size, c.p. angles with domes, bony cage & soft tissue) report of the patient is also divided into three categories as shown in Table 4 below;

a) The U.S.G. whole abdomen report (which includes liver, C.B.D., GB walls, pancreas, kidneys, spleen, R.P., bladder, and prostate) is also categorized into three linguistic categories;

Now, we consider a patient $p_1$ with HRCT thorax, blood report, chest X-ray, U.S.G. report, kidney & liver function test, and RTPCR report given in Table 1. Now, we diagnose the disease with the help of mediative fuzzy projection in various steps as follows;

Step 1: Let us consider mediative fuzzy sets for the patient and diseases namely; COVID-19, pneumonia and viral fever;

\[ p_1 = \{ (s_1, 0.9, 0.1), (s_2, 0.8, 0.1), (s_3, 0.6, 0.2), (s_4, 0.7, 0.1), (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0.1) \} \]

\[ d_1(COVID - 19) = \{ (s_1, 0.8, 0.2), (s_2, 0.2, 0.8), (s_3, 0.9, 0.1), (s_4, 0.5, 0.5), (s_5, 0.9, 0.1), (s_6, 0.9, 0.1), (s_7, 1, 0) \} \]

\[ d_2(pneumonia) = \{ (s_1, 0.7, 0.1), (s_2, 0.3, 0.7), (s_1, 0.7, 0.2) \} \]
Step 3: Then the intuitionistic fuzzy projection is defined as;
\[ R_1 = \{ (s_1, 0.9, 0.1), (s_2, 0.8, 0.1), (s_3, 0.6, 0.1), (s_4, 0.7, 0.1) \} \]

Step 4: Now, find the intuitionistic fuzzy projection \( R_2 \) is defined as;
\[ R_2 = \{ (s_1, 0.8, 0.2), (s_2, 0.2, 0.8), (s_3, 0.9, 0.1), (s_4, 0.5, 0.5), (s_5, 0.8, 0.1), (s_6, 0.6, 0.1), (s_7, 0.9, 0.1) \} \]

Step 5: Now, the mediative fuzzy projection \( R_p \) is defined as;
\[ \lambda_{R_p}(x) = \max_y \lambda_{R_p}(y) \] where \( \lambda_{R_p} = \left[ 1 - \left( \frac{\pi_{R_p} + \zeta_{R_p}}{2} \right) \right] \mu_{R_p} + \left[ \pi_{R_p} + \frac{\zeta_{R_p}}{2} \right] \nu_{R_p} \]
\[ R_p = \{ (s_1, 0.86), (s_2, 0.695), (s_3, 0.425), (s_4, 0.55), (s_5, 0.6), (s_6, 0.6), (s_7, 0) \} \]
Step 6: Now, the mediative fuzzy projection $R_A$ is defined as $\lambda_{R_A}(x) = \max_x \lambda_{R_A}(x)$

$$R_A = \{(s_1, 0.74), (s_2, 0.26), (s_3, 0.86), (s_4, 0.5), (s_5, 0.695), (s_6, 0.425), (s_7, 0.55)\}$$

Step 7: For pneumonia

Now $p_1 = \{(s_1, 0.9, 0.1), (s_2, 0.8, 0.1), (s_3, 0.6, 0.2)\}$

$$(s_1, 0.7, 0.1), (s_2, 0.7, 0.1), (s_3, 0.7, 0.1), (s_7, 0.1)\}$$

$d_1(\text{pneumonia}) = \{(s_1, 0.7, 0.1), (s_2, 0.3, 0.7), (s_1, 0.7, 0.2)\}$

$$(s_1, 0.4, 0.5), (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0.1)\}$$

Then the relation between $p_1$ and $d_2$ is defined in the form of mediative fuzzy set $R$ as;

$$R = \{(s_1, s_1), 0.7, 0.1), ((s_1, s_2), 0.3, 0.7), ((s_2, s_1), 0.3, 0.5), ((s_1, s_3), 0.7, 0.1), ((s_4, s_2), 0.3, 0.7), ((s_2, s_1), 0.7, 0.2), ((s_2, s_3), 0.4, 0.5), ((s_2, s_3), 0.7, 0.1), ((s_2, s_6), 0.7, 0.1), ((s_2, s_7), 0, 0.1), ((s_3, s_1), 0.6, 0.2), ((s_3, s_4), 0.6, 0.2), ((s_3, s_7), 0.3, 0.7), ((s_4, s_4), 0.4, 0.5), ((s_4, s_7), 0.7, 0.1), ((s_5, s_4), 0.7, 0.1), ((s_5, s_5), 0.7, 0.1), ((s_5, s_7), 0.7, 0.1), ((s_6, s_2), 0.3, 0.7), ((s_6, s_3), 0.7, 0.2), ((s_6, s_4), 0.7, 0.1), ((s_6, s_5), 0.7, 0.1), ((s_6, s_6), 0.7, 0.1), ((s_6, s_7), 0, 0.1), ((s_7, s_1), 0.7, 0.1), ((s_7, s_3), 0.3, 0.7), ((s_7, s_5), 0.7, 0.1), ((s_7, s_7), 0, 0.1)\}$$

Then the intuitionistic fuzzy projection $R_I$ is defined as;

$$R_I = \{(s_1, 0.7, 0.1), (s_2, 0.7, 0.1), (s_3, 0.6, 0.2), (s_4, 0.7, 0.1), (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0, 1)\}$$

Now, find the intuitionistic fuzzy projection $R_2$ is defined as;

$$R_2 = \{(s_1, 0.7, 0.1), (s_2, 0.3, 0.7), (s_3, 0.7, 0.2), (s_4, 0.4, 0.5), (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0, 1)\}$$

Now, the mediative fuzzy projection $R_{p_1}$ is defined as;

$$\lambda_{R_{p_1}}(x) = \max_x \lambda_{R_{p_1}}(x), \text{where } \lambda_{R_{p_1}} = \left[1 - \left(p_{R_{p_1}} + \frac{\bar{\lambda}_{R_{p_1}}}{2}\right)\right] \mu_{R_{p_1}} + \left[p_{R_{p_1}} + \frac{\bar{\lambda}_{R_{p_1}}}{2}\right] \nu_{R_{p_1}}$$

$$R_{p_1} = \{(s_1, 0.55), (s_2, 0.55), (s_3, 0.48), (s_4, 0.55), (s_5, 0.55), (s_6, 0.55), (s_7, 0)\}$$

Now, the mediative fuzzy projection $R_{p_2}$ is defined as; $\lambda_{R_{p_2}}(x) = \max_x \lambda_{R_{p_2}}(x)$
\[ R_2 = \{(s_1, 0.55), (s_2, 0.36), (s_3, 0.6), (s_4, 0.43), (s_5, 0.55), (s_6, 0.55), (s_7, 0)\} \]

Now, for viral fever
\[ p_1 = \{(s_1, 0.9, 0.1), (s_2, 0.8, 0.1), (s_3, 0.6, 0.2), (s_4, 0.7, 0.1), \]
\[ (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0, 1)\} \]
\[ d_3(\text{viral fever}) = \{(s_1, 0.5, 0.5), (s_2, 0.8, 0.1), (s_3, 0.5, 0.4), (s_4, 0.4, 0.5), \]
\[ (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0, 1)\} \]

Then the relation between \( p_1 \) and \( d_3 \) is defined in the form of mediative fuzzy set \( R \) as;
\[ R = \{(s_1, s_1), 0.5, 0.5), (s_1, s_2), 0.8, 0.1), (s_1, s_3), 0.5, 0.4), \]
\[ (s_1, s_4), 0.8, 0.1), (s_1, s_5), 0.5, 0.4)\} \]
Fig. 5. Geometrical representation of x projection and y projection for non-membership values of COVID-19.

Fig. 6. Graph of mediative fuzzy relation between patient $p_1$ and disease $d_1$ using non-membership value.

$((s_1, s_4), 0.4, 0.5)$, $((s_1, s_5), 0.7, 0.1)$,
$((s_1, s_6), 0.7, 0.1)$, $((s_1, s_7), 0.1)$, $((s_2, s_1), 0.5, 0.5)$,
$((s_2, s_2), 0.8, 0.1)$, $((s_2, s_3), 0.5, 0.4)$,
$((s_2, s_4), 0.4, 0.5)$, $((s_2, s_5), 0.7, 0.1)$, $((s_2, s_6), 0.7, 0.1)$,
$((s_2, s_7), 0.1)$, $((s_3, s_1), 0.5, 0.5)$, $((s_3, s_2), 0.6, 0.2)$,
$((s_3, s_3), 0.5, 0.4)$, $((s_3, s_4), 0.4, 0.5)$, $((s_3, s_5), 0.6, 0.2)$,
$((s_3, s_6), 0.6, 0.2)$, $((s_4, s_1), 0.1)$, $((s_4, s_2), 0.5, 0.5)$.
Fig. 7. Projection graph of x projection and y projection for mediative grades for disease $d_1$.

Fig. 8. Geometrical representation of x projection and y projection for membership values of Pneumonia.
Fig. 9. Graph of mediative fuzzy relation between patient $p_1$ and disease $d_2$ using membership value.

Fig. 10. Geometrical representation of $x$ and $y$ projection for non-membership values of Pneumonia.

$((s_4, s_2), 0.7, 0.1), ((s_4, s_1), 0.5, 0.4), ((s_4, s_4), 0.4, 0.5)$

$((s_4, s_3), 0.7, 0.1), ((s_4, s_2), 0.7, 0.1), ((s_5, s_7), 0.1),$ 

$((s_5, s_1), 0.5, 0.5), ((s_5, s_5), 0.7, 0.1)$

$((s_5, s_3), 0.5, 0.4), ((s_5, s_4), 0.4, 0.5), ((s_5, s_5), 0.7, 0.1), ((s_5, s_6), 0.7, 0.1),$
Then the intuitionistic fuzzy projection $R_1$ is defined as;

$R_1 = \{(s_1, 0.8, 0.1), (s_2, 0.8, 0.1), (s_3, 0.6, 0.2), (s_4, 0.7, 0.1), (s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0.1)\}$

Now, find the intuitionistic fuzzy projection $R_2$ is defined as;

Fig. 11. Graph of mediative fuzzy relation between patient $p_1$ and disease $d_2$ using non-membership value.

Fig. 12. Projection of $x$ projection and $y$ projection mediative grades for disease $d_2$. 
\( R_2 = \{(s_1, 0.5, 0.5), (s_2, 0.8, 0.1), (s_3, 0.5, 0.4), (s_4, 0.4, 0.5), \\
(s_5, 0.7, 0.1), (s_6, 0.7, 0.1), (s_7, 0, 1)\}\)

Now, the mediative fuzzy projection \( R_p \) is defined as:

\[
\lambda_{R_p}(x) = \max_y \lambda_{R_p}(y), \text{ where } \lambda_{R_p} = \left[1 - \left(\pi_{R_p} + \frac{\xi_{R_p}}{2}\right)\right] \mu_{R_p} + \left[\pi_{R_p} + \frac{\xi_{R_p}}{2}\right] \nu_{R_p}
\]

\( R_p = \{(s_1, 0.955), (s_2, 0.695), (s_3, 0.48), (s_4, 0.55), (s_5, 0.55), (s_6, 0.55), (s_7, 0)\}\)

Now, the mediative fuzzy projection \( R_d \) is defined as:

\[
\lambda_{R_d}(x) = \max_x \lambda_{R_d}(x)
\]

\( R_d = \{(s_1, 0.5), (s_2, 0.695), (s_3, 0.47), (s_4, 0.43), (s_5, 0.55), (s_6, 0.55), (s_7, 0)\}\)

**Step 8:** For the values obtained in step 7, we can easily observe the mediative projection values are highest in the case of viral fever. So that the patient \( p_1 \) is suffering from viral fever disease.
The effect of mediative fuzzy projection of fuzzy relation between COVID-19 and patient p₁ is shown by Fig. 3 & 5 and Fig. 8 & 10 indicates the fuzzy relation and their mediative fuzzy projection on the relation defined between patient p₁ and d₂ i.e., pneumonia. Furthermore, Fig. 13 & 15 represents the impact of mediative projection on patient p₁ in case of disease d₃ i.e., viral fever. After the numerical computation, we observed that the mediative fuzzy projection is greater in the case of viral fever as compared to the cases of COVID-19 and pneumonia.
8. Conclusion

Due to the contradictory, non-contradictory, and doubtful situations, the mediative fuzzy logic concept comes under the study to handle such situations more appropriately than the fuzzy and intuitionistic fuzzy logic. The entire work done in this article is illustrated by the following points;

- The proposed mediative fuzzy projection can easily handle the contradictory and non-contradictory, and doubtful situations that cannot be dealt with the previously existing logic (like fuzzy logic and intuitionistic fuzzy logic).
- In the numerical computation section, we gave a score value to each input factor that involves; CT scan, X-Ray, Blood report etc. with their respective ranges provided by the medical experts. Further, for the significance prospective in Fig 3, Fig 5, Fig 8, Fig 10, Fig 13, & Fig 15, mediative projection on x is shown by ‘red colour’, mediative projection on y is shown by ‘green colour’, and ‘blue colour’ represents the fuzzy relation among them.
- To make it easier for the reader, we also gave bar graphs, to represent the mediative fuzzy relation (for membership and non-membership values) between patient $p_1$ and disease $d_1$ (as shown in Fig 4 & 6). The mediative projection for disease $d_1$ on x and y axes is also given in Fig. 7.
- The mediative fuzzy relation (for membership and non-membership values) between patient $p_1$ and disease $d_2$ (as shown in Fig 9 & 11). The mediative projection for disease $d_2$ on x and y axes is also given in Fig. 7.
- Fig 14 & 16, represent the mediative fuzzy relation (for membership and non-membership values) between patient $p_1$ and disease $d_2$. Fig. 17 represents the mediative projection for disease $d_2$ on x and y axes respectively.

In addition, by making use of the proposed mediative fuzzy projection, we can easily analyze medical images for the disease diagnosis process of the patients.

Declaration of Competing Interest

The Author(s) declare(s) that there is no conflict of interest for the manuscript titled “Post-symptomatic Detection of COVID-2019 Grade based Mediative Fuzzy Projection” which is submitted for possible publication in the VSI:Covid of journal ‘Computers and Electrical Engineering’.

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