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Applications in Diagnosis of Covid-19 Patients With the Help of Picture Fuzzy Sets

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Abstract In current scenario people with symptom of Covid-19 like fever, cough, sneezing, sore throat, loss of taste and smell etc., were panic about the disease, and the diagnosis of Covid-19 takes many hours and people cannot go for the test frequently. Some other diseases like flu, pneumonia, cold etc., also has the same symptoms. Each patients has unique experience of that particular symptom and some time they may not experience that symptom even though they were affected by the Covid-19. In this paper, we tried to diagnosis Covid-19 with the help of picture fuzzy sets which helps to record all symptoms in prÃ©cised manner.

Keywords and phrases: Picture fuzzy set, distance between fuzzy sets, Covid-19 patient-record all symptoms in precise manner.

AMS (2000) subject classification: 03E72, 08A72, 94D05.

1 Introduction

Traditional logic, which is interpreted as either true or false, found to be difficult to solve uncertain real-life problems. As a counter measure, Zadeh (1965) [28] invented fuzzy set theory, where the involvement of elements in a set is characterized by membership grade, which belongs to [0, 1]. To handle much uncertainty, fuzzy sets were extended by the different researchers in different ways such as vague set (Gau and Buehrer 1993) [13], intuitionistic fuzzy set (IFS) (Atanassov 1986a, 1986b) [1, 2], fuzzy soft set (Das et al. 2018) [10], rough set (Pawlak 1982) [21], fuzzy interval theory (Gorzalczany 1987) [15], intuitionistic multi fuzzy set (Das et al. 2013) [9], interval-valued intuitionistic fuzzy set (Park et al. 2008) [22] , intuitionistic fuzzy soft set (Deng 1982) [12] and neutrosophic soft set (Das et al. 2019) [11] . Consequently, the application of fuzzy set theory and its extensions increased rapidly in the decision-making methods in various domains like medical diagnosis (Das et al. 2013) [9], pattern recognition (Wei and Lan 2008) [26], data analysis (Zou and Xiao 2008) [29], forecasting (Xiao et al. 2011) [27], optimization (Kov-kov et al. 2007) [17], simulation (Kalayathankal and Singh 2010) [16] and texture classification (Mushrif et al. 2006) [20]. Recently in 2014, Cuong (2014)[8] developed the picture fuzzy set (PFS) as the generalized form of fuzzy set and IFS. The PFS approaches are found to be more appropriate in those cases when the views of someone contain more option types like yes, abstain, no and refusal. The general election of a country is noted as a good example to describe PFS, where a voter can cast his vote in favour of the candidate (yes),

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against the candidate (no), may not cast his vote (abstain) or may refuse to cast his vote in favour of the given candidates and prefer for nota (refusal) (Cong and Son 2015) [7].

Nowadays, the whole world has become fully unbalanced and passing through an uncontrolled situation due to the dangerous and novel virus Covid-19. Most countries are totally stagnant and the people are quarantined to make themselves safe from Covid-19 (Ren et al. 2020) [23]. Many researchers are continuously contributing to developing various type of mathematical and hybrid models to predict the future trends, strength and transmission capability of Covid-19 virus, and have drawn some useful conclusions which assist the health department to take the necessary precaution to track and handle the Covid-19 situations. The authors in Melin et al. (2020) [19] introduced a novel hybrid prediction model that can mergethe ensemble architectures of fuzzy logic-based neural networks for response integration. The fundamental concept of the proposed model is to merge several fuzzy-based neural network predictors, control the uncertainty of the individual networks and try to reduce the uncertainty of the total predictions. This model was able to predict the future trends of Covid-19 up to some extent and help the authorities make the necessary decision to handle the health care system in a better manner. The authors in Sun and Wang (2020) [25] collected the Covid-19 data from a decided location within a specific time interval and trained through the ordinary differential equation model for fitting.Then, they modified the simulation by the trained model to realize the effect of the Covid-19 affected visitors. They found that the affected visitors have a great role in the newly introduced case of Covid-19. Stochastic simulations proved that the physical connections could be rapidly increased due to the affected visitors which are considered sufficient for the local outbreak of Covid-19. The confirmed case of asymptomatic patients was significantly less than the model predictions quantity. This indicated that a major portion of asymptomatic patients are not identified/found. Fuzzy-based hybrid approaches for forecasting the confirmed cases and deaths of the countries according to their time series are given in Castillo and Melin (2020) [4]. The fundamental concept of this proposed hybrid method (Castillo and Melin 2020) [4] is to combine the fractal dimension and fuzzy logic for enabling efficient and accurate forecasting of Covid-19 time series. The fractal dimension is provided to differentiate and categorize the object. They introduced a fuzzy rule-based system to represent the knowledge about the forecasting time series of the countries. The authors in Castillo and Melin (2021) [5] introduced the hybrid procedure for composing the fuzzy logic and fractal dimension which measured the uncommon activities of times series to classify countries according to their Covid-19 time series data. The proposed method generates an accurate classification of countries based on the complexity of the Covid-19 time series data. Editors (Boccaletti et al. 2020) [3] of the journal â€˜â€˜Chaos, Solitons and Fractalsâ€™â€™ analysed the impact of Covid-19 pandemic throughout the world and felt the necessity to create a unique platform for the researchers to help the society to avoid the worst effects of future pandemics. Recently, Mishra et al. (2021) [23] proposed an extended fuzzy decision-making framework using hesitant fuzzy sets for the drug selection to treat the mild symptoms of Covid-19. Although the researchers are working hard, they are still struggling to recover from this unwanted situation. The scientists from different domains are consistently trying to apply their knowledge in different perspectives such as dominating the virus, identifying the virus, isolating from the virus, protecting from the virus, and finding the treatment of the virus

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affected patients, to manage the superfluous situation (Kumar et al., 2020 [18], Ghosh et al. , 2020) [14], which are considered to be the longterm project. As an intermediate solution, the most important aspect is to provide suitable medical service to the affected patients and recover those who are critically ill due to perilous virus Covid-19. The health department of India has classified the Covid-19 affected patients into some categories according to the patientâ€™s physical condition. The extreme condition is called severe cases, and this type of patient requires quality treatment (Clinical Management Protocol 2020) [6]. In current scenario people with symptom of Covid-19 like fever, cough, sneezing, sore throat, loss of taste and smell etc., were panic about the disease, and the diagnosis of Covid-19 takes many hours and people cannot go for the test frequently. Some other diseases like flu, pneumonia, cold etc., also has the same symptoms. Each patients has unique experience of that particular symptom and some time they may not experience that symptom even though they were affected by the Covid-19.

To fill up this research gap, this paper proposes an alternative PFS based approach, here we tried to diagnosis Covid-19 with the help of picture fuzzy sets which helps to record all symptoms in prÃ©cised manner.

2 Preliminaries

Definition 2.1 *[8] A picture fuzzy set* (PFS) P *on the universe* X *is defined as* $P = \{(x, \mu_P(x), \eta_P(x), \nu_P(x)) | x \in X\}$ *where* $\mu_P(x) \in [0,1]$ *be the degree of positive membership of* x *in* P, *similarly* $\eta_P(x) \in [0,1]$ *be the degree of neutral membership of* x *in* P, $\nu_P(x) \in [0,1]$, *be the degree of negative membership of* x *in* P *and satisfies* $0 \leq \mu_P(x) + \eta_P(x) + \nu_P(x) \leq 1, \forall x \in X$.

Then, the refusal membership grade $\rho_P(x)$ of x in P can be defined as $\rho_P(x) = 1 - (\mu_P(x) + \eta_P(x) + \nu_P(x)), \forall x \in X$. The neutral membership $\nu_P(x)$ of x in P can be thought as degree of positive membership as well as degree of negative membership, whereas refusal membership $\rho_P(x)$ can be explained as not to take care of the system.

When $\forall x \in X, \eta_P(x) = 0$, then the PFS reduces into IFS.

For a fixed $x \in P$, $(\mu_P(x), \eta_P(x), \nu_P(x))$ is defined as a picture fuzzy number (PFN), where $\eta_P(x) \in [0,1]$, $\nu_P(x) \in [0,1]$, $\rho_P(x) \in [0,1]$ and $\mu_P(x) + \eta_P(x) + \nu_P(x) + \rho_P(x) = 1$. Simply, PFS is signified as $(\mu_P(x), \eta_P(x), \nu_P(x))$.

For two PFSs $P = (\mu_P, \eta_P, \nu_P)$ and $N = (\mu_N, \eta_N, \nu_N)$. Cuong (2014) [8] defined some operations as given below.

$P \cup N = \{x, max(\mu_P(x), \mu_N(x)), min(\eta_P(x), \eta_N(x)), min(\nu_P(x), \nu_N(x)) | x \in X\}$

$P \cap N = \{x, min(\mu_P(x), \mu_N(x)), max(\eta_P(x), \eta_N(x)), max(\nu_P(x), \nu_N(x)) | x \in X\}$

$\overline{P} = \{(x, \mu_P(x), \eta_P(x), \nu_P(x)) | x \in X\}$.

Cuong and Krenovich (2014) [8] defined some properties on PFSs as given below.

1. $P \subseteq N$ if $(\forall x \in X, \mu_P(x) \leq \mu_N(x), \eta_P(x) \leq \eta_N(x), \nu_P(x) \leq \nu_N(x))$.
2. $P = N$ if $(P \subseteq N$ and $N \subseteq P)$.
3. If $P \subseteq N$ and $N \subseteq M$ then $P \subseteq M$.

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4. $\overline{\overline{P}} = P$.

Distances between the two $PFSs$ are defined by Cuong and Kreinovich (2014) [8]; Cong and Son (2015) [7]; Si et al. (2019) [24]. The distance between two $PFSs$ $A = (\mu_A, \eta_A, \nu_A)$ and $B = (\mu_B, \eta_B, \nu_B))$ in $X = \{x_1, x_2, \ldots, x_n\}$ is calculated as given below.

1. Hamming distance (briefly, HD):

$$d_H(A,B) = \frac{1}{3}\{\sum_{i=1}^{n} [|\mu_A(x_i) - \mu_B(x_i)| + |\eta_A(x_i) - \eta_B(x_i)| + |\nu_A(x_i) - \nu_B(x_i)|]\}.$$

2. Normalized Hamming distance (briefly, NHD):

$$d_{NH}(A,B) = \frac{1}{3n}\{\sum_{i=1}^{n} [|\mu_A(x_i) - \mu_B(x_i)| + |\eta_A(x_i) - \eta_B(x_i)| + |\nu_A(x_i) - \nu_B(x_i)|]\}.$$

3. Euclidean distance (briefly, ED):

$$d_{ED}(A,B) = \sqrt{\frac{1}{3}\{\sum_{i=1}^{n} [[\mu_A(x_i) - \mu_B(x_i)]^2 + [\eta_A(x_i) - \eta_B(x_i)]^2 + [\nu_A(x_i) - \nu_B(x_i)]^2]\}}$$

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4. Normalized Euclidean distance (briefly, NED):

$$d_{NED}(A,B) = \sqrt{\frac{1}{3n}\{\sum_{i=1}^{n} [[\mu_A(x_i) - \mu_B(x_i)]^2 + [\eta_A(x_i) - \eta_B(x_i)]^2 + [\nu_A(x_i) - \nu_B(x_i)]^2]\}}$$

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3 Covid 19 Patient

In current scenario people with symptom of Covid-19 like fever, cough, sneezing, sore throat, loss of taste and smell etc., were panic about the disease, and the diagnosis of Covid-19 takes many hours and people cannot go for the test frequently. Some other diseases like flu, pneumonia, cold etc., also has the same symptoms.

Each patients has unique experience of that particular symptom and some time they may not experience that symptom even though they were affected by the Covid-19.

Here we tried to diagnosis Covid-19 with the help of picture fuzzy sets which helps to record all symptoms in prÃ©cised manner.

3.1 Algorithm and flow chart

This section includes the algorithm based on the computation of the Hamming distance, Normalized Hamming distance, Euclidean distance and Normalized Euclidean distance between the $PFSs$.

Step:1 Identify the universe set with most common symptoms of the Covid-19 patients.

Step:2 Formulates the PFS of each patient based on their experience of each symptom of universe set.

Step:3 Formulates the ideal PFS from the patients who affected by Covid-19 based on their experience of each symptom of covid-19.

Step:4 Compute the various distances between the ideal PFS of Covid-19 affected patients and the PFS of the patient who experiences the symptoms of Covid-19.

Step:5 Compare the distance between the PFS sets and also between the various distances.

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Step:6 Conclude, the patient with minimum distance from the PFS of Covid-19 patient has the huge chance to affected by Covid-19 virus.

3.2 Flow chart

Identify universe set of Covid-19 symptoms
↓
Formulates the PFS of each patient
↓
Formulates the ideal PFS from the covid-19 patient
↓
Compute distance between the ideal PFS the PFS of the patient
↓
Conclude, huge chance for affected by covid-19 by who has minimum distance.

Example: Let A, B, C denote the patients who has the symptoms of Covid-19. Now their symptoms can be represented by the PFS and their members are taken from the universe set X which includes the all possible symptoms of Covid-19 are f denotes fever, t denotes tiredness, d denotes dry cough, s denotes shortness of breath, p denotes body pain / chest pain, a denotes diarrhea, l denotes loss of taste or smell, st denotes sore throat, b denotes difficulty in breathing and r denotes rhinorrhea.

We convert the frequency of experience of the symptoms of the patients from last three days as picture fuzzy set by considering the severe symptom as the degree of positive membership, mild symptom as the degree of nutral membership and no experience of that symptom as the degree of negative membership.

Now, the ideal picture fuzzy set $I = \{(x, \mu_i(x), \eta_i(x), \nu_i(x))/x \in X\}$ denotes the model set for the Covid-19 patient which is framed by the data collected from the hospital resources. The membership values of the elements of I are

$(f, \mu_i(f), \eta_i(f), \nu_i(f))$, where $\mu_i(f) \geq 0.8, \eta_i(f) \geq 0, \nu_i(f) \geq 0.1$
$(t, \mu_i(t), \eta_i(t), \nu_i(t))$, where $\mu_i(t) \geq 0.5, \eta_i(t) \geq 0.4, \nu_i(t) \geq 0.02$
$(d, \mu_i(d), \eta_i(d), \nu_i(d))$, where $\mu_i(d) \geq 0.7, \eta_i(d) \geq 0.2, \nu_i(d) \geq 0.02$
$(s, \mu_i(s), \eta_i(s), \nu_i(s))$, where $\mu_i(s) \geq 0.6, \eta_i(s) \geq 0.2, \nu_i(s) \geq 0.04$
$(p, \mu_i(p), \eta_i(p), \nu_i(p))$, where $\mu_i(p) \geq 0.4, \eta_i(p) \geq 0.5, \nu_i(p) \geq 0.05$
$(a, \mu_i(a), \eta_i(a), \nu_i(a))$, where $\mu_i(a) \geq 0.2, \eta_i(a) \geq 0.3, \nu_i(a) \geq 0.4$
$(l, \mu_i(l), \eta_i(l), \nu_i(l))$, where $\mu_i(l) \geq 0.6, \eta_i(l) \geq 0.3, \nu_i(l) \geq 0.06$
$(st, \mu_i(st), \eta_i(st), \nu_i(st))$, where $\mu_i(st) \geq 0.7, \eta_i(st) \geq 0.2, \nu_i(st) \geq 0.02$
$(b, \mu_i(b), \eta_i(b), \nu_i(b))$, where $\mu_i(b) \geq 0.5, \eta_i(b) \geq 0.3, \nu_i(b) \geq 0.16$
$(r, \mu_i(r), \eta_i(r), \nu_i(r))$, where $\mu_i(r) \geq 0.78, \eta_i(r) \geq 0.19, \nu_i(r) \geq 0.01$
$\mu_i(x)$ - severe symptom,
$\eta_i(x)$ - mild symptom,
$\nu_i(x)$ - no symptom and
$0 \leq \mu_i(x) + \eta_i(x) + \nu_i(x) \leq 1$. The decision can be made, which patient have the

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more chances to have the Covid-19 by finding the distance between the ideal PFS and the $PFSs$ of the patients A, B, C. In the following table symptom, membership values, Ideal PFS, Patient A, Patient B, Patient C, Hamming Distance (I, A), Hamming Distance (I, B), Hamming Distance (I, C), Euclidean distance (I, A), Euclidean distance (I, B) and Euclidean distance (I, C) are briefly denoted as sym, mval, $IPFS$, PA, PB, PC, $HD(I, A)$, $HD(I, B)$, $HD(I, C)$, $ED(I, A)$, $ED(I, B)$ and $ED(I, C)$.

IPFS	PA	PB	PC	HD(I,A)	HD(I,B)	HD(I,C)	ED(I,A)
0.08	0.7	0.59	0.5	0.10	0.21	0.09	0.01
0.00	0.01	0.1	0.3	0.01	0.10	0.2	0.0
0.10	0.2	0.09	0.18	0.10	0.01	0.09	0.01
0.5	0.7	0.84	0.03	0.2	0.34	0.47	0.04
0.28	0.01	0.12	0.03	0.27	0.16	0.22	0.07
0.02	0.03	0.02	0.7	0.01	0.0	0.18	0.0
0.7	0.6	0.62	0.4	0.1	0.08	0.3	0.01
0.2	0.2	0.31	0.02	0	0.11	0.18	0.0
0.02	0.01	0.05	0.40	0.01	0.03	0.38	0.0
0.6	0.02	0.29	0.2	0.58	0.31	0.4	0.34
0.2	0.6	0.47	0.14	0.4	0.27	0.06	0.16
0.04	0.01	0.1	0.6	0.03	0.06	0.56	0.0
0.4	0.03	0.3	0.16	0.37	0.1	0.24	0.14
0.5	0.6	0.42	0.21	0.1	0.08	0.29	0.01
0.05	0.07	0.2	0.5	0.02	0.15	0.45	0.0
0.2	0.09	0.72	0.4	0.11	0.52	0.2	0.01
0.3	0.42	0.19	0.1	0.12	0.11	0.2	0.01
0.4	0.26	0.02	0.2	0.14	0.38	0.2	0.02
0.6	0.57	0.44	0.3	0.03	0.16	0.30	0.00
0.3	0.19	0.21	0.01	0.11	0.09	0.29	0.01
0.06	0.08	0.19	0.63	0.02	0.13	0.57	0.00
0.7	0.72	0.41	0.5	0.02	0.29	0.2	0.0
0.25	0.23	0.5	0.2	0.02	0.25	0.05	0.0
0.02	0.04	0.8	0.24	0.02	0.06	0.22	0.0
0.5	0.44	0.6	0.21	0.06	0.1	0.89	0.0
0.3	0.26	0.17	0.43	0.04	0.13	0.13	0.0
0.16	0.19	0.2	0.3	0.03	0.04	0.14	0.0
0.78	0.65	0.6	0.51	0.13	0.18	0.27	0.02
0.19	0.08	0.3	0.24	0.11	0.17	0.05	0.01
0.01	0.08	0.18	0.20	0.07	0.17	0.19	0.0

3.3 Calculation

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Hamming distance:

$d_{HD}(I,A)$ = 1.110
$d_{HD}(I,B)$ = 1.577
$d_{HD}(I,C)$ = 2.747

Normalized Hamming distance:

$d_{NHD}(I,A)$ = 0.111
$d_{NHD}(I,B)$ = 0.158
$d_{NHD}(I,C)$ = 0.275

Euclidean distance:

$ED(I,A)$ = 0.544
$ED(I,B)$ = 0.621
$ED(I,C)$ = 0.994

Normalized Euclidean distance:

$NED(I,A)$ = 0.172
$NED(I,B)$ = 0.196
$NED(I,C)$ = 0.314

Threfore, from the above table we observe that
$d_{HD}(I,A) < d_{HD}(I,B) < d_{HD}(I,C)$
$d_{NHD}(I,A) < d_{NHD}(I,B) < d_{NHD}(I,C)$
$ED(I,A) < ED(I,B) < ED(I,C)$ and
$NED(I,A) < NED(I,B) < NED(I,C)$

with this evidence we may conclude that the patient A have the more chance to affected by the Covid-19 among these three patients.

4 Conclusion

In this paper, we have tried to diagnosis Covid-19 with the help of picture fuzzy sets which helps to record all symptoms in prÃ©cised manner. In future, researchers can extend this model to other extensions of fuzzy sets such as rough sets and utilize the interdependency among the various evaluation criteria for better judgement. As the hidden information in neutral membership grades can be well expressed using rough set theory, one can use it to determine the interdependency of neutral membership grade with the positive and negative membership grades.

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