Original Article

DEVELOPMENT OF FUZZY INFERENCE SYSTEM FOR COVID-19 DATA ANALYSIS

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Abstract

As COVID-19 Pandemic and related data is very recent. COVID-19 infected most of the population from entire globe with different impact. It disclosed the limitation of access of health and care resources. Various parameters like different symptoms, different existing health conditions, different age, diagnosis level and great uncertainties made the condition vaguer. Fuzzy can handle such vagueness and uncertainty of such voluminous data of patients and can support to medical stakeholders, experts, hospitals, pharmaceuticals etc. Fuzzy Logic is widely used to address so many uncertainties, incompleteness or imprecision. The current experiment implements Fuzzy Inference System for pattern identification and classification by applying fuzzy approach with Fuzzy Logic in R for performance improvement. This focuses on designing Fuzzy Rule base, Model and inference for COVID 19 data analysis.

Keywords: COVID-19 Pandemic, Fuzzy Inference System, Fuzzy Logic, Medical Stakeholders, Uncertainty.

INTRODUCTION

The Researcher developed Fuzzy Inference System or Fuzzy Inference Model to get more refined classification and patterns in data, also identified certain impact value for uncertain data spread. By accepting fuzzy variables and rules once established, it can be easily seized and applied repeatedly to acquire further suitable and bug free technical solutions.

Analysis of Input Constraints or Parameters

Table 1 Parameters Assumption Case

Parameter Name	Parameter Type	Total Number of Membership Function
Symptoms	Input	MostCommon, LessCommon, Severe
Age	Input	Kids, Young, Old
O2 Level	Input	VeryLow, Low, Normal
Impact	Output	Deferred, Average, Serious

Source: Compiled by Researcher

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As represented in table No. 1, The FIS (Fuzzy Inference System) with different three input parameters and one output parameter as Impact of Infection to patient is proposed to develop[11,12].

Rule Analysis

Instead of Binary classification of COVID testing as only positive and negative, impact of COVID in positive class varies to different level according to symptoms, age, diagnosis, oxygen level values. Accordingly, some important input variables are identified as constraints to design rulebase are symptoms, age, O2level to get output variable Impact as shown in table no 2. Different mixtures for input degree values results in altered output variable Impact class which reflects Serious, Average and Differed patient's ranges.

Table 2 Knowledge Base

Symptoms	**Age**	**O2 Level**	**Output Variable Impact**
Severe	Old	VeryLow	Serious
LessCommon	Young	Low	Average
MostCommon	Kids	Normal	Deffered

Source: Compiled by Researcher

Need of fuzzy logic

Different blends of Linguistic input of Symptoms, Numeric Age and Oxygen Level such dissimilar input constructions will be passed as input constraints to fuzzy function of designed knowledge base of fuzzy model which will infer inputs using knowledgebase designed in model for fitness of membership. Approximate Membership Fitness and defuzzied value will be used to get linguistic output.

Fuzzy approach for COVID-19 Data

A fuzzy system consisting of 4 variables and 6 rules.

Variables:

Symptoms (MostCommon, LessCommon, Severe)

Age (Kids, Young, Old)

O2level (VeryLow, Low, Normal)

Impact (Deferred, Average, Serious)

Rules:

Symptoms %is% Severe && O2level %is% Low => Impact %is% Average

Symptoms %is% Severe && Age %is% Old && O2level %is% Normal => Impact %is% Deferred

Symptoms %is% Severe && Age %is% Kids && O2level %is% Low => Impact %is% Average

Symptoms %is% LessCommon && Age %is% Kids && O2level %is% VeryLow => Impact %is% Serious

Symptoms %is% LessCommon || Age %is% Young || O2level %is% Low => Impact %is% Average

Symptoms %is% MostCommon => Impact %is% Deferred

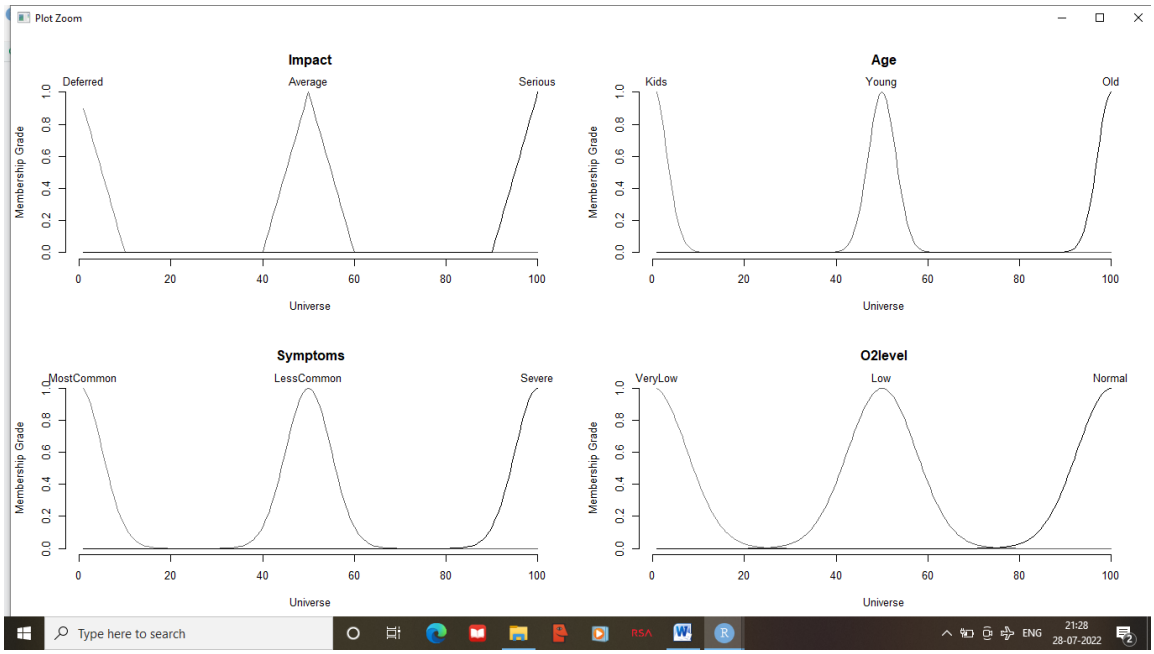

Figure 1: Fuzzy Inference Model design for COVID-19 Data.

Initially Symptoms are pre-processed using tm package in R and term matrix is generated to count number of serious symptoms observed in patients to numeric from linguistic form to pass as parameters along with age and O2level (Oxygen Level) input to fuzzy inference and applied as depicted in Figure No. 1. It provides Impact of COVID-19 infection output partitions for applied combination of symptoms, age and O2level (Oxygen Level).

As input value passed accordingly membership fitness function is applied.

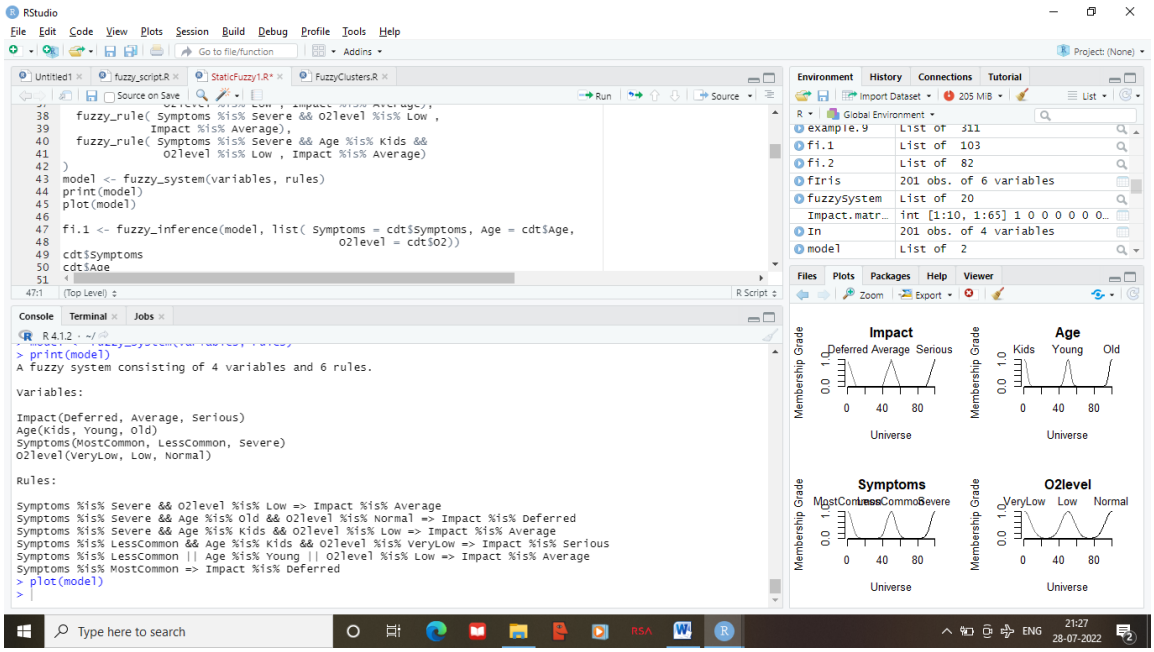

Figure 2 Rule Base for FIS

The Figure No. 2 shows the console result of output of designed knowledge base and implementation of fuzzy inference system for the knowledge base and input-output variable combination for mix of different membership ranges. To connect three input parameters in one rule logical connector 'AND' and 'OR' are used.

The knowledge base designed for variable partitions and rules are implemented as below:

Rules:

Symptoms %is% Severe && O2level %is% Low => Impact %is% Average

Symptoms %is% Severe && Age %is% Old && O2level %is% Normal => Impact %is% Deferred

Symptoms %is% Severe && Age %is% Kids && O2level %is% Low => Impact %is% Average

Symptoms %is% LessCommon && Age %is% Kids && O2level %is% VeryLow => Impact %is% Serious

Symptoms %is% LessCommon || Age %is% Young || O2level %is% Low => Impact %is% Average

Symptoms %is% MostCommon => Impact %is% Deffered

Variables:

Symptoms (MostCommon, LessCommon, Severe)

Age (Kids, Young, Old)

O2level (VeryLow, Low, Normal)

Impact (Deferred, Average, Serious)

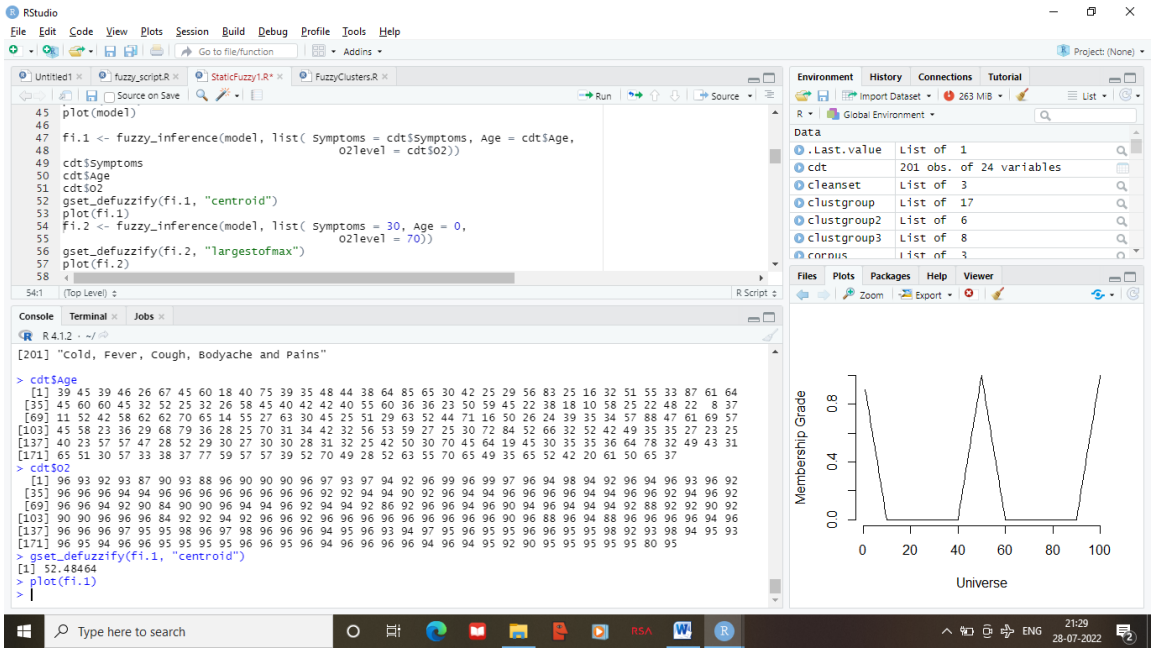

Figure 3 Output of defuzzification for COVID-19 Impact membership

Before passing input, parameters symptoms corpus is pre-processed and count of observed serious symptoms is generated, as well as while passing parameters all NA values for parameters are replaced with zero. For the designed FIS the Output of Impact shows 52.76 impact range membership which belongs to class overall average impact of dataset for 200 records populated, which is obtained as defuzzification result using centroid method to get certain values is shown in the figure 3.

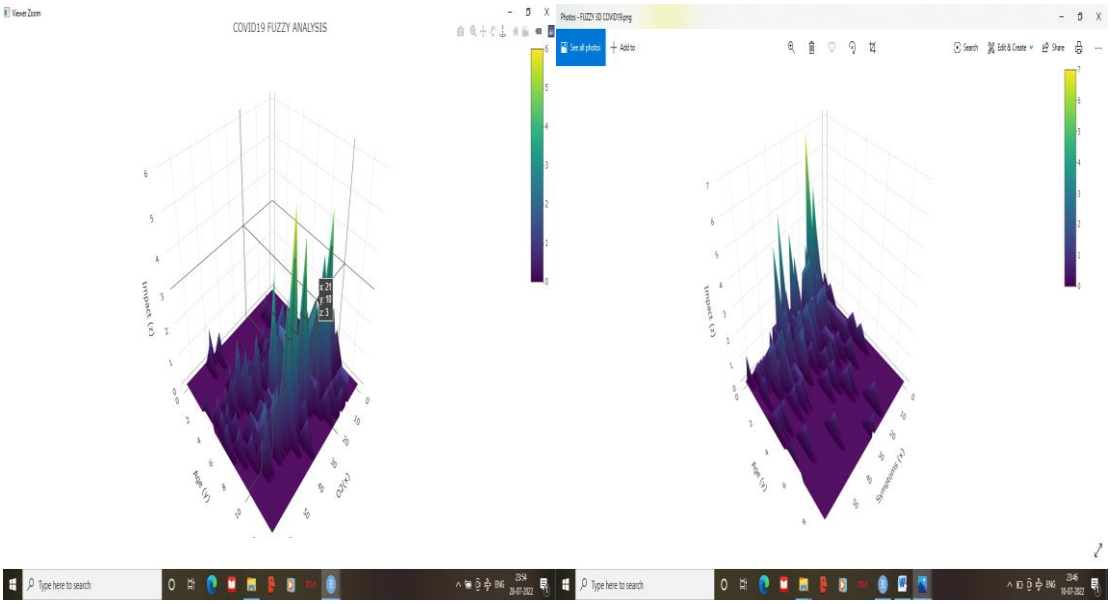

Figure 4: Patterns Membership Graph

As shown in Figure 4, the 3D plot of output patterns class shows patterns of impact based on input parameters O2level and Age or Age and Symptoms. With green colour Strong positive membership is represented that is if age and symptoms are high and O2 level is low patient shows highest impact range as serious impact. The Graph is plotted for different scales representing degrees of membership and 3D patterns are plotted on graph using different colour scale from Purple to Green showing membership of impact for scale as explained in legend of graph.

This experiment implements parameter identification, relevance analysis and development of fuzzy inference system for COVID-19 patient's data analysis classification and pattern analysis

Findings (Results) and Discussion:

Fuzzy based COVID-19 Classification and Analysis

Traditional approaches to handle uncertainty and to provide solution to such vague problems are binary values (only two values zero and/or one) general statistical measures of central tendency. It also has limitation to handle linguistic problems and estimations. Fuzzy logic is multi-value solution to handle certainty with different partitions or sub-ranges or classes of interval. So Fuzzy can deal with linguistic variables, by transforming linguistic data to numeric classes and again back numeric result to linguistic. So COVID-19 patients are commonly classified as either COVID infected or non-infected patient. This binary classification can be represented with 1 and 0 binary form. But all COVID infected cases cannot be at same level of severity, and can't be treated and handled using same set of treatment and care actions. Gradual interval of infected impact between 0 and 1 can be as serious, average and deferred, fuzzy infer the infected cases with classification rule set. After application of fuzzy classification to pre-processed 200 COVID-19 data records is resulted in average impact class around 53% (52.76% obtained result).

But all different cases will have different impact using fuzzy classification patterns in form of their proper degree of classification can be identified. Fuzzy by handling incompleteness, imprecision and incompleteness can result in more precise set of values identifying its belonging class. With this purpose investigator framed fuzzy ranges for degrees of membership to acquire resemblance through fuzzified patterns for mixture of various input value degrees.

Initially all various related input parameters are studied, analysed and identified as important parameters of relevance influencing to COVID-19 disease impact. The identified parameters are pre-processed data achieved in crisp result is used to experiment different implementations and evolutions of machine learning approach. So Symptoms, Age and O2 level are accepted as input constraint for fuzzy implementation. In fuzzy model, researcher has made these input constraints with different variable partitions as in case of Symptoms constraint MostCommon, LessCommon and Severe sub-ranges can be classified as {0, 0.50, 1}. Likewise other constraint are classified for interval ranges marking to improve impact output variable classification from extreme outcomes to closely associated outcome classes. The degree of membership for input fitness for all different input parameters is validated in contradiction of stated knowledge base or rule base for different combinations customized in model design. The chapter 4 (4.15) explains the rule base where total 64 mixtures of 3 input parameter are possible to get precise and correct result, but 6 rule by using logical connectors are considered to form Rule-base or knowledge-base by maintaining precision and scaling. Application of fuzzy logic for pattern detects output degree class by matching fitness function. In the designed fuzzy model, outcome variable Impact is obtained after implementation of fuzzification-membership fitness-defuzzification to COVID-19 data.

By using centroid defuzzification result obtained in fuzzified inference is transformed to certain value. This certain outcome again classified into partitions for impact study as Serious, Average and Deferred class. So fuzzy function accepts input parameter values which are pre-processed in Chapter 4. This fuzzy model returns fuzzy Output parameter which evaluates to the Average Impact of infection who undergone treatment in Hospital. This means as per designed model, overall Impact on infected patients is average showing common behaviour but escalation of treatment was cured. Fuzzy system initially implemented for classification analysis and estimation of overall impact value and patterns in relation to input parameters values in data set, further investigator also used evolutionary approach with integration of fuzzy-genetic-machine learning for processed parameters to get better-quality prediction of RT-PCR testResult for pre-processed COVID-19 data.

Results Summary

Overall application of machine learning techniques fuzzy classification, integrated evolutionary approach, Principal Component Analysis used for COVID-19 data analysis with different aspects as shown in table no. 7.2 provides patterns of classification, prediction as positive RT-PCR testResult for same set of behaviour of dimensions and positive and strong positive group of similarity for fuzzy clusters obtained and components of dominance.

So different techniques applied, results obtained and evaluation method used are as represented in Table 3.

Table 3 Results Summary

Approach	**Result**	**Evaluation Technique**
Fuzzy Classification Approach	Varied patterns are framed showing different classes.	Membership fitness with patterns of data identified using Centroid defuzzification method

Conclusion:

In the research work, the investigator has investigated and formed strategy for COVID-19 Data Normalization, fuzzy classification for pattern and certainty analysis used; graphical relative analysis, Coefficient of relationship which will help in analysis in form relevance analysis, classification, prioritization and grouping to support medical stakeholder's especially hospitals, pharmaceuticals and laboratories to manage their resources and in decision making in treatment and care for viral diseases.

Implementation at Micro level units for day to day or routine healthcare setup design.-

Diverse health settings in large population countries like India and China is also challenge to provide medical treatments and facilities, create awareness in different kind of society, so micro level units and hospitals, clinics or individual practitioners if would implement these automated solution at their service points or clinics, this will reduce the load on specialty hospitals and government hospitals.

Hospital and Pharmaceuticals Management-

As the proposed work focuses clinical decision making support it will provide management solutions and techno-medical- management strategic models can be designed in future work for Hospital Management.

Future Scope for Research:

In future research, deep learning can be applied to COVID-19 data set. Researcher would like to suggest developing AI based model for unstructured data also. The Researcher has planned to implement machine learning and evolutionary model for COVID-19 patient's data with different approaches as explained in table no. 4.

Table 4 Future Approach of implementation

Sr. No.	Algorithm	Approach
1	Fuzzy Classification	To get Fuzzy patterns of Output class.
2	Fuzzy-Genetic-Machine Learning	To predict values of RT-PCR testRersult for determined set of input parameters.
3	Fuzzy Clustering Means	To identify group correspondence based on data centres to form clusters.
4	Principal Component analysis	To analyse dominant components of COVID-19 patients data by applying principal Component analysis.

As the pandemic and related data is very recent, respiratory disease and solutions are attractions of recent research, so can be applied with different expert and recommendation systems. The emergent investigation and ultimatum in research scholar positions for COVID is also screening the interest of scientific community. Investigator would like to propose enhancement in the work in collaboration with medical research fellows to focus on innovative methods for computerised medical support systems. This work can be further enhanced fuzzification of images and video identifying as new parameters and by simplifying it to standard form and allocating weights for more exact set of perditions. One can also apply image processing to HRCT scan image reports to accept it as major, vital input constraint.

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