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Application of Fuzzy Logic to Predict Diseases: An Overview

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ABSTRACT: Clinical judgment for the diagnosis and management of men's diseases is an art. It can neither be acquired from textbooks alone, nor can it be taught, but has to be developed slowly through years of observation and experience. This is because unlike other professions, which thrive on calculations based on yes/no or present/absent, very little is clearly black and white in clinical medicine. Most clinical scenarios are present in shades of grey. Instead of "present or absent" patients' symptoms are described using terms like "never, rarely, sometimes, often, most of the times, always, etc". Moreover, each specific symptom may also be graded as "mild, moderate or severe". Medical problems, therefore, cannot be generalized and analysed using Aristotelian or binary logic, and an analytical program is desperately required which could integrate this complex network of problems and devise individualized solutions. Fuzzy logic is the nearest response to the call. It has the potential of combining human heuristics into computer-assisted decision making.

In this work we will review some literature based on fuzzy logic to diagnose clinical disease with their basic symptoms. Definitely this survey of literature on previous work done by various researcher opens a new door with these concerns.

KEYWORDS: Fuzzy logic, Boolean logic, Fuzzy inference system (FIS), COVID-19 pandemic, Fuzzy Based Decision-Making Approach

INTRODUCTION

Man is God's most complex creation. Clinical judgment for the diagnosis and management of mans' diseases is an art. It can neither be acquired from textbooks alone, nor can it be taught, but has to be developed slowly through years of observation and experience. This is because unlike other professions, which thrive on calculations based on yes/no or present/absent, very little is clearly black and white in clinical medicine. Most clinical scenarios present in shades of gray. Instead of "present or absent" patients' symptoms are described using terms like "never, rarely, sometimes, often, most of the times, always, etc". Moreover, each specific symptom may also be graded as "mild, moderate or severe". This is compounded by the fact that most symptoms are experienced and described differently by patients and many symptoms may overlap in the same patient. Each individual patient may also have a multitude of characteristics other than the disease, rendering it unique in itself. Medical problems, therefore, cannot be generalized and analyzed using Aristotelian or binary logic, and an analytical program is desperately required which could integrate this complex network of problems and devise individualized solutions. Fuzzy logic is the nearest response to the call. It has the potential of combining human heuristics into computer-assisted decision making.

The concept was first introduced by Lotfi Zadeh in 1965. He defined fuzzy logic as "a class of objects with a continuum of grades of membership". It accounts for all the complexities and variations in patients and results in a statistical analysis which is appropriate for an "individual", unlike evidence-based medicine, which is applicable to a group of patients. It enables the scientific community to look into all shades of gray and determine the grade and severity of the disease. Fuzzy logic is a well-established concept in mathematics and engineering but its usefulness in medicine was not realized till the last decade.

Literature reveals that fuzzy logic has been used effectively in medicine. Different types of methodologies have been applied to diagnose the diseases based on symptoms, historical and clinical data of an individual. Increase in the number of recent applications of medicine with fuzzy-logic is an indication of growing popularity of fuzzy systems. In the traditional approach, a physician is required to diagnose disease based on historical and clinical data but the intelligent system will help

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physicians as well as individuals to detect disease at any location of the world.

What is Fuzzy logic?

Fuzzy logic is a multi-valued logic which was introduced by Zadeh in order to deal with vague and indecisive ideas. It has been described as an extension to the conventional Aristotelian and Boolean logic as it deals with "degrees of truth" rather than absolute values of "0 and 1" or "true/false". Fuzzy logic is not like a computer software which understands only binary functions or concrete values like 1.5, 2.8, etc; instead, it is similar to human thinking and interpretation and gives meaning to expressions like "often", "smaller" and "higher". Fuzzy logic takes into account that real world is complex and there is uncertainty.

Characteristics of Fuzzy Logic

There are a few basic principles of fuzzy logic which were laid down by Zadeh in 1992.

- Exact reasoning is viewed as a limiting case of approximate reasoning.
- Everything is a matter of degree.
- Knowledge is interpreted as a collection of elastic, fuzzy constraints on a collection of variables.
- Inference is viewed as a process of propagation of elastic constraints.
- Any logical system can be "fuzzified".

Fuzzy Sets

A classical set of binary logic has "crisp" boundaries whereas fuzzy sets have fuzzy or imprecise boundaries. A fuzzy set consists of linguistic variables where values are words and not numerical. For example, intracranial pressure (ICP) can be defined as low, normal or high. Thus, ICP is a linguistic variable where the values have fuzzy margins and can overlap each other. The transition from one value to another is gradual and each value is given a membership function which represents the degree to which it belongs to that value. A fuzzy set can be represented by the following equation-

Fuzzy sets: low, medium and high

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

Where A is a fuzzy set in X and $\mu_A(x)$ is the membership function, which can have any value between 0 and 1 inclusive.

Membership functions overlap each other as evident. Thus, a value for ICP can be both low and normal to a certain degree. Membership functions are not equivalent to probabilities. A membership value of low ICP does not signify that there is a certain probability of having low ICP or not; instead, it is the degree to which it is a low ICP.

Fuzzy Rules

Fuzzy rule is based on "if then" rule and connects the different input and output fuzzy variables. It can be expressed as:

If is x A then y is B

Where A is the antecedent and B is the consequent. Fuzzy rules are similar to common sense rules as they resemble human thinking and are based on human experience. For example, in order to control ICP in a patient with traumatic brain injury, sedation is often required but needs to be carefully monitored. A simple rule can be, "If the ICP is high, increase protocol infusion", or "If the ICP is low, stop protocol infusion". These rules are based on collective experience of specialists in the field as well as available literature. Thus, as more fuzzy rules and sets are obtained from various sources, uncertainties are potentially reduced.

Fuzzy Reasoning

Fuzzy reasoning is also called approximate reasoning and is the process of drawing conclusions from fuzzy sets and fuzzy rules.

Fuzzy Inference System

Fuzzy inference system (FIS) is a framework which is based on fuzzy sets, fuzzy rules and fuzzy reasoning. It has four main components including fuzzifier, rule base, inference engine and defuzzifier. The fuzzifier creates fuzzy sets from "crisp" values like a fuzzy set for ICP will be divided into "low, normal and high" and a fuzzy set for protocol infusion will be divided into "stop, decrease and increase". Next, the fuzzy rules are formed based on these two input fuzzy sets: "If the ICP is low, stop protocol infusion", "If the ICP is normal decrease protocol infusion" and "If the ICP is high, increase protocol infusion". The inference engine applies all the fuzzy rules on the fuzzy sets to determine the resultant fuzzy output. If a "crisp" output value is required, the process of defuzzification converts the fuzzy output into a "crisp" output value by determining the center of mass of the combined, overlapping membership functions.

Diagnosis as the initial step of medical practice is one of the most important parts of complicated clinical decision making which is usually accompanied with the degree of ambiguity and uncertainty. Since uncertainty is the inseparable nature of medicine, fuzzy logic methods have been used as one of the best methods

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to decrease this ambiguity. Recently, several kinds of literature have been published related to fuzzy logic methods in a wide range of medical aspects in terms of diagnosis. Consequently, the result approved the effectiveness of applying different fuzzy methods in diseases diagnosis process, presenting new insights for researchers about what kind of diseases which have been more focused. This will help to determine the diagnostic aspects of medical disciplines that are being neglected.

REVIEW OF LITERATURE

Overall, this systematic review provides an appropriate platform for further research by identifying the research needs in the domain of disease diagnosis. It is appropriate to review the important research works done by researchers in the area application of fuzzy logic to predict diseases.

N. H. Phuong and V. Kreinovich (2001) discussed thefuzzy set theory and fuzzy logic are a highly suitable and applicable basis for developing knowledgebasedsystems in medicine for tasks such as the interpretation of sets of medical findings, syndrome differentiation in Eastern medicine, diagnosis of diseases in Western medicine, mixed diagnosis of integrated Western and Eastern medicine, the optimal selection of medical treatments integrating Western and Eastern medicine, and for real-time monitoring of patient data.

S. K. De, R. Biswas, and A.R. Roy (2001) studied the Sanchez's approach for medical diagnosis and extend this concept with the notion of intuitionist fuzzy set theory (which is a generalization of fuzzy set theory).

N. Bhatla and K. Jyoti (2012) discussed heart disease is a term that assigns to a large number of medical conditions related to heart. These medical conditions describe the abnormal health conditions that directly influence the heart and all its parts. Heart disease is a major health problem in today's time.This paper aims at analyzing the various data mining techniques introduced in recent years for heart disease prediction.

R. Hndoosh, M. Saroa and S. Kumar (2014) analyzed an Adaptive-Network-based Fuzzy Inference System ANFIS with different techniques of clustering is successfully developed to solve one of the problems of medical diagnoses, because it has the advantage of powerful modeling ability. In this paper, they proposed the generation of an adaptive neuro-Fuzzy Inference System model using different clustering models such as a subtractive fuzzy clustering (SFC) model and a fuzzy mean clustering (FCM) model in the Takagi-Sugeno (TS) fuzzy model for selecting the hidden node centers.

Allahverdi (2014) studied that include design processes of some fuzzy expert systems for applications in some medical area. Recent studies of their that include fuzzy expert systems that make use of fuzzy logic method were described. All designed fuzzy expert systems can help in support decision process of physicians. It can be claimed that in many cases such systems can help the physicians in diagnostics, treatment of illness, patient pursuit, prediction of disease risk and etc.

K. K. Oad, X. Dezhi and P. K. Butt (2014) studied the health care domain systems globally face lots of difficulties because of the high amount of risk factors of heart diseases in peoples. To reduce risk, improved knowledge based expert systems played an important role and has a contribution towards the development of the healthcare system for cardiovascular disease. In their proposed system, they designed a fuzzy rule based expert system and also by using data mining technique they have reduced the total number of attributes. Their system mainly focuses on cardiovascular disease diagnosis, and the dataset taken from UCI.

I. Dragovic, N. Turajlic, D. Pilcevic, B. Petrovic and D. Radojevic(2015) established the fuzzy inference systems (FIS) enable automated assessment & reasoning in logically consistent manner akin the way in which humans' reason. Since no conventional fuzzy set theory is in Boolean frame, it is proposed that Boolean consistent fuzzy logic should be used in the evaluation of rules. Given that patients could be located far away from healthcare institutions (as peritoneal dialysis is a form of home dialysis) the proposed Boolean FIS would enable patients easily estimate likelihood of having permit.

R. A. Mohammadpour, S. M. Abedi and S. Bagheri (2015) determined the accuracy of fuzzy rule-based classification that could noninvasively predict CAD based on myocardial perfusion scan test and clinical-epidemiological variables. To increase the classification rate, they deleted the extra rules to reduce the fuzzy rules after introducing the membership functions.

L. Zadeh (2015) analyzed the principal contributions to the development of fuzzy set theory and fuzzy logic. Among the contributions which are discussed are: introduction of the concept of a fuzzy set, FL-generalization, the concept of a linguistic variable, information granulation, precipitation of meaning, generalized theory of uncertainty (GTU), the concept of a

restriction, restriction-centered theory of truth and meaning, the information principle, and similarity-based definitions of possibility and probability.

K. Polat and S. Gunes (2017) detected on diabetes disease, which is a very common and important disease using principal component analysis (PCA) and adaptive neuro-fuzzy inference system (ANFIS). In the second stage, diagnosis of diabetes disease is conducted via adaptive neuro-fuzzy inference system classifier. They took the diabetes disease dataset used in their study from the UCI (from Department of Information and Computer Science, University of California) Machine Learning Database.

R. R. Córdoba, J.A. Olivas, F. P. Romero, F. A. Gonzalez, J. S. Guerrero (2017) studied the decision support systems, embedded in modern telemedicine applications, are a tool to improve the skills of general practitioners and patients in decision- making in medicine. Then, the diagnosis of a fuzzy disease set is based on the exclusion of symptoms and tests results, due to the similarity between them. In the present article, it is proposed the development of a Clinical Decision Support System framework to diagnose a set of fuzzy diseases, concretely applied to Fibromyalgia and associated syndromes.

H. Ahmadi, M. Gholamzadeh, andL. Shahmoradi (2018) discussed adiagnosis as the initial step of medical practice, is one of the most important parts of complicated clinical decision making which is usually accompanied with the degree of ambiguity and uncertainty. They conducted a systematic review to determine the contribution of utilizing fuzzy logic methods in disease diagnosis in different medical practices.

S. Thukral and V. Rana (2019)discussed the review aims at providing current state of evidence in the field of medicine with fuzzy logic for diagnosing diseases. Literature reveals that fuzzy logic has been used effectively in medicine. This study indicates all the benefits of the fuzzy logic to the society and direction to tackle the diseases that still need software for their accurate detection. Further, different case studies for celiac disease have been reported earlier. The current review aims at exploring the future direction for fuzzy methodologies and domain on celiac disease.

G. Pandey, P. Chaudhary, R. Gupta, and S. Pal (2020) analyzed COVID-19 pandemic has become a major threat to the country. In this study, outbreak of this disease has been analysed for India till 30th March 2020 and predictions have been made for the number of cases for the next 2 weeks. SEIR model and Regression model have been used for predictions based on the data collected from John Hopkins University repository in the time period of 30th January 2020 to 30th March 2020.

D. Painuli, D. Mishra, S. Bhardwaj and M. Aggarwal (2020proposed a fuzzy rule-based system which is used with MATLAB tools for simulations to give predictions related to whether one is suffering from Covid19 or not. At present, the testing kits of Covid19 are very limited and they take lot of time to give results but our proposed system can be used in initial predictions, which can save both time and money.

K. B. Uplenchwar and R.S. Kokate (2020) analyzed the Fuzzy Logic is an extremely vital role in the area of computer science, Artificial Intelligence, control theory and mathematic. This paper offers the idea of fuzzy logic and its uses in various branches. This review denotes the usage of fuzzy logic approach in soil science, operations research, agriculture, machining, chemical science, medical science, in environmental science, traffic engineering and household.

G. Ghosh, S. Roy and A. Merdji (2020)discussedthat due to the busy schedule of every human being in today's world, consciousness towards one's health has become quite alarming. The idea is to develop a logic, which could be incorporated in a pocket friendly device in future that would generate an alarm whenever there is imbalance in blood sugar or blood pressure levels. The concept of the fuzzy inference rule and first-order logic is implemented to develop this study.

S. Chatterjee, A. Sarkar, S. Chatterjee, M. Karmakar and R. Paul (2020)investigated a standard epidemiological model, known as the SIRD model, to study the COVID-19 infection in India, and a few other countries around the world. The projection of the model is highly sensitive to the choice of the parameters and the available data. Besides, since the pandemic is an ongoing dynamic phenomenon, the reported results are subjected to regular updates in consonance with the acquired real data.

A.Baz, and H. Alhakami (2020) theirexamination expects to assess the severity ofCOVID-19 pandemic in cities of KSA. In addition, computational model for evaluatingthe severity of COVID-19 with the perspective of social influence factor isnecessary for controlling the disease. The analysis tabulated in their study will assist in mapping the rules and building a systematic structure that is immediate need in the cities with high severity levels due to the pandemic.

C. Yang and J. Wang (2020) proposed a mathematical model to investigate the current outbreak of the coronavirus disease 2019 (COVID-

19) in Wuhan, China. Their model describes the multiple transmission pathways in the infection dynamics, and emphasizes the role of the environmental reservoir in the transmission and spread of this disease. They conduct a detailed analysis of this model, and demonstrate its application using publicly reported data. Among other findings, their analytical and numerical results indicate that the coronavirus infection would remain endemic, which necessitates long-term disease prevention and intervention programs.

S. Kumar, V. Agiwal, A. Kumar and J. Kumar (2020)studied the outbreak of coronavirus disease 2019 (COVID-19) is continuously increasing in India, so epidemiological modeling of COVID-19 data is urgently required for administrative strategies. Time series and is capable to predict future observations by modeling the data based on past and present data. Here, they have modeled the epidemiological COVID-19 Indian data using various models. They recommended that a comparison between various predictive models provide the accurate and better forecast value of the COVID-19 outbreak for all study variables.

Y. Li, B. Wang, R. Peng, C. Zhou, Y. Zhan, Z. Liu, X. Jiang and B. Zhao (2020) analyzed the since receiving unexplained pneumonia patients at the Jinyintan Hospital in Wuhan, China in December 2019, the new coronavirus (COVID-19) has rapidly spread in Wuhan, China and spread to the entire China and some neighboring countries. They establish the dynamics model of infectious diseases and time series model to predict the trend and short-term prediction of the transmission of COVID-19, which will be conducive to the intervention and prevention of COVID-19 by departments at all levels in mainland China and buy more time for clinical trials.

B. Ivorra, M. R. Ferrandez, M. V. Parez and A. M. Ramos (2020) developed a mathematical model for the spread of the coronavirus disease 2019 (COVID-19). It is a new θ-SEIHRD model (not a SIR, SEIR or other general purpose model), which takes into account the known special characteristics of this disease, as the existence of infectious undetected cases and the different sanitary and infectiousness conditions of hospitalized people. It is complex enough to capture the most important effects, but also simple enough to allow an affordable identification of its parameters, using the data that authorities report on this pandemic.

Peter P Grounmpos (2020) discussedthe approach of FuzzyCognitive Maps (FCM) that is considering the causality factorsis proposed, for the first time, to investigate the whole spectrumof COVID-19. An FCM model is proposed and referred as theclassical FCM methods. Simulations wereperformed and results were compared with the classical FCMapproach. Useful conclusions and future research directions areprovided.

Pimar Cihan (2020) discussed that today in additionto clinical studies; computer-aided studies are also widelycarried out for Covid-19 outbreak. Artificial intelligencemethods are successfully applied in epidemic studies. In thisstudy, fuzzy rule basing system (FRBS) used to predict thenumber of Covid-19 daily cases. As a result of the study, thenumber of daily cases was successfully estimated with FRBS.

P. Harjule, V. Tiwari and A. Kumar (2021) studied theworld Health Organization (WHO) announced novel coronavirus (COVID-19) disease, a pandemic on March 12, 2020, a disease caused by SARS-CoV2 virus. The main purpose behind this review paper is to convey to the readers the different dimensions of already existing applications and present an initial description of how mathematical modeling can help predict the spread of COVID-19 more accurately and reliably.

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