

Study of Various Fuzzy Approaches for Disease Diagnosis

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Abstract—Diagnosis is the fundamental step of medical practice. The role of diagnosis is crucial in complex clinical decisions, as these decisions are ambiguous and uncertain. Uncertainty and ambiguity are the in the nature of medicinal diagnosis, which can be easily handled by fuzzy methods – which are considered to be the best practice to deal with uncertainties. In recent years, fuzzy set theory and fuzzy logic are successfully applied in health practices. Recently, numerous literatures have been published in the field of fuzzy theory and its related applications. It is widely used in a medical area respectively for diagnosis. This paper intends to provide a small survey on application of fuzzy set theory in health sector. This paper discusses the latest literature including the medical diagnosis and need of fuzzy systems. Also, the performance of various fuzzy approaches for the diagnosis of different diseases is discussed.

Index Terms— medical diagnosis, fuzzy system, uncertainty, vague and intuitionistic fuzzy sets.

I. INTRODUCTION

The process which is related to the social, economic and environmental decisions is called sustainable development. Parameters defined by sustainable decision making are complex and ill-defined having high degree of uncertainty. Fuzzy logic is considered to be a standard tool for the appraisal of sustainability.

Fuzzy Logic is one of the tools of artificial intelligence and it is gaining popularity in recent years. Fuzzy Logic deals with uncertainty i.e. it deals with the information that is imprecise and nonnumerical. The term “fuzzy” comes from this vagueness. It is a mathematical model of representing vague and imprecise information. Fuzzy models have the capability of recognizing, representing, manipulating, interpreting, and utilizing data and information that are vague and lack certainty. Models based on Fuzzy Logic deals with sources of vagueness and uncertainty that are nonstatistical in nature. The foundation of Fuzzy Logic is fuzzy set theory proposed by Zadeh in 1965. It is a current and innovative methodology that modifies conventional system design with engineering expertise. Anything designed using conventional techniques can also be designed using Fuzzy Logic. It is found that fuzzy logic plays a crucial role in designing the framework of medicine [1].

II. MEDICAL DIAGNOSIS

Medical diagnosis is the process of determining the person’s illness on the basis of available symptoms of that person. It is a complicated task and depends on multiple factors as same symptoms can lead to multiple diseases. Thus, its solution depends on the human decision capability and its intuition, thus involving the consciousness. [2, 3]. In medical field, decision making is a complex task to accomplish and accurate diagnosis to perceive at

the exact disease depends upon the proper interpretation done on the basis of clinical test and perceptions done by it. Automation technologies based on artificial intelligence techniques are used by medical practitioners to increase the efficiency of medical diagnosis procedures. These techniques help them to do accurate diagnosis of diseases and to avoid false diagnosis [4, 5]. In the literature, various authors worked on medical diagnosis using fuzzy theory [6] used bipolar valued fuzzy-sets for medical diagnosis in uncertain environment. A variant of fuzzy sets as intuitionistic fuzzy sets is used as an application in medical diagnosis by [7] Similar medical investigation on the Intuitionistic Fuzzy data is carried by [8] and [9]. [10] used neuro fuzzy system to detect Parkinson's disease.

III. ISSUES REGARDING MEDICAL DIAGNOSIS

The human anatomy is very complex. Its functioning can be characterized by the complex and highly interactive interplay of its organs and mind. The overall effort of this is homeostasis, which results in symmetry of physiological quantities. On the physiological bounds, the actual level at which the balance of each individual is maintained, varies from individual to individual. If there is some deviation from the actual balance due to internal or external factor, it indicates some kind of disorder. To find the deviations from the actual is the goal of medical diagnosis [2].

It is not possible to see inside a sick patient and determine the primary cause that lead to a multiple effects and reactions for which the patient complains, through the available diagnostic methods. Not many times, circumstantial evidences, the symptoms present in the patient and the current knowledge of medical mechanism which relates the symptoms to the concluding disease is supported by diagnosis. The incomplete data is not only the issue regarding diagnosis, but other than that practical limitations including theoretical limitations related to the reversal of the association leading from the initial impact to the observable effects [11].

First of all, in medical field, considering the causes and their effect relationships between diagnoses and their symptoms, are not properly mapped. A single symptom can relate to multiple diagnoses. Thus, it is difficult to identify overlapping range of symptoms for differentiating diseases. Secondly, the observations coming after diagnosis are subject to error, to correct these errors require strong assumptions that are not available in practice, due to their stochastic nature. Lastly, the requirements which are necessary are not always made on continuous basis. Contrary to this, it is needed a high risk or cost to obtain a meaningful information, so they have to work with significantly less important information [12]. This is especially a problem for the diagnosis of dynamic perturbations that evolve over an extended period of time. Diagnosticians have to speculate in most of the cases.

IV. NEED FOR FUZZY SYSTEM

It seems hard to find to design a theoretical, mathematical and analytical solution to the problems of medical diagnosis. Other than this it is seen that the intelligence of humans in diagnosis is sufficient to achieve satisfactory results on the variety of diagnostic problems available. The system designed on the basis of guessing or intuition cannot achieve a better performance compared to human diagnosis. So, a mathematical model should be designed which could automatically diagnose the disease with high accuracy on the basis of available data for diagnosis of disease. The medical artificial intelligence helps in identifying structures and associated methods [2, 13]. Artificial Intelligence is found to be most prominent to deal with such health sector problems. There are two approaches to deal with diagnosis:

- I. Heuristic diagnosis
- II. Model-based diagnosis.

Heuristic diagnosis is associative in nature and depends on the expert's experience in the respective field (which is case based, i.e. expert can specialize in their area) [14]. In model-based diagnostic, the reference comes from a model that explicitly describes the nominal behaviour. Models can be static or dynamic and can be used for simulation. The heuristic diagnosis approach tries to nullify the physiological cause-effect relationships directly, while the model-based algorithms diagnose the available inputs (observed symptoms), simulating the relationships found to determine the cause indirectly [15].

Heuristic diagnosis can be improved in positive direction with the help of fuzzy logic. It is known that the knowledge of experts in medical field and the resulting diagnosis are not certain. It comprises of uncertainty. Uttered expert knowledge therefore abounds with imprecise formulations [16]. The imprecision which comes is an intrinsic part of the expertise acquired by the experts through their experience. Any formal method designed

to handle uncertainty is therefore ill-suited to capture this knowledge, keeping it away from the uncertainty entails the danger of misconception due to misplaced precision.

To handle such problems of vagueness and uncertainty, the fuzzy set theory was designed by Lofti Zadeh in 1965. With the help of appropriate inference rules, it provides a suitable framework on the basis of evidence and other inputs to deduce consequents, which are the best possible results on the basis of knowledge provided. Figure 1 shown on the previous page show the process of applying fuzzy logic in diagnosis of diseases.

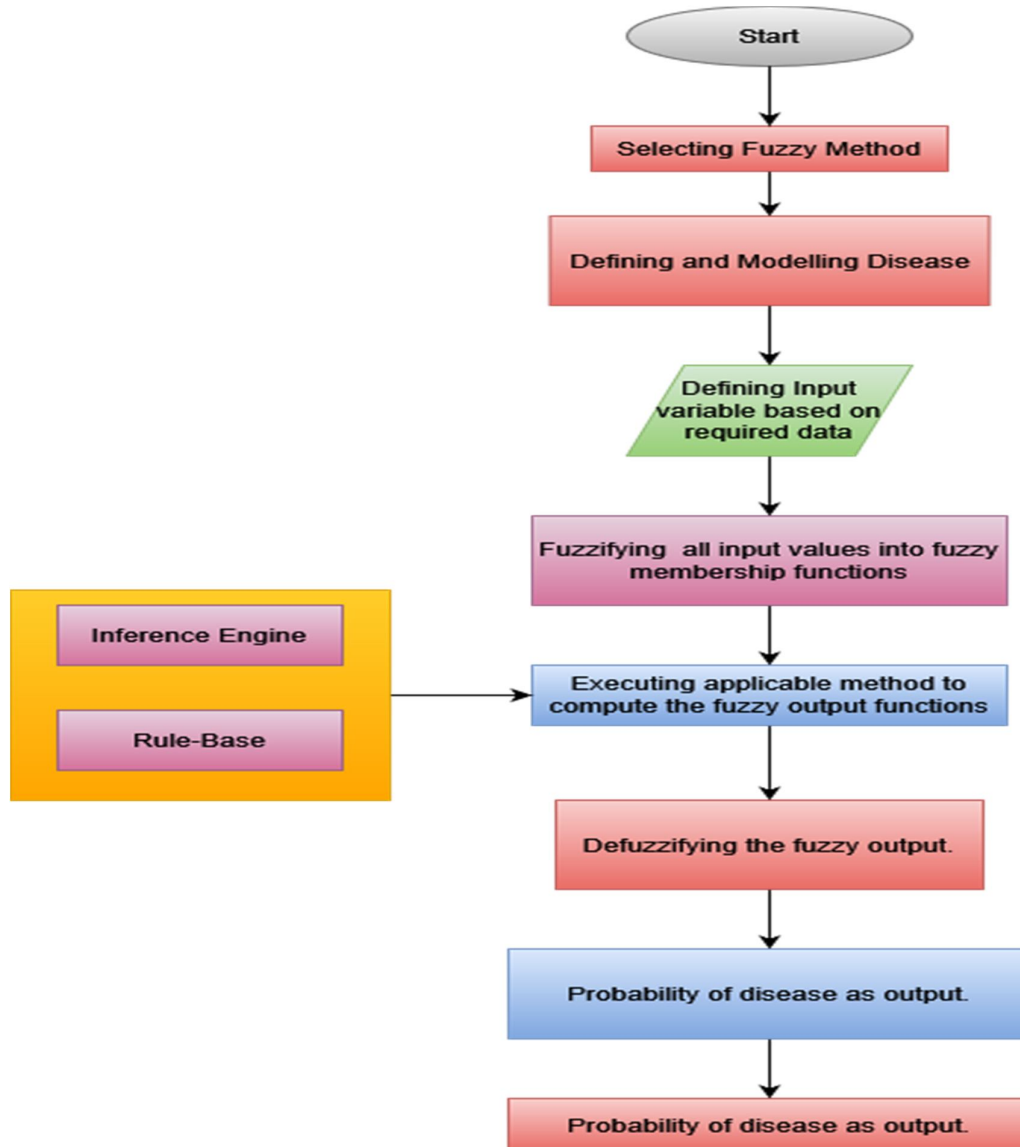


Figure 1. Disease diagnosis done through fuzzy logic

V. APPLICATION AREAS

Lee et al, 2020: This paper uses the hybrid neural fuzzy logic system to develop an approach for recognition of heartbeat. They designed an expert fuzzy model for heart beat classification [17]. They proposed a methodology for unmanned heart beat classification using an Electro Cardio Gram signal. They proposed the use of local transform pattern (LTP) operator using hybrid neuro fuzzy system with self-organizing map. This paper measured the performance of the fuzzy system on parameters sensitivity, positive productivity, classification

accuracy and false positive rate. When applied on heartbeat classification it showed modest performance with sensitivity of 87%, positive productivity of 73.8%, false positive rate of 1.1% and accuracy up to 98.8%. The performance of heartbeat classification improved by the combination of LTP operator with Neuro Fuzzy found to be comparatively better in performance measurement and efficiency measurement with the techniques suitable for ECG processing.

Kora et al, 2019: They proposed a model based on fuzzy system for coronary risk prevention [18]. This paper implements a model based on fuzzy clinical detection for coronary risk prevention with implementation of designing weighted fuzzy standards and creating a fuzzy guidelines-based choice supporting network as two necessary objectives. The primary risk factors of coronary heart disease include smoking, hypercholesterolemia, diabetes, serum cholesterol, hypertension, and high body mass index (BMI). They exhibited an accuracy of 93.3% while detecting coronary disease using fuzzy-based classifier and performs better than traditional classifiers like SVM and KNN.

Sharif et al, 2019: This paper uses fuzzy expert system in the emergency department of the hospital. Emergency department of hospital deals with critical, and life-threatening cases [19]. Accurate diagnosis and faster treatment are the main characteristics of emergency department. But in reality, it takes large waiting time and uncertainty in accurate diagnosis results in degradation of emergency department services. This paper covers disease of asthma. Asthma can be of two types. The first one is acute asthma that remains for few minutes to few days and other one is chronic asthma that is for the lifetime. They designed a fuzzy expert system called fuzzy rule-based expert system for asthma severity identification (FRESAS) to reduce the waiting time and uncertainty in emergency department investigating of under-treatment, uncertainty and severity in asthma diagnosis. The result shows that this expert system is 100% reliable, while the diagnosis done by doctors is 14% reliable.

Mahanta and Panda, 2019: They designed a fuzzy expert system for the diagnosis of prostate cancer based on Mamdani approach [20]. They used various input parameters for predicting the probability of having prostate cancer. Prostate-specific antigen (PSA), age, prostate volume (PV) and % free PSA are the inputs taken and the output obtained is the risk of prostate cancer. The test of this system was applied on clinical dataset. The prediction of the model is 73.77 % on positive biopsy cases. Most of the patient considered were above the age of 55.

Nair et al, 2019: This study aims is to classify the type of autism spectrum disorder for various body movements [21]. They used Fuzzy C Mean Technique and ID3 for autism detection. Autism spectrum disorder is a neurological irregularity with multiple behavioural syndromes. People having this disorder have trouble in communication, low eye contact, a little attentiveness and complex behaviours. They applied this expert system on the dataset of 500 brain MRI of autistic patients. They evaluated the result on 11 features as entropy, energy, mean, kurtosis, variance, standard deviation, skewness, contrast, homogeneity, correlation. Also used different areas from 28 MRI data set. This paper achieved an overall accuracy of 77% by designing a decision tree in detection of autism.

Shaleeg and Ellabib, 2013: This paper [22] compares the performance of Mamdani-type FIS and Sugeno-type model on breast cancer diagnosis and proved that Sugeno type is better compared to Mamdani type. This paper concludes that the performance of both the model is similar. But the risk evaluation capability of Sugeno model is much better compared to Mamdani model when working at full capacity with proper operational performance.

VI. RESULT ANALYSIS

On the basis of above paper's studied, the following observations are made, shown below in Table I.

TABLE I. RESULT ANALYSIS

Author	Area	Objective	Result
Lee et al, 2020	Classification of heart beat	Designing a neuro fuzzy approach for the recognition of heartbeat.	Accuracy 98.8%
Kora et al, 2019	Cardiac arrhythmia detection	Designing a fuzzy model for coronary risk prevention	Accuracy 93.3%
Sharif et al, 2019	Asthma	Designing fuzzy expert system to reduce the waiting and uncertainty in emergency department.	100% reliable
Mahanta and Panda, 2019	Diagnosing prostate cancer	Designing a fuzzy expert system-based on Mamdani to predict the chances of having prostate cancer.	Prediction 73.77%
Nair et al, 2019	Qualitative reasoning in health care	Designing a fuzzy system for measuring linguistic terms and qualitative reasoning	A curacy 77%
Shaleeg and Ellabib, 2013	Breast cancer diagnosis	Compared Mamdani and sugeno model	Sugeno model performance is better

VII. CONCLUSIONS

The review of studies done above is conducted about applying fuzzy methods in medical disease diagnosis. The main focus of this study is to help in identifying that the expert systems based on fuzzy methodology can help in improving the diagnosis of diseases in an accurate way. Few research papers were included, which shows that the model designed on fuzzy approaches provides huge accuracy in diagnosis of diseases compared to other methods based on machine learning. Also, the research shows that if fuzzy model is combined with other technology such as neural network making it a neuro fuzzy system, then the performance of the system is highly improved with accuracy above 90%. The research tells that these systems if effectively used can help the doctors in diagnosis of diseases in a better way. Sustainability is maintained at social, human and economic ground. As probability of accuracy of medical diagnosis is increased with these systems, thus maintaining the sustainability. This is because in future, diagnosis of exact disease, where symptoms are in common can be done with high accuracy and good interpretability, simplifying the expertise of doctor for medical diagnosis.

Fuzzy logic is not only the single approach to deal with uncertainty and vagueness, in recent years, uncertainty in Artificial Intelligence is also becoming the most shoot up disciplines in the area, and fuzzy set theory among the many choices is working tremendously better for medical diagnosis. New fuzzy measures for quality (sensitivity, specificity, positive and negative predictive value) measurement can also be introduced with respect to medical diagnosis.

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