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Medical Applications on Fuzzy Logic Inference System: A Review

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ABSTRACT

Traditional approaches based on algorithms are not feasible for solving detection of diseases throughout the world. Fuzzy Logic becomes more and more popular for diagnosing diseases based on different parameters and methodologies. This paper represents the literature review of articles in fuzzy logic to deal with various medical applications for last decade (2008-2018)because of identified different methodologies developed in this time-period. On the basis of different fuzzy applications in medical field, this article focused on eight common medical issues like heart disease, asthma disease, liver disease, breast cancer, Parkinson disease, cholera, dental and diabetes disease. Based on these different medical applications, the basic objective is to explore and implement fuzzy logic in existing and different domains in future.

Keywords- **ANFIS, Back-Propagation, Fuzzy Logic, Perceptron, Neuro-Fuzzy System**

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I. Introduction

Fuzzy logic is an alternative to probability theory in which outcome represents the degree to which it leads to true or false. Fuzzy logic will be beneficial to work on incomplete, vagueness and uncertain problems. It totally depends upon membership functions based upon optimum results for given application. The conventional approach based on crisp sets to evaluate the results but with fuzzy logic we step forward to implement with fuzzy sets for approximate reasoning. So, it behaves as mimic nature as of human thinking to deal with specific problem. Fuzzy logic totally based on fuzzy if-then rules to produce an output for an application. Fuzzy rule based inference approach combines all three basic representation as matching, inference and combination to meet the final response. There are two ways to demonstrate fuzzy rules based on fuzzy mapping and fuzzy implication. The role of fuzzy mapping lies when we don't know all the values of the parameters in specific application whereas fuzzy implication focused on approximate reasoning with different statements. The objective of fuzzification is to convert crisp sets to fuzzy sets and defuzzification is to produce an output in the similar way as input. Through fuzzy logic, we can generate an intelligent machine which resembles the working as of human brain. To tackle the emergent need to society in medical field, the contribution of fuzzy logic is growing rapidly in every sector of medicine.

The rest of the paper is organized section II-IX presented with different surveys taken in medical field with methodologies, tool used and findings. Finally, section X contains discussions and section XI concluding remarks and future outline of fuzzy logic in medical applications.

II. Fuzzy Logic with Heart Disease

It is a type of disease caused due to damage or blockage of blood vessels in heart affecting less nutrients and oxygen supply to heart organ. Different types of heart diseases are very common like artery problem, cardiac arrest, heart failure, arrhythmia, stroke etc. Fuzzy logic is constantly growing to detect heart patients throughout the world with the help of developing new software's on the basis of different parameters. From the viewpoint of Sengur; identification of heart valve with comparative analysis of LDA and ANFIS approach was done in 2008. The whole implementation was proved in MATLAB software for identification of heart disease [1]. Considering similar parameters by Anbarasi in 2010proved better results as compared to existing software's for heart disease prediction on the basis of Genetic algorithm with implementation based on Weka tool [2]. In 2011, Soni J et al. developed IHDPS software which showed 89% accuracy with decision tree algorithm when compared with Naïve Bayes and KNN. It takes 609 ms to predict heart disease with Naïve Bayes algorithm that was implemented on Tangara tool [3]. Another remarkable work has been done by Ansari A.Q and Gupta N.K in the same yearto predict high/low risk of cardiac patients in his work with 7 input parameters by using Neuro Fuzzy approach implemented in MATLAB [4]. The similar neuro fuzzy approach was implemented by Ephzibah in 2012 for the development of Neuro-Fuzzy Expert system through which we can input the symptoms and the system will display the output with risk factor and recommendations [5]. Later in 2016, Olainiyi et al. performed comparative analysis with KNN, Decision Tree, Naïve Bayes and Back-Propagation algorithm with 13 inputs and 2 output variables and produced 85% recognition rate with back-propagation using MATLAB

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Toolbox [6].After a couple of years, Chauhan represented classification model to predict heart disease by using Random Forest classifier and Decision Tree algorithm with 5 input parameters and showed 79.35% true positive rate with decision tree algorithm in 2108 [7]. Table 1 provides a brief summary of different researchers in heart disease detection.

Table 1: Heart Disease Systems

Authors/Years	Methodology	Tool	Findings
Sengur (2008) [1]	LDA and ANFIS approach	MATLAB Tool	To identify heart valve disease
Anbarasi M (2010) [2]	Genetic Algorithm	Weka Tool	Better results as compared to existing software's
Soni J et al. (2011) [3]	Decision Tree, Naïve Bayes and KNN	Tangara Tool	89% Accurate results with decision tree algorithm on IHDPS software and 609 ms to predict with naïve bayes algorithm
Ansari A.Q and Gupta N.K (2011) [4]	Mamdani Fuzzy Logic with 7 input parameters, Neuro Fuzzy Inference System	MATLAB Simulation	To identify high/low risk of cardiac patients in his study
Ephzibah (2012) [5]	Neuro-Fuzzy approach	MATLAB Tool	Development of Neuro-fuzzy as expert system
Olainiyi et al. (2016) [6]	Back-Propagation, Feed Forward Algorithm with 13 features and 2 output variables	MATLAB Tool	Comparative Analysis with KNN as 45.67%, Decision Tree as 84.35%, Naïve Bayes as 82.31% and BPNN as 85% recognition rate
Chauhan (2018) [7]	Random-Forest Classifier and Decision Tree with 5 input parameters	MATLAB Tool	75.6% Accuracy 79.35% True Positive scenario with decision tree algorithm

III. Fuzzy Logic with Asthma Disease

Asthma is a chronic lung disorder affecting lungs due to narrow airways. It is a type of life threatening disease causing breathing problem to an individual. In the year 2010, Zarandi M.H et al. proposed a system to diagnose asthma by assigning parameters with fuzzy logic. The whole representation was performed in Iran and concluded with 100% specificity and 94% sensitivity [8]. In 2014, the proposal of diagnosing adult asthma was given by Patra S and Thakur G.S by using Neuro-Fuzzy fitting tool with SOM, LVQ and BPNN algorithms. The back-propagation considered to be the best among all at epoch 9 by providing 535 samples [9]. Another classification was done by Badnjevic A et al. in 2015 for asthma and chronic disease with MATLAB tool profiler with different classification algorithms as NN and LM which provides 99.41% correctly classified results with specificity 100% and sensitivity 99.28% [10]. Table 2 provides a brief summary of methodologies and findings in asthma systems.

Table 2: Asthma Disease Systems

Authors/Years	Methodology	Tool	Findings
Zarandi M.H et al. (2010) [8]	Parameters assigned with Fuzzy Values	Mamdani Fuzzy Inference System	Case Study in Iran with Specificity of 100% and Sensitivity of 94%
Patra S and Thakur G.S. (2014) [9]	Self-Organizing Map (SOM), Learning Vector Quantization,Back-Propagation Algorithm	Neuro-Fuzzy Fitting Tool	Back-Propagation best in output and best validation performance at epoch 9 with 535 samples
Badnjevic A et al. (2015) [10]	Neural Network Classifier, Levenberg-Maquardt Algorithm	MATLAB Tool Profiler	99.41% correctly classified with Specificity of 100% and Sensitivity of 99.28%

IV. Fuzzy Logic with Liver Disease

It is a type of hepatic disease that causes liver to prevent functioning and its working. The majority of factors of liver disease are due to alcoholic or genetic nature. The most common types of liver disease are fatty liver, hepatitis B or C, cirrhosis, alcoholic hepatitis, hemochromatosis etc. To predict liver disease, Satarkar S.L and Ali M.S in 2013 worked on diagnosis liver disease on the basis of expert system collaborated with fuzzy logic. According to them, the representation was given with Mamdani approach by using 3 inputs and 1 output variables to identify the risk in the individuals regarding liver disease [11].After a couple

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of years, the work was further refined in 2015 by Hashmi Aby doing classification on the basis of blood test to diagnose liver disease using fuzzy approach. In his classification, he focused on 4 inputs and 3 output parameters and compared results with MATLAB simulation and computed values with outcomeas better software for the society to diagnose in a better way having an error of just 0.7% [12]. Table 3 provides tools and findings with brief summary report.

Table 3: Liver Disease Systems

Authors/Years	Methodology	Tool	Findings
Satarkar S.L and Ali M.S (2013) [11]	Mamdani Fuzzy Logic with 3 input and 1 output parameters	Fuzzy Logic Toolbox	Identify risk status with max-min approach and centroid method proved results with defuzzification
Hashmi A (2015) [12]	Mamdani Fuzzy Inference System with 4 input and 3 output variables	MATLAB FIS	MATALAB simulation results 17.20 as compared to 16.89 with calculated values and error rate 0.7% for anemia diagnosis

V. Fuzzy Logic with Breast Cancer

Breast cancer is a type of disease caused due to lumps found in breast that forms the cells. This disease considered to be the second most deadliest in women as compared to lung cancer. Gallardo J et al. in 2008 interoperate on mammographic images to focus on breast cancer using fuzzy logic and considered to be early diagnosis to tackle the disease. The methodology was used as image segmentation along with 4 input and 1 output parameters carrying 72 rules to conclude an appropriate decision with 80% accuracy [13]. Another automated detection approach was given by Adeli M and Zarabadipour H in 2011 with pattern recognition by using Genetic, Radial basis and GRNN algorithm with 19 distinct features. Genetic algorithm considered to be best with 96.77% classification accuracy for diagnosing breast cancer [14]. Sizilio G et al. in 2012 proposed a model for pre-diagnosis breast cancer with Finite Needle Aspirate (FCA) approach implemented in MATLAB. The accuracy of the system was measured as Sensitivity 98.59% and Specificity as 85.43% [15]. Another disease classification was done by Sagir A.M in 2017 paid attention to deal with breast cancer by implementing ANFIS, Modified LM and Gradient Descent algorithms and proved 84% accurate via fuzzy logic toolbox [16]. Different methodologies and findings in brief represented in Table 4 as follows.

Table 4: Breast Cancer Systems

Authors/Years	Methodology	Tool	Findings
Gallardo J et al. (2008) [13]	Fuzzy Logic with Image Segmentation with 4 input and 1 output along with 72 rules	Fuzzy Logic Toolbox	80% accuracy with radiologist and oncologist
Adeli M and Zarabadipour H (2011) [14]	Genetic Algorithm, Radial Basis Function , GRNN algorithm with 19 features	Fuzzy Logic Toolbox	Genetic Algorithm proved best among all as compared to other algorithms as 96.77% and 97.84% classification accuracy with and without pattern recognition.
Sizilio G et al. (2012) [15]	PDM-FCA (Pre-Diagnosed Module and Fine Needle Aspirate) approach and IVEMI approach	Fuzzy Logic Toolbox	Sensitivity 98.59% Specificity 85.43%
Sagir A.M (2017) [16]	ANFIS Grid Partitioning, Modified LM, GD Algorithm	MATLAB Toolbox	84% Accuracy

VI. Fuzzy Logic with Parkinson Disease (Neurological)

It is a type of disease caused stiffness and tremors as Parkinson's midbrain to be effected mostly. It is totally based on nervous system disorder that affects neurons at specific locations in brain. Geman O in 2013 presented a model on Parkinson disease using fuzzy logic based on 7 input selected parameters. The model was based on expert system and non-linear dynamic approach which proved to be probable diagnosis of neurological disease with 95.46% accuracy [17]. Authors brought into light to tackle Ebola fever with fuzzy logic, by considering weight and score approach with 7 inputs and 1 output variable by Emokhare B.O and Igbape E.M. in 2015. The overall objective was to reduce mortality rate of patients carrying Ebola fever for diagnosis [18]. Another representation was given by Naskar S in 2016 based on neural network technique with genetic algorithm to tackle Parkinson disease. Different types of algorithms have been applied to provide best accuracy for the system.

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Genetic, Naïve Bayes, Perceptron, Back-Propagation and Gradient Descent algorithms has been implemented in MATALAB providing 96.55% accuracy with neural network genetic approach [19]. Hybrid representation of neural network and fuzzy logic as ANFIS approach was given by Kaur P et al. in 2017 with 71 membership functions based on 7 input and 1 output parameters. The produced output specified best outcomes in terms of sensitivity and specificity at epoch 12 with minimal error rate [20].Continue in the same direction, Karunanithi D and Rodrigues P in 2018 proposed a model to diagnose Parkinson's disease with FIS approach using 23 distinct attributes but selected only 4 parameters based on optimum results using fuzzy height [21]. Table 5 provides a brief summary of different researchers in Parkinson's disease detection.

Table 5: Parkinson's Disease Systems

Authors/Years	Methodology	Tool	Findings
Geman O (2013) [17]	Mamdani Fuzzy Logic with 7 input parameters	MATLAB Toolbox	Results compared with clinical and probable diagnosis with accuracy 95.46%
Emokhare B.O and Igbape E.M. (2015) [18]	Mamdani Fuzzy Logic with 7 input and 1 output variables with weight and scoring system	MATLAB Toolbox	To reduce mortality rate of Ebola patients for better diagnosis and drugs
Naskar S (2016) [19]	Genetic Algorithm, Naïve Bayes Classifier, Multilayer Perceptron, Back Propagation, Gradient Descent	MATLAB	Neural network with Genetic algorithm best in findings with accuracy 96.55% and 100 precision value and F-Measurement as 92.31%
Kaur P et al. (2017) [20]	Mamdani Fuzzy Logic with 7 inputs and 1 output parameter with 71 membership functions	MATLAB Toolbox	Better results with ANFIS in terms of accuracy, sensitivity and specificity and best results at epoch 12 with error just having 0.00029
Karunanithi D and Rodrigues P (2018) [21]	FIS method with 23 attributes; selected 4 attributes chosen from analysis	Fuzzy Logic Toolbox	Identify Parkinson's Disease affected or healthy set on the basis of fuzzy height

VII. Fuzzy Logic with Cholera Disease

Cholera is a bacterial disease mostly occurred after consumption of drinking contaminated water. It is a type of disease that can lead to dehydration, diarrhea and up to death if not tackle at right time. In view of Uduak A and Mfon a proposed model on cholera was based of Mamdani fuzzy approach using 3 inputs and 1 output parameter in 2013. The representation was given with centroid method as defuzzification and proved better results with MATLAB simulation [22]. In another study Okpor M.D in 2014 classified his analysis on cholera using fuzzy classification with 5 inputs and 1 output parameter. The outcomes were satisfactory for tackling cholera as compared to existing applications [23]. Table 6 provides a summary on cholera with simulation results as follows.

Table 6: Cholera Disease Systems

Authors/Years	Methodology	Tool	Findings
Uduak A and Mfon (2013) [22]	Mamdani Fuzzy Logic with 3 input and 1 output parameter	MATLAB with max-min function and centroid	MATLAB results 5.91% better as compared to calculated results as 5.60%
Okpor M.D (2014) [23]	Fuzzy Classifier Algorithm with 5 input parameters and 1 output parameter	Fuzzy Logic Toolbox	Simulation results was satisfactory for diagnosing cholera

VIII. Fuzzy Logic with Dental Disease

It is a type of disease that infecting surrounding teeth in the form of tooth decay, periodontal disease, gingivitis, dental plaque etc. Allahverdi N and Akcan T diagnosed on periodontal dental problem in 2011. The objective of using fuzzy logic based on 164 fuzzy rules as fuzzy extraction with 5 input variables to minimize the time taken for identification of dental disease [24].In the next year Parewe A.M et al. represented dental problem with hybrid fuzzy on evolution paradigm with 8 input parameters. The outcomes were 82% accurate as compared to fuzzy with 70% having RMSE of less than 1 [25]. Later on, Allahverdi in 2014 proposed a model of combining three different diseases covered in one fuzzy expert approach. He worked on dental, heart and anemia problem with 11 input parameters for diagnosing multiple diseases [26]. Recently Ambara B et al. in 2017 focused on dental disease by asking 27 different types of questions to individuals on the basis of image selection and proved

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94.627% accuracy of the system [27]. Table 7 showed different dental software's to diagnose enamel effects with methodologies.

Table 7: Dental Disease Systems

Authors/Years	Methodology	Tool	Findings
Allahverdi N and Akcan T (2011) [24]	Mamdani Fuzzy Logic with 5 input variables and 164 rules	Fuzzy Logic Toolbox	Dental Disease identification time minimized
Parewe A.M et al. (2012) [25]	Mamdani Fuzzy Logic with 8 input parameters	MATLAB	82% accurate results as compared to FIS as 70% with RMSE of 0.82
Allahverdi (2014) [26]	Mamdani Fuzzy Logic with 11 input variables but chosen 4 variables as input and 1 output variable	Fuzzy Logic Toolbox	Common expert system for dental, heart and anemia risk etc.
Ambara B et al. (2017) [27]	Fuzzy Expert System approach based on 27 questions with image selection	Fuzzy Logic Toolbox	94.627% accuracy with dental and oral disease detection

IX. Fuzzy Logic with Diabetes Disease

It is a type of disease resulting high blood glucose level in body. It considered as metabolic disease in which cells of the body to insulin flow disturbed causes type 1, type 2, gestational diabetes etc. Insulin provides glucose to cells for providing energy to the body. Too much sugar level in the body leads various problems like damaging kidney and nerves. Polat K and Gunes S in 2008 paid attention to proposed a model to diagnose diabetes disease based on PCA and ANFIS methodology with 8 input features implemented in MATLAB. The expert system proved 89.47% accurate with 85% sensitivity, 92% specificity and 0.262 root mean square error [28]. Another proposal was given on diabetic neuropathy for diagnosing diabetic disease using ASP software by Katigari et al. in 2017. The results were computed based on questionnaire approach with 8 input and 1 output parameter sensitivity 89%, specificity 98% and system accuracy considered to be 93% [29]. Table 8 provides conclusive report in diabetes disease detection.

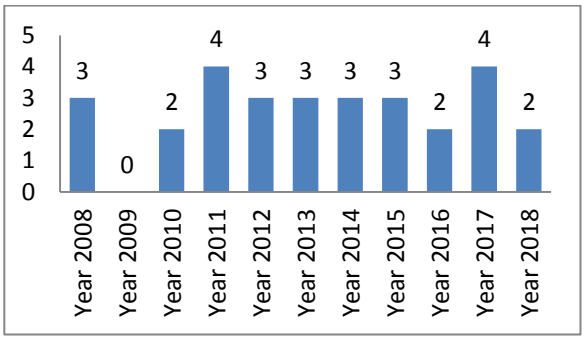
Table 8: Diabetes Disease Systems

Authors/Years	Methodology	Tool	Findings
Polat K and Gunes S (2008) [28]	PCA and ANFIS approach with 8 input feature and reduced to 4 features	MATLAB	89.47% Accuracy Sensitivity 85% Specificity 92% RMSE 0.262
Katigari et al. (2017) [29]	Fuzzy Logic approach with 8 input and 1 output parameter	ASP.net with MATLAB	Duration of diabetic score on the basis of questionnaire with sensitivity 89%, specificity 98% and accuracy of system as 93%

X. Discussions

The literature review on medical field using fuzzy logic is too broader to think. Different types of methodologies have been applied to detect or predict an appropriate disease. It is very clear from the recent articles in this paper that to deal with different diseases; we need different algorithms and tools to get the optimum results. The year wise selection of articles that was student using fuzzy logic depicted in Figure 1.

Figure1: Year wise article collection



Another way to represent different categories implemented in this review paper discussed in the form of pie chart as represented in Figure 2. The authors tried to collect

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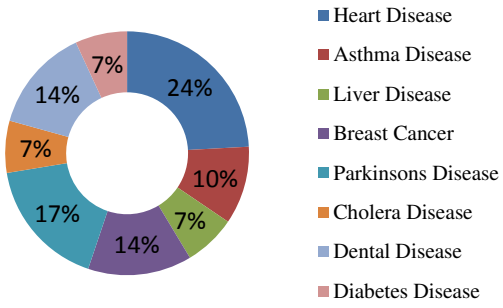
different articles in concerned domain but due to broader domain, it's very difficult to collect all.

Figure2: Category wise article collection



Some of the researcher's having similar methodologies but the selection of disease was different and getting better results to traditional algorithms. But from the other viewpoint, it was quite obvious that from the same medical problem, different methodologies played a crucial role to deal with better outcomes. Different types of medical problems discussed in this paper considered to be diversified in latest era.

XI. Concluding Remarks and Future Outline

This literature review paper based on medical applications with fuzzy logic being applied different methodologies to generate intelligent fuzzy diagnostic systems in the last decade. In this review, almost all fuzzy systems used Mamdani and Sugeno type inference to formulate fuzzy rules. Type-2 fuzzy logic has been applied by some authors to diminish the rules for linear as well as complex problems. Few authors tried to get the dataset from observations, UCI Repository and existing records from various hospitals. There are different types of algorithms like Genetic, Back-Propagation, Decision Tree, Self-Organising Map, LM, Modified LM, Perceptron, and Gradient Descent to evaluate the detection of multiple diseases with fuzzy logic. But Back-Propagation and Genetic Algorithm considered being best among all for providing better results with accuracy in each and every recognition of a disease. There are various tools used for diagnosed but MATLAB tool considered as best provider for optimum results as compared to Tangara and WEKA tool. The diagnosed would be much better if Back-Propagation or Genetic Algorithm will be implemented with MATLAB by using more than 7 parameters because of maximum number of rules for optimum accuracy for disease detection. The conclusion based on experimental approach to develop these types of systems and the emergent need where specific expertise not available and the user can predict the disease from existing software's. Due to overlap of symptoms among different diseases it's very difficult to understand the exact disease without getting laboratory outcome which usually need time and cost. To focus this viewpoint, the role of developing fuzzy medical diagnosis systems was desired need for the benefit of the society. There are lots of researchers working in every corner of the world to deal with medical problems with fuzzy logic for the development of intelligent machines to predict different diseases. But still there are various fields in medicine that require systems for disease prediction on the basis of symptomatic or asymptomatic approach like in gluten sensitivity, viral infections, tuberculosis, cervical cancer, celiac disease, neurological problems, alopecia etc. Every disease has been represented in tabular format with suitable methodology and their findings. Another future paradigm is to identify various drugs to be recommended in addition to disease detection or prediction and further diseases can be examined in new direction. It is assumed that fuzzy logic will alter existing systems into hybrid intelligent systems in future.

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