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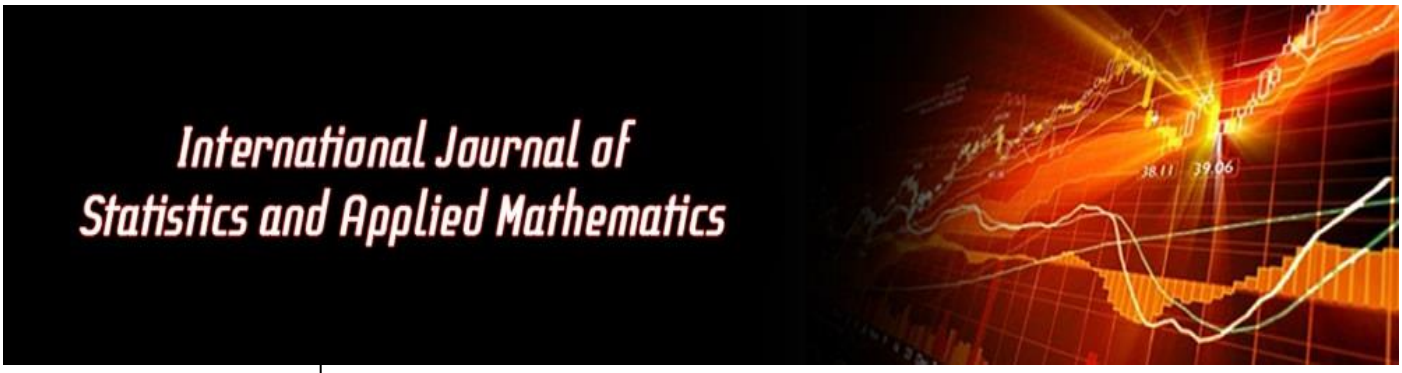

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Impact of fuzzy logic and its applications in medicine: A review

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Abstract
In recent years Artificial Intelligence Techniques (AITs) have now highly increased in solving complex and critical problems of more uncertainties that occur in the process of the system. AITs, offer the possibility of designing intelligent mathematical models involving Fuzzy Logic (FL), Artificial Neural Network (ANN), Genetic Algorithm (GA), and as such. In this, Fuzzy set theory is a highly suitable and applicable basis for developing knowledge-based systems in medical fields for diagnosing diseases and predicting risk factors. Fuzzy Logic decides uncertainty, incomplete, vagueness, and flexible structure with the use of intuitive methods. Due to the advent of digitalization in the field of the medical diagnostic process, Fuzzy Logic is highly suitable to make the decisions for diagnosis and treatment of different diseases. This article mainly focuses on a review of the applications of Fuzzy Logic in the Application areas of Medicines like Heart Disease, Asthma, Cold and Flu, Malaria, Parkinson's Disease, Diabetic Disease, Tuberculosis, Breast Cancer, and COVID-19 as well.

Keywords: Fuzzy logic (FL), artificial neural network (ANN), genetic algorithm (GA), artificial intelligence techniques (AIT)

Introduction
World Health Organization (WHO), defined "health as a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity". The number of patients suffering from various diseases is increasing due to insufficient medical specialists in the developed and developing countries in the Globe/Universe. Nowadays, most medical diagnosis is carried out with the aid of computer-related technologies and its usage is increasing accordingly. Based on the principles of AI, the systems are designed not only to diagnose but also to prescribe treatments based on such results. One of the most efficient computational methods is Fuzzy Logic. Fuzzy Logic has largely been used in different areas of medical applications. The diagnosed disease involves several levels of vagueness and fuzziness, and it is intrinsic to medicine such as a common symptom inpatient may lead to different diseases, hence fuzziness brings more clarity in the world of medicine. According to Aristotelian logic, for a given proposition or statement only have two logical values such as True/False, Black/White, Yes/No, 1/0 is considered, but in real life situations things are not either, but most of the time the results may be in 0.05, 0.99, 0.90, etc. that is, the range may be in the degree of measure. In health, there is a range of conditions. A person without any disease can have a headache or a stomachache; does it mean they are no longer healthy? Or else, does it measure the health only in terms of serious conditions? Consider an example here that person X has a headache, so X is not healthy; person Y does not have a headache, so Y is healthy? Everybody is healthy to some degree and sick to some degree. If someone only has a headache, we may say they are 99% healthy and 1% sick. Here comes the tolerance of the headache which differs from person to person as bearable headache, normal headache, severe headache, extreme headache these are the linguistic variable that occurs in the Natural Language Process.
Recently uncertainty is considered essential for scientific study and Fuzzy Logic is a way to model and deal with it using natural language also it comes under a qualitative approach.

Fuzzy Logic produces more realistic answers by replacing the inflexible options like "Yes/ No" with a current adjustment in the form of degrees as minor, moderate, severe, very severe which are termed as linguistic variables applicable in the process of decision. Since uncertainty is inherent in fields such as medicine, Fuzzy Logic takes into account such uncertainty, Fuzzy Set Theory can be suitable to formalize and deal with the imprecision intrinsic to many biomedical and health-related problems. This article brings out the basic terminologies of Fuzzy Set Theory, Fuzzy Logic, and Membership Functions which highlights its developed applications in the medical field to access nature and analyzes the diseases such as Cancer, Diabetic, Asthma, and Cardiac.

Fuzzy Logic

In the year 1930, Fuzzy Logic was introduced by Jan Lukasiewicz; a polish philosopher by extended the truth values between 0 to 1. Later, Max Black (1937) [37] defines the first Fuzzy Set. In 1965, Lotfi Zadeh [38] rediscovered fuzziness, identified and explored it through terminologies, membership function, and application. According to the flexible structure sure of intuitive methods, Fuzzy Logic is preferred by researchers in the entire field nowadays. This logic has been widely used to interpret uncertain knowledge in the system or process including vague human assessment in problems. Fuzzy Logic is a set of mathematical principles for knowledge representation based on degrees of membership rather than a crisp membership of classical binary logic. Unlike two-valued Boolean Logic, Fuzzy Logic is multi-valued and it deals with degrees of membership and degrees of truth.

Fuzzy Logic introduces partial truth values occurring in between Yes/No. For Example, to judge the pain and no pain of the patient after surgery, the answer may be less pain, tolerable pain, more pain, slightly paining which is not measured but able to explain orally, and also varies from one patient to another patient based on the metabolic or immune system of an individual body. Here occurs the vagueness and use of fuzzy logic to design a model that coincides with the natural language lead to a qualitative computational approach. Fuzzy logic is an extension of a Boolean logic based on the mathematical concept of the fuzzy set which is the broad view of the classical set theory that describes fuzziness. Fuzzy Logic attempts to model our sense of words, our decision making, and our common sense lags foundation and development of more human intelligent systems.

The Fuzzy Logic approach is the need of the hour where more researchers (inter and multidisciplinary) are working on the development of an intelligent machine for the prediction of diseases and their characteristics existing in every corner of the world. In recent days, the application of Fuzzy Logic in Medicine has received much appreciation. Fuzzy Logic produces more realistic answers by replacing the inflexible “Yes/No" with a current adjustment in the form of a “More or Less” and by introducing linguistic shades into the process of decision. Based on the Fuzzy Logic model, several Medical Diagnostic systems have been developed and employed in the diagnosis and treatments of Diabetics, Cancer, HIV’s many more. Some of the recent research works of Fuzzy Logic in the area of Medicine is

- Fuzzy Logic Controller (FLC) – used in medical devices as the control unit.
- A Fuzzy Cognitive Map was used along with an algorithm designed to evaluate the human immune system.
- Fuzzy Logic is used in data analysis to evaluate the facial expression and human behavior.
- Fuzzy Logic in Medicine

In general, the various concepts in medical practices nowadays are tied out with complexity leading to inappropriate analysis traditional approaches is impossible to give exact definitions and symptoms of medical concepts and does interrelationship between the variable exist, without having a clear definition and idea about the boundaries tends to impreciseness, vagueness and more uncertainties. To deal in these situations one of the AIT’s Fuzzy Logic is to be applied and with other combination of Neural Network, Machine Learning Algorithm, Genetic Algorithm, and Classification models as well. Following are some of the disease groups which show the applications of Fuzzy Logic.

- For C-section, appropriate anesthesia dosage to be determined.
- Able to improve decision-making in radiation therapy for cancer patients.
- Tumors of central nervous systems can be diagnosed invariably of their size and location.
- Instead of common dosage of drugs among Diabetics Patients can be modified as quantitatively.
- To access the diagnosis of COVID-19 patients with severe symptoms.

Medline is used to identify the medical publications with Fuzzy Logic. With the help of the primary component of PubMed, the total number of articles that appeared per year is shown in Table: 1. The data from 2000 to 2021 has 6323 publications in Fuzzy Logic and 479 publications in Fuzzy Logic in Medicine.

Table 1: Year-wise Publications of Fuzzy Logic & Fuzzy Logic in Medicine

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Fuzzy Logic	96	151	119	141	182	195	278	257	292	313	339
Fuzzy Logic in Medicine	12	24	8	11	25	11	13	18	17	17	24
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fuzzy Logic	334	346	336	360	348	351	333	348	395	388	421
Fuzzy Logic in Medicine	15	17	13	24	36	37	35	28	24	36	34

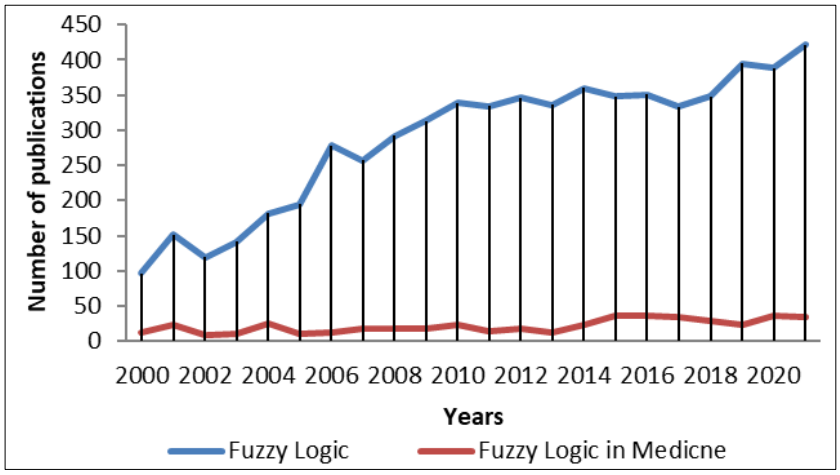

Fig 1: Year-wise Publications indexed in MEDLINE using Fuzzy Logic & Fuzzy Logic in Medicine

Even though the Fuzzy Logic approach has taken its footstep in the last decade of the 20th Century and shown an exponential growth in the medical field making use of technology digital initiative's advances by showing its journey in the 21st Century.

Fuzzy Logic System

A system that comprises various components with fuzziness is known to be a Fuzzy Logic System (FLS) and consists of four components such as Fuzzifier, Inference Engine, Knowledge Base, and Defuzzifier.

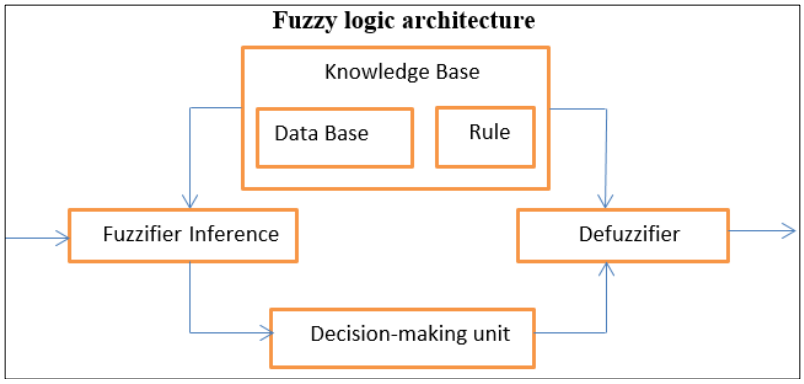

Fig 2: Fuzzy logic architecture

Knowledge Base

The most valuable component of the Fuzzy Logic System is the Knowledge Base composed of a database and rule base. A knowledge base can be constructed either by experts or self-learning algorithms where experts of the proposed system are designed by the Fuzzy-if-then rules, whereas the self-learning algorithm constructs the rule base (ie) train the system and construct the rule base and is expected to solve by the system. Hence it is known to be Neuro-fuzzy systems.

Fuzzifier

The process of a fuzzifier is to transform a crisp object into a fuzzy set for grading the membership function of linguistic variables in fuzzy sets.

Inference

The resultant fuzzy sets from the Fuzzifier are processed in the Inference Engine according to the rules of Rule Base that acts as the processing unit of the Fuzzy Logic System.

Defuzzifier

Using Knowledge Base, the output is received from the Inference Engine which is also a fuzzy set and needs to be transformed into an understandable way and case to real-world applications. A fuzzy output set should be a value, fabricated by considering all the points in the fuzzy output interval.

Fuzzy Set

A fuzzy set is a set with a smooth (UNSHARP) boundary and generalizes the notion of membership from a black and white binary categorization in classical set theory into one that allows partial membership where the membership function is the generalization of the characteristic function of ordinary sets. The notion of membership in fuzzy sets thus develops a matter of degree, which is a number between 0 and 1. A membership degree of 0 represents complete non membership, while a membership degree of 1 represents a complete membership usually; the membership or characteristic function is denoted by the Greek lower case letter μ. Mathematically speaking, a fuzzy set is characterized by a mapping from its universe of discourse into the interval [0, 1]. This mapping is the membership function of the set. A fuzzy set is created to define linguistic variables. In medical science, it is rarely possible to give exact definitions or descriptions of medical concepts and relationships between concepts. In the fuzzy theory, fuzzy set A of universe X is defined by function $\mu_A(x)$ called the membership function of set A.

$$\mu_A(x): X \rightarrow [0,1], \quad (1)$$

where

$\mu_A(x) = 1$ if x is totally in A; $\mu_A(x) = 0$ if x is not in

A; $0<\mu_A(x)<1$ if x is partly in A.

For any element x of universe X, membership function $\mu_A(x)$ equals the degree to which x is an element of set A. this degree, a value between 0 and 1, represents the degree of membership, also called membership value, of element x in set A.

Linguistic Variable

A linguistic variable is like a composition of symbolic variables (a variable whose value is a symbol) and a numeric variable (a variable whose value is a number). An example, the linguistic variable "Diabetes" can be defined as X = Diabetes level, with T(X) = {very low, low, normal, high, very high} and A = [140, 199]. The linguistic value 'normal' is represented by compatibility (membership function). In medical diagnosis, which is strongly influenced by human perception & judgment, in many cases, it is more appropriate to describe the underlying knowledge using linguistic variables than by quantitative descriptions. A linguistic variable is characterized by the quintuple *(X, T(X), A, G, and M)* where X→ name of the variable, T(X) → term set of X that is the set of its linguistic values., A → a universe of discourse, G → a syntactic rule that generates the terms T (X), M → semantic rule which associates with each linguistic value x its meaning, M (x) Where M (x) denotes a fuzzy set of A.

Fuzzy Membership Function

A Membership Function for a Fuzzy Set A on the universe of discourse X is defined as μ_A: X→ [0, 1] where each element of X is mapped to a value between 0 and 1. This value is called membership value or degree of membership, quantifies the grade of Membership of the element in X to the Fuzzy Set A. Here, X is the universal set and A is the Fuzzy Set derived from X. Fuzzy Membership function is the graphical way of visualizing degree of membership of any value in given fuzzy set. In the graph, the X-axis represents the universe of discourse, and Y-axis represents the degree of membership in the range [0.1].

Toolbox includes 11 built-in Membership function types. Some functions are in turn, built from several basic functions *viz*., piecewise linear functions, the Gaussian distribution function, the sigmoid curve, quadratic and cubic polynomial curve. By convention, all membership functions have the letters 'mf' at the end of their names. The membership functions are formed using straight lines.

Triangular Membership Function

The simplest is the Triangular Membership Function, and it has the function name 'TRIMF'. It is nothing more than a collection of three points forming a triangle. It is defined by its lower limit a, its upper limit c, and the modal value b, so that a<b<c. where the value b-m margin when it is equal to the value m-a. Mathematically express as:

$$\text{Triangular (x: a, b, c)} = \begin{cases} 0 & if \quad x \le a \\ \dfrac{(x-a)}{(b-a)} & if \quad x\varepsilon(a,b) \\ \dfrac{(c-x)}{(c-b)} & if \quad x\varepsilon(b,c) \\ 1 & if \quad x \ge c \end{cases}$$

$$= \max\left[\min\left[\frac{x-a}{b-a}, \frac{c-x}{c-b}\right], 0\right] \quad (2)$$

Trapezoidal Membership Function

The Trapezoidal Membership Function, 'TRAPMF', has a flat top and is just a truncated triangle curve. These straight-line membership functions have the advantage of simplicity. It is specified by 4 parameters (a, b, c, d).

$$\text{Trapezoid(x, a, b, c, d)} = \begin{cases} 0 & x < a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{d-x}{d-c} & c \le x \le d \end{cases} =$$

$$\max\left[\min\left[\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right] 0\right] \quad (3)$$

Gaussian Membership Function

Two membership functions are built on the Gaussian. A simple Gaussian curve and a two-sided composite of two different Gaussian curves. The two functions are 'GAUSSMF' and 'GAUSS2MF'.

$$\text{Gaussian (x: c, } \sigma) = \exp\left[-\frac{1}{2}\left|\frac{x-c}{\sigma}\right|^2\right] \quad (4)$$

where m & σ denote the center and spread of the curve. This is a more natural way of representing the data distribution, but due to mathematical complexity, it is not much used for Fuzzification.

Bell-shaped membership function

Generalized Bell Membership Function is specified by three parameters and has the function name 'GBELLMF'. Gaussian and Bell Membership Functions are popular methods for specifying Fuzzy Sets because of their smoothness and concise notation but they are unable to specify asymmetric membership functions, which are important in certain applications.

$$\text{Bell(x: a, b, c)} = \frac{1}{1+\left|\dfrac{x-c}{a}\right|^{2b}} \quad (5)$$

Where

Parameter b is usually positive.

Sigmoidal Membership Function

Sigmoidal functions are widely used in classification tasks in machine learning. Specifically, it is used in Logistic Regression and Neural Network, where it suppresses the input and maps it between 0 and 1. The Sigmoidal Membership Function is either open left or right. Asymmetric and closed (i.e. not open to the left or right) membership functions can be synthesized using two sigmoidal functions, so in addition to

the basic 'SIGMF', we also have the difference between two sigmoidal functions, 'DSIGMF', and the product of two sigmoidal functions 'PSIGMF'.

$$\text{Sig m(x: a, c)} = \frac{1}{1+e^{-a(x-c)}} \quad (6)$$

It is controlled by the parameters a and c. where a controls the slope at the crossover point x=c

Polynomial Based Curves

Three related membership functions are the Z, S, and Pi curves, all named because of their shape (The functions ZMF, SMF, and PIMF). S Membership Functions is a smooth membership function with two parameters: 'a' and 'b'. The value is 0 for points below a, 1 for points above b, and 0.5 for the midpoint between a and b.

$$\text{S(x: a, b)} = \begin{cases} 0 & x < a \\ 2\left(\frac{x-a}{b-a}\right)^2 & a \le x \le \frac{a+b}{2} \\ 1-2\left(\frac{x-b}{b-a}\right)^2 & \frac{a+b}{2} \le x < b \\ 1 & x \ge b \end{cases} \quad (7)$$

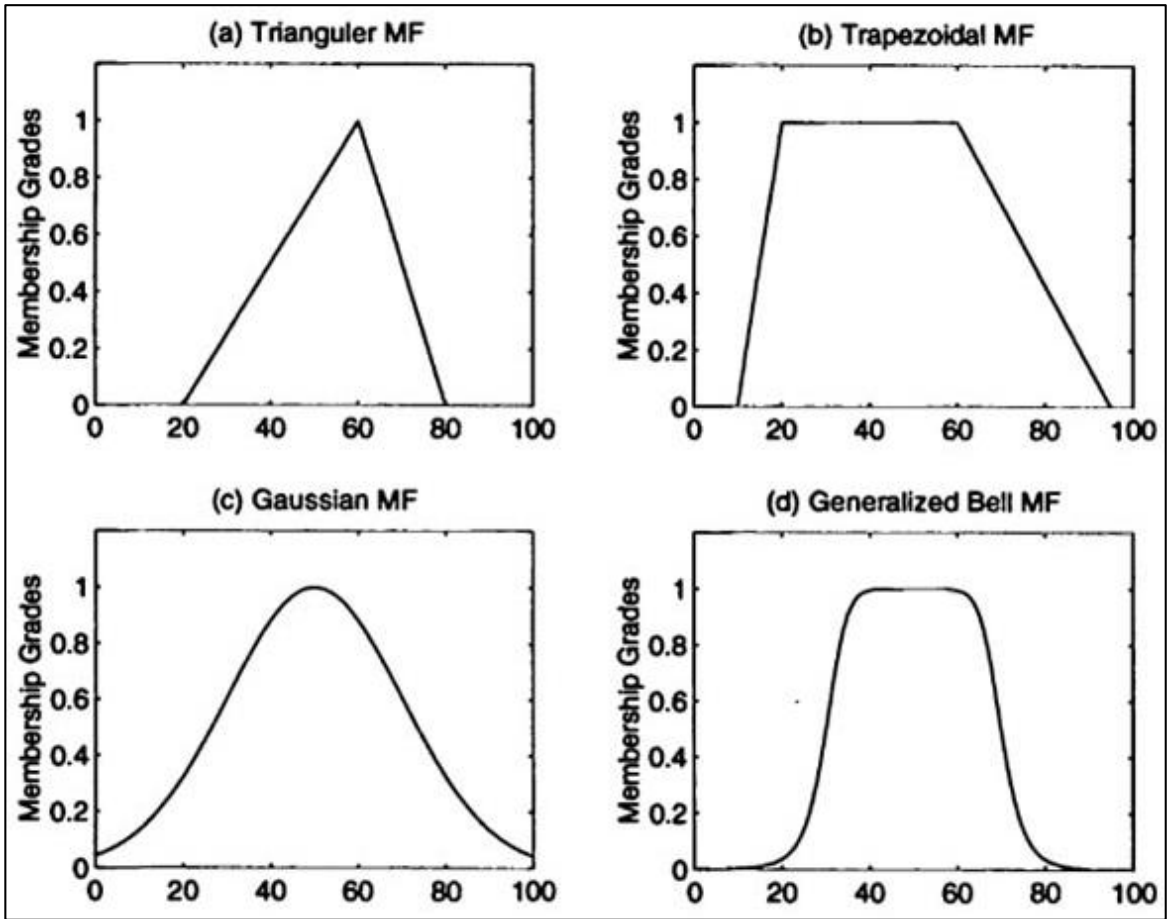

Fig 3: Shapes of Membership Functions

Fuzzy Expert System

Fuzzy Logic is a multi-valued logic similar to human thinking and is highly suitable and applicable for the development of Knowledge Base systems especially in the medical findings, diagnosis and treatment selections. An Expert System is a computer-based system that emulates the reasoning process of human experts within the specific domain knowledge. In the 1980's Expert Systems were known as practical devices of the real world problem and become popular with the 5th generation computer system project in Japan and amplification in the Fuzzy Expert System continued in the 1990s. In the medical field, the decision-making may vary among the medical practitioners in providing treatments with uncertainty and vagueness in the knowledge and information. Based on the increase in the complexity of the system it is a great task to take a particular path of diagnosis without any mistake. Accordingly, an Expert System with a knowledge base with Fuzzy Logic is developed known to be Fuzzy Expert System. A Fuzzy Expert System is a type of rule-based form of Artificial Intelligence using a collection of Membership Functions and rules to reason about data. Fuzzy Expert System started its applications in various fields such as Agriculture, Engineering, Environment, Education, Medicine, etc. Research into the use of Artificial Intelligence in medicine started in the 1960s and invented various experimental systems. MYCIN, ONCOCIN, Stanford University (1976 & 1981), designed to assess physicians in treating cancer patients receiving chemotherapy. Fuzzy Expert System helps to diagnose various diseases like Tuberculosis, Cancer, Breast Cancer HIV, and Asthma and is widely used in hospitals for the better decision-making process. It provides tools for modeling ambiguity in human reasoning. Fuzzy Expert System represents knowledge in IF-THEN rules and implements fuzzy reasoning and has a wide scope of development of real life.

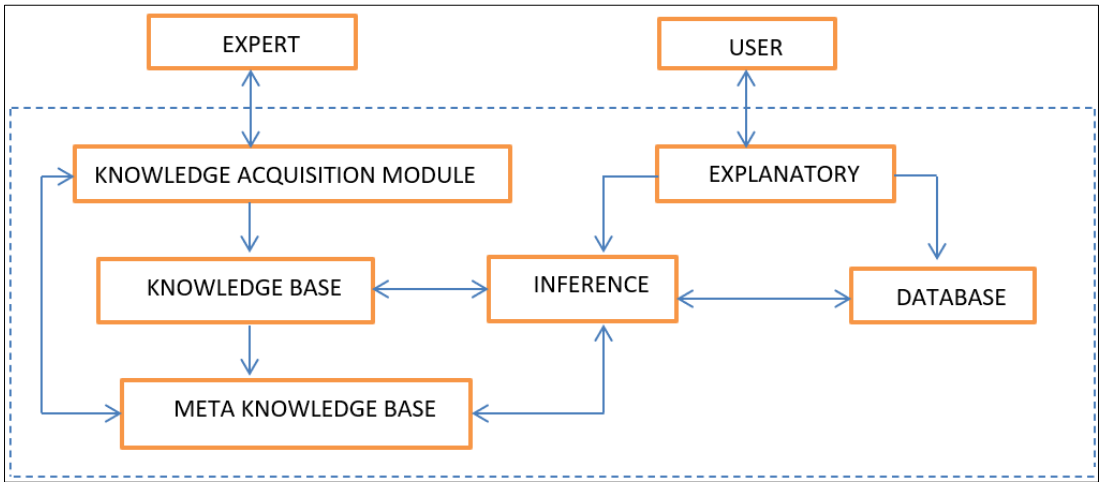

Fig 4: Fuzzy Expert System

Fuzzy Logic in Medicine

Fuzzy Logic is one of the major Artificial Intelligence techniques that play a prominent role in the field of medicine due to its effectiveness in treating uncertain and imprecise data of any kind. Fuzzy Logic System is excelling in handling ambiguous and imprecise information prevalent in medical diagnosis. Expert system based on Fuzzy Logic has proved to be of great importance, providing a clear and impressive evaluation report of medical data. Fuzzy Expert System provides a quick and easy means of medical diagnosis even in the absence of a medical practitioner or an expert. Here are some of the major applications of the Fuzzy Logic System, Fuzzy Expert System in the medical field.

Reflection of Fuzzy in Medical Diagnosis

Asthma Disease

The prevalence of asthma has been increasing in recent decades, as well as the costs for asthma care. One of the problems related to asthma is that several patients with asthma are either improperly diagnosed or misdiagnosed for having other respiratory diseases such as Chronic Obstructive Pulmonary Disease (COPD), Common Cold, and Acute Bronchitis. Commonly used pulmonary function tests are used to detect asthma and COPD are Spirometry and Impulse Oscillometry System (IOS). Barua *et al*. 2004 [39] presented a system based on trained Neural Networks that uses the results of measurements performed by IOS for the classification of asthma. Winkler *et al*. 2009 [40] diagnosed asthma and COPD patients using different measurement methods on IOS. Made a classification of respiratory abnormalities using an adaptive Neuro-Fuzzy Inference System based only on Spiro Metric measurements Zarandi M.H *et al*. in the year 2010 [20] proposed a framework to determine asthma by allotting boundaries to have Fuzzy Logic. Patra S and Thakur G.S in 2014 by utilizing Neuro-Fuzzy fitting instrument with SOM, LVQ, and BPNN calculations. Badnjevic *et al*. in 2015 [2] for asthma and constant sickness with MATLAB instrument profiler with various grouping calculations.

Diabetes Disease

Diabetes is a disease in which the body cannot control the amount of sugar (glucose) in the blood. Glucose in the blood gives us the energy when we walk briskly, run for a bus, ride a bike, and for our day-to-day tasks. Glucose in the blood is produced by the liver from the foods we eat. Insulin is shaped by the pancreas, a small organ near the stomach that also conceals important enzymes that help in the digestion of food. Insulin allows glucose to move the blood into the liver, muscle, and fat cells. Diabetes patients will either don't produce enough insulin (type 1 diabetes) or cannot use insulin properly (type 2 diabetes). In diabetes, glucose in the blood cannot move into cells and stays in the blood. This not only harms the cells that need the glucose for fuel but also harms certain organs and tissues showing high glucose levels.

Absorbed and proposed a model to analyze diabetes sickness dependent on PCA and ANFIS strategy with 8 information highlights actualized in MATLAB. Another proposition was given on diabetic neuropathy for diagnosing diabetic illness utilizing ASP programming.

Heart Disease

Heart diseases are branded into distinct types like Congenital Heart Disease, Coronary Heart Disease (CHD), Arrhythmia, Dilated Cardiomyopathy, Heart Failure, Myocardial Infarction (MI), Hypertrophic Cardiomyopathy, and Mitral Regurgitation. Heart Disease involves many risks like gender, age, obesity, high blood pressure, high cholesterol, diabetes, family history, drinking alcohol, and smoking. Apart from these, in this technical and modern world, there are many other threats like working in underemployment industrialization, work overload, physical inactivity, depression, stress, diet/routine changes, and distressed sleepless night that have increased. Several kinds of heart complaints are normal like Stroke, Cardiovascular breakdown, Arrhythmia, Heart Failure, Vein issues, and so forth Fuzzy Logic is constantly developing to identify heart patients all through the world with the assistance of growing new programming based on various boundaries. In addition to this, change in lifestyle, egoism, greed, and the narcissistic approach of people have triggered the occurrence of chronic diseases in patients. Chest pain, faintness, or coolness in arms and legs are some of the symptoms of heart problems. However, controlling blood pressure, eating a well-balanced nutritious diet, regulating exercise regime, limited usage of alcohol, tobacco, smoking, and gazettes can treat illness and failure of the heart. In India, one-fifth of the total deaths occurring from stroke and ischemic heart disease, especially in younger adults according to the World Health Organization. It is a kind of sickness caused because of harm or blockage of veins in the heart influencing fewer supplements and oxygen supply to the heart organ. Sengur has recognizable proof of heart valve with a similar investigation of LDA and ANFIS approach was done in 2008. The entire performance was verified in MATLAB programming for

familiar proof of coronary illness. Anbarasi in 2010 [41] proved better outcomes when contrasted with existing programs for coronary illness prospect based on Genetic calculation with effecting dependent on Weka apparatus. In 2011, Soni J *et al.* [42] created IHDPS programming which indicated 89% exactness with choice tree calculation when contrasted and Naïve Bayes and KNN.

Cancer Disease

In today's world Cancer is a life-threatening disease. More than hundreds of people die every year because of cancer due to the constraint of medical sources and unable to use the existing sources successfully. Patient's death can be reduced by using numerical (quantitative) techniques in the system of Medical. Early precaution is very important for people who have not fallen ill yet with a disease like cancer that has a high mortality rate and expensive treatment. Cancer is developed by the abnormal cell increase and cell growth as a result of DNA damage and cells being out of the program. The earlier cancer is diagnosed, so the treatment would be that successful. Most cancers can be treated and this may include chemotherapy and radiotherapy and/or surgery. The reason for the selection of the Fuzzy Logic model is that the system uses the Fuzzy Logic model enables to provide effective results depending on uncertain verbal knowledge just like the logic of human beings. The growth of abnormal cells that start in one or both lungs is called Lung Cancer a genetic disease that is in 2003, Ravi Jain [43] has made a comparative study and performed four Fuzzy rule generation methods which generate Fuzzy If-Then rules on Breast Cancer. Victor Balanica in 2011 [34] has proposed a Fuzzy Logic technique for the prediction of the risk of Breast Cancer among the patient's age and automatically extracted tumor features. Ahmed Abou Elfetouh Saleh in 2011 [1] developed a Fuzzy decision support system for the identification of cancer risk status in situations of data diversity and imprecision. A Neuro-fuzzy and Fuzzy rule-based Inference system for detection and Diagnosis of Lung Cancer were proposed using a Fuzzy toolbox. The input variables are accepted and outputs are delivered using the Fuzzy Logic toolbox.

COVID-19

In recent years, from Nov-2019 onwards, the globe is facing epidemic or pandemic challenges in the name of COVID-19. Originated from Wuhan and spread in the Chinese during January 2020 till nowadays taking its face as different variances. Apart from the symptoms of Corona Virus such as Fever, Cough, Shortness of Breath. Several factors including the environment affect the spread of COVID-19 during phases-I & II, human-to-human transmission occurs through various routes such as direct transmission, contact transmission, air storm transmission, and other sources. COVID-19 has presented itself as a global pandemic in a short period resulting in a rapid curve shift of infected patients, increasing mortality rates, huge global economic burden, and mobilization of medical resources across the globe. Different countries suffered a lot due to impreciseness and vagueness present in the symptoms of the virus based on the nature of the variant as per the geographical and environmental location, in this Fuzzy Expert System, is the better model for analysis and predicting the result.

Maad Shatnawi *et al.* (2021) [21] proposed a smart Fuzzy Inference System for the rare detection of COVID-19 based on the symptoms including fever, flu, dry cough, cold, breathing difficulties, throat sore and headache. Based on the Gaussian Membership Function designed a model with 13 linguistic Fuzzy Rules can assist the physician in identifying the diseases. COVID-19 and further can be integrated with other identification techniques such as PCR tests and CT scans. Muhamed Kalamuddin Ahamad and Ajay Kumar Bharti (2021) [24] proposed a Fuzzy Rule System which is implemented with MATLAB fuzzy tools for simulation to assess the health condition of the patients and prevention from COVID-19 disease, also validating the identification symptoms by applying the fuzzy rules and an effort to face the situations.

Conclusion

The Fuzzy Logic theory is widely used and applied in the medical field for diagnosis, prediction of diseases, risk analysis, especially for complicated cases such as Heart/Cardiac Diseases, Cancer, Diabetes, Drug Addiction, etc. It is based on natural language and also uses method instead of a specific algorithm and with more advantages such as flexibility in structure, tolerance of impreciseness with known degrees or range. This paper brings out an overview and reflections based on the literature on the Fuzzy Logic in medical applications and gives an insight for further study to build and design different models and methods of diagnosing the diseases with Fuzzy statistical distributions. Fuzzy Logic System makes the computation time-optimal and provides more accurate results in the health science field. In near future, the diagnosis system into a web application to be implemented, and data mining techniques are applied to generate Fuzzy rules from the data set of the patients.

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