A Survey On Fuzzy Logic Applications in Medical Diagnosis

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Abstract - Medical diagnosis involves vagueness, hesitation, linguistic uncertainty, measurement imprecision, natural diversity and subjectivity. Medical diagnosis is a problem complicated by many and manifold factors and its solution involve all of a human’s abilities including intuition and the subconscious.
Fuzzy logic is a tool that deals with the uncertainty and imprecision by introducing partial values between true and false. Fuzzy logic plays an important role in the medicine. This paper will present the importance of logic in the medical field.
Keywords – MDSS,Fuzzy Logic

I. INTRODUCTION
With the increased volume of information available to physicians from new medical technologies, the process of classifying different sets of symptoms under a single name and determining the appropriate therapeutic actions become increasingly difficult. A single disease may manifest itself quite differently in different patients at different disease stages. Further, a single symptom may be indicative of several different diseases and the presence of several diseases in a single patient may disrupt the expected symptom pattern of any one of them. Although medical knowledge concerning the symptom – disease relationship constitutes one source of imprecision and uncertainty in the diagnostic process, the knowledge concerning the state of the patient constitute another.
Computer tools can help practitioners to organize, store and retrieve appropriate medical knowledge needed by them in dealing with each difficult case and suggesting appropriate diagnosis, prognosis, therapeutic decisions and decision-making technique.

II. MEDICAL DECISION SUPPORT SYSTEM
Medical decision-support systems (MDSS) are computer systems designed to assist physicians or other healthcare professionals in making clinical decisions. MDSS can also be known as clinical decision-support systems. MDSS can help physicians to organize, store, and apply the exploding amount of medical knowledge. They are expected to improve the quality of care by providing more accurate, effective, and reliable diagnoses and treatments. In addition, MDSS aimed at providing a more specific and faster diagnosis, by processing drug prescriptions more efficiently. The medical diagnosis of an illness can be done in many ways: from the patient’s description, physical examination and/or laboratory tests.

III. HISTORY OF MEDICAL DECISION SUPPORT SYSTEM
Research into the use of artificial intelligence in medicine started in the early 1970's and produced a number of experimental systems.

1. AAPHelp: de Domals system for acute abdominal pain (1972)
An early attempt to implement automated reasoning under uncertainty. De Dombal's system, developed at Leeds University, was designed to support the diagnosis of acute abdominal pain and, based on analysis, the need for surgery. The system's decision making was based on the naive Bayesian approach.
This system reports a controlled prospective unselected real-time comparison of human and computer-aided diagnosis in a series of 304 patients suffering from abdominal pain of acute onset. The computing system's overall diagnostic accuracy (91.8%) was significantly higher than that of the most senior member of the clinical team to see each case (79.6%).

2. INTERNIST I (1974)
Pople and Myers begin work on INTERNIST, one of the first clinical decision support systems, designed to support diagnosis, in 1970.
INTERNIST-I was a rule-based expert system designed at the University of Pittsburgh in 1974 for the diagnosis of complex problems in general internal medicine. It uses patient observations to deduce a list of compatible disease states (based on a tree-structured database that links diseases with symptoms).
INTERNIST is a computerized diagnostic program which emphasizes a very broad coverage of clinical diagnostic situations. The INTERNIST database currently covers approximately 80% of the diagnoses of internal medicine, and thus is the largest of these AIM(artificial intelligence to medicine ) programs. Although INTERNIST is close to its goal of covering most of internal medicine, other problems lie downstream for these researchers, including human engineering issues centered on usability of the program's interface, possibly significant costs of running the program and maintaining the database, introducing some model of disease evolution in time, and dealing with treatment, as
diagnosis is hard to divorce from therapy in any practical sense.

3. MYCIN (1976)
Dr. Edward Shortliffe, Feigenbaum and Buchanan developed MYCIN in the mid-1970s at Stanford University. MYCIN was a rule-based expert system designed to diagnose and recommend treatment for certain blood infections (antimicrobial selection for patients with bacteremia or meningitis). It was later extended to handle other infectious diseases. Clinical knowledge in MYCIN is represented as a set of IF-THEN rules with certainty factors attached to diagnoses. It was a goal-directed system, using a basic backward chaining reasoning strategy. It is probably the most famous early expert system, described by Mark Musen as being "the first convincing demonstration of the power of the rule-based approach in the development of robust clinical decision-support systems".

The EMYCIN (Essential MYCIN) expert system shell, employing MYCIN’s control structures was developed at Stanford in 1980. This domain-independent framework was used to build diagnostic rule-based expert systems such as PUFF, a system designed to interpret pulmonary function tests for patients with lung disease.

4. CASNET/Glaucoma A Model of Causal Connectives
CASNET is in principle a general tool for building causal models with which well-known diseases may be diagnosed and treated. CASNET (Causal ASSociational NETworks), developed in the 1960s, was a general tool for building expert system for the diagnosis and treatment of diseases. The most significant Expert System application based on CASNET was CASNET/Glaucoma for the diagnosis and treatment of glaucoma.

Expert clinical knowledge was represented in a causal-associational network (CASNET) model for describing disease processes. CASNET/Glaucoma was developed at Rutgers University.

THE CONSULTATION PROGRAM; CASNET/glaucoma CASNET/glaucoma is an interactive program running in 35K words of memory on the PDP-10 computer under either the TOPs-10 or TENEX operating systems. Because of speed and efficiency considerations, it is written in FORTRAN. Modifications and updating of the glaucoma model are carried out by interaction with a separate editing program, written in SNOBOL. This program checks the model for consistency and compiles it so that it will run efficiently under CASNET/glaucoma.

5. PIP
PIP, the Present Illness Program, was a system built by MIT and Tufts-New England Medical Center in the 1970s that gathered data and generated hypotheses about disease processes in patients with renal disease.

6. ONCOCIN
A rule-based medical expert system for oncology protocol management developed at Stanford University. Oncocin was designed to assist physicians with the treatment of cancer patients receiving chemotherapy. ONCOCIN was one of the first DSS which attempted to model decisions and sequencing actions over time, using a customised flowchart language. It extended the skeletal-planning technique to an application area where the history of past events and the duration of actions are important.

7. DXplain
DXplain is a decision support system which uses a set of clinical findings (signs, symptoms, laboratory data) to produce a ranked list of diagnoses which might explain (or be associated with) the clinical manifestations. DXplain provides justification for why each of these diseases might be considered, suggests what further clinical information would be useful to collect for each disease, and lists what clinical manifestations, if any, would be unusual or atypical for each of the specific diseases” [LCS MGH Harvard Medical School]. DXplain includes 2,200 diseases and 5,000 symptoms in its knowledge base. Developed by Laboratory of Computer Science, Massachusetts General Hospital, Harvard Medical School.

IV. FUZZY LOGIC
Among all the soft computing techniques, the concept of fuzzy logic is adopted mainly due to its capability to make decisions in an environment of imprecision, uncertainty and incompleteness of information. In addition, another advantage of choosing fuzzy logic is due to the fact that, fuzzy logic resembles process of human decision making and it has ability to work from approximate reasoning and ultimately find a precise solution. Fuzzy expert systems incorporate elements of fuzzy logic, which is a logically consistent way of reasoning that can cope with uncertainty, vagueness and imprecision inherent in medical diagnosis. Fuzzy inference system is a linguistic framework work by which human thinking process can be modeled.

V. APPLICATIONS OF FUZZY LOGIC IN MEDICAL DIAGNOSIS
Following are the examples in different subfields of medicine which uses concept of fuzzy logic.

1. ASTHMA
[Ashish Patel et al.] An automated system has been developed using a self-organizing fuzzy rule-based system. It utilizes the intrinsic ability to deal with the uncertainty and rejects the dealing of add-on mechanisms with imperfect data. Five symptoms have been taken (DSF (Day
time symptoms frequency) and NSF (Night time symptoms frequency) PEFR (Peak Expiratory Flow Rate), PEFR variability and SaO2 (Saturation of oxygen) as input and one output for the decision of the asthmatic conditions.

2. TUBERCULOSIS
[K.Soundararajan et al.,2012 ] designed a fuzzy rule based system to serve as a decision support for tuberculosis diagnosis. This system is mainly specialized for the pulmonary physicians that are focusing on tuberculosis and for patients already diagnosed with tuberculosis. A Rule–based Fuzzy Diagnostics Decision Support System is used to assign class labels for tuberculosis and fuzzy logic technique is used for class assignment process, Fuzzy rule sets are prepared by doctors. Tuberculosis symptoms and class details are updated in rule based system. Learning and testing operations are performed by this process. The system is designed to detect class of tuberculosis and these fuzzy rules are updated using rule mining techniques. Based on this method that generates classes of tuberculosis suits the needs of pulmonary physicians and reduce the time consumed in generating diagnosis.

System inputs and symptom scores with corresponding levels of intensity are as follows: cough (0-10), cough duration (0-30 days), body temperature (33-45), fever duration (0-30 days), sputum discoloration (0-10), nose sputum (0-10), afternoon chills (0-10), night sweats (0-10), weight loss (020 kgs), and loss of appetite (0-10). System used 16 rules for conditions. Used mamdani inference mechanism.

3. CANCER
[Vijay K Mago et al.,2012] used Multilayer networks with online gene selection ability and relational fuzzy clustering to identify a small set of biomarkers for accurate classification of four heterogeneous childhood cancers, neuroblastoma, non-Hodgkin lymphoma, rhabdomyosarcoma, and Ewing sarcoma present a similar histology of small round blue cell tumor (SRBCT). Identification of biomarkers for distinguishing these cancers is a well-studied problem.

[Wang and Palade.2010] They used Multi-Objective Evolutionary Algorithms based Interpretable Fuzzy (MOEAIF) methods for analyzing high dimensional biomedical data sets, such as microarray gene expression data and proteomics mass spectroscopy data in evaluating the lung cancer.

[Gláucia R Sizilio et al.,2012] designed a fuzzy logic technique for the prediction of the risk of breast cancer based on a set of judiciously chosen fuzzy rules utilizing patient age and automatically extracted tumor features. 

a) fuzzy system: Mamdani;

b) membership functions of the entry set: trapezoidal;

c) input set composed of 4 variables
AREA ,PERIMETER ,UNIFORMITY ,

HOMOGENEITY

d) rules base: 16 rules;
e) membership functions of the output set: trapezoidal for classificationBenign, trapezoidal for classificationMalignant; triangular for classificationUndefined
f) defuzzification: Centroid function;
g) output variable: 1 (result = pre-diagnosis).

[Ismail Säritas et al.,2003] In this study a fuzzy expert system design for diagnosing, analyzing and learning purpose of the prostate cancer diseases was described. For this process it was used prostate specific antigen (PSA), age and prostate volume (PV) as input parameters and prostate cancer risk (PCR) as output. This system allows determining if there is a need for the biopsy and it gives to user a range of the risk of the cancer diseases. There was observed that this system is rapid, economical, without risk than traditional diagnostic systems, has also a high reliability and can be used as learning system for medicine students.

System uses 80 rules, mamdani inference approach, triangular and trapezoidal mf. Centroid method is used for defuzzification.

4. FECG
[M. A. Hasan et al.,2009] provides concise information about FECG and reveals the different methodologies to analyze the signal for efficient FHR monitoring. Fetal electrocardiogram (FECG) signal contains potentially precise information that could assist clinicians in making more appropriate and timely decisions during labor.

5. MRI
[Indah Soesanti et al.,2011] presented an optimized fuzzy logic method for Magnetic Resonance Imaging (MRI) brain images segmentation. The results of this paper show that the method effectively segmented MRI brain images with spatial information, and the segmented MRI normal brain image and MRI brain images with tumor can be analyzed for diagnosis purpose.

6. HYPOTHYROIDISM
[P.B. Khanale and R.P. Ambilwade,2010] They presented a fuzzy inference system that will diagnose the thyroid disease specially a major disorder known as Hypothyroidism.

Rule-based systems have been successfully used to model human problem-solving activity and adaptive behavior, where the classical way to represent human knowledge is the use of if-then rules. The proposed system uses the Mamdani fuzzy inference system for implementation. An accuracy of 88% is achieved in diagnosis of hypothyroidism. The proposed system consists of 3 input, 1 output and 18 rules. The diagnosis is based on three input variables (1) SymptomScore expressed as a percentage of
severity of symptoms, (2) T4 and (3) TSH are nothing but the values obtained from blood report of the patients. The system output is the actual diagnosis of the patient which gives the severity of the hypothyroidism which is divided into four types. The shape of membership function used for this lowrisk and highrisk are of trapezoidal type and for med risk is of triangular type.

7. HEART DISEASE DIAGNOSIS
[Adeli and Neshat,2010] designed a Fuzzy Expert System for Heart Disease Diagnosis designed with follow membership functions, input variables, output variables and rule base and this system simulates the manner of expert-doctor.

The system has 13 input fields and one output field. Input fields are chest pain type, blood pressure, cholesterol, resting blood sugar, maximum heart rate, resting electrocardiography (ECG), exercise, old peak (ST depression induced by exercise relative to rest), thallium scan, sex and age. The output field refers to the presence of heart disease in the patient. It is integer valued from 0 (no presence) to 4 (distinction presence (values 1, 2, 3, 4)). This system uses Mamdani inference method.

Membership functions that are used for various input fields are trapezoidal and triangular. This system includes 44 rules. Antecedent part of all rules has one section.

For defuzzification process, designed system uses “Centroid” method.

8. MENIGIOMA
[Bencichi L,2006] used an algorithm integrating fuzzy-c-mean (FCM) and region growing techniques for automated tumor image segmentation from patients with meningioma which is used to correctly locate tumors in the images and to detect those situated in the midline position of the brain.

9. MENINGITIS
[Samar Samir Mohamed et al.,2011] used fuzzy cognitive maps to assist in the modeling of meningitis which is characterized by an inflammation of the meninges, or the membranes surrounding the brain and spinal cord, as a support tool for physicians in the accurate diagnosis and treatment of the condition.

10. Malaria
[X.Y. Djam et al.,2011] In this paper, a fuzzy expert system for the management of malaria (FESMM) was presented for providing decision support platform to malaria researchers, physicians and other healthcare practitioners in malaria endemic regions. The developed FESMM composed of four components which include the Knowledge base, the Fuzzification, the Inference engine and Defuzzification components. The fuzzy inference method employed in this research is the Root Sum Square (RSS). The Root Sum Square of drawing inference was employed to infer the data from the fuzzy rules developed.

Triangular membership function was used to show the degree of participation of each input parameter and the defuzzification technique employed in this research is the Centre of Gravity (CoG). Traingular fuzzifier which is widely used will be used in this research. FESMM inference engine uses a forward chaining mechanism to search the knowledge for the symptoms of a disease.

11. Prenatal examination
[Smith and Arabshahi,] Under this work the three biometric measurements of head circumference, abdominal circumference, and femur length are examined. Simplified geometries for the head-abdomen circumferences and femur are used.

Fuzzy inference is implemented using a series of rules to classify a fetus as normal, slightly abnormal, or abnormal based on measurements of head circumference, abdominal circumference, and femur length. Trapezoidal membership functions are used. The implication method chosen (shaping of the consequent) is clipping (min operator).

The Centroid defuzzification is used to arrive at a single number representing degree of normality. This system uses Mamdani inference method. It uses seven different rules.

12. Medicine Dose Determination
[Novruz Allahverdi Ismail Saritas Iker Ali Ozkan Mustafa Arimgogan] In this study, a fuzzy expert system is designed to determine the dose of a salazopyrin medicine used in the treatment of chronic intestinal infection - in relation to two criterions, though it can be determined in relation to many criterions. Trapezoidal and triangular memberships functions are used for input and output.

Input parameters : Prostate Specific Antigen (PSA), Sedimentation (SD)
Output parameters : salazopyrin (SL)

Nine fuzzy rules are used. System used mamdani inference mechanism. In the defuzzification the exact expression is obtained with “centroid” method according to validity degree.

13. Jaundice
[Ali and Satarkar, 2013 ] In this paper, they presented a fuzzy expert system for the pathological investigation of jaundice. The developed system has eight input variables (Bili_T, Bili_D, Bili_ID, AST, ALT, ALP, HB and RC) and one output variable L_D. The output variable is a value from 1 to 11 representing various causes of Jaundice. The system uses Mamdani interface method. The system is designed in MATLAB software. The developed system can prove to be very useful in comparison with other traditional diagnostic system as it is faster, cheaper and more reliable.

VI. Conclusion
This paper provides the several applications of fuzzy logic in medical decision support. Based on this study, future
developments of fuzzy control and monitoring technologies in medicine and healthcare can be forecast. Fuzzy logic provides a means for encapsulating the subjective decision making process in an algorithm suitable for computer implementation. As such, it appears to be eminently suited to aspects of medical decision making. Furthermore, the principles behind fuzzy logic are straightforward and its implementation in software is relatively easy.

References


