RESEARCH ARTICLE

DESIGN OF FUZZY EXPERT SYSTEM FOR DIAGNOSIS OF CARDIAC DISEASES

Smita S Sikchi[1], Sushil Sikchi[2], M S Ali[1]
[1] Prof. Ram Meghe Institute of Technology & Research, Badnera-Amravati, India
[2] Punjabrao Deshmukh Memorial Medical College, Amravati, India

Correspondence to: Smita S Sikchi (sikchismita@gmail.com)

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ABSTRACT
Background: The logical thinking of medical practitioners play significant role in decision making about diagnosis. It exhibits variation in decisions because of their approaches to deal with uncertainties and vagueness in the knowledge and information. Fuzzy logic has proved to be the remarkable tool for building intelligent decision making systems for approximate reasoning that can appropriately handle both the uncertainty and imprecision.
Aims & Objective: To develop a generic fuzzy expert system framework that can be used to design specific fuzzy expert systems for particular medical domain.
Material and Methods: The generic fuzzy expert system has been designed for diagnosis of cardiac diseases. The interface between visual basic and MatLab is powerful feature of the system that offers user friendly graphical user interface.
Results: Need to arrive at the most accurate medical diagnosis in a timely manner is the main outcome that may reduce the further complications. A generic fuzzy expert system for the diagnosis of various heart diseases yields better result than the classic designed systems, because this system simulates the manner of an expert in true sense.
Conclusion: The particular focus is on diagnosis of heart disease by employing the fuzzy logic in expert systems.
The system has been designed and tested successfully. Exhaustive rule base specifically formed for almost all heart diseases ensures the accuracy to arrive at certain decision.

KEY-WORDS: Fuzzy Expert System; Generic Framework; Medical Diagnosis; Heart Disease Diagnosis

Introduction

The interaction between doctors and engineers, and computer engineers and other engineers opened the unprecedented opportunities almost in every field. This has just possible because of the emergence of interdisciplinary technologies during past few years. The advancements in computer technology are playing a key role in development of medical diagnostic systems with demand for development of more intelligent and knowledge based systems. The medical practitioners are also employing computerized technologies to assist in diagnosis and access the related information. They differ in diagnosis and opinions because medical diagnosis is full of uncertainty. Fuzzy logic provides the solution for dealing with these uncertainties. Fuzzy techniques provide decision support and expert systems with powerful reasoning capabilities in the form of approximate reasoning. Fuzzy logic provides powerful framework for combination of evidences and deduction of consequences based on knowledge stored in knowledge base. Fuzzy logic which is one of the soft computing techniques can render precise from what is imprecise. The purpose of this paper is to propose a generic technique for diagnostic decisions. The particular focus is on diagnosis of heart disease by employing the fuzzy logic in expert systems. The paper discusses about fuzzy expert system designed for diagnosis of heart diseases. An exhaustive rule base and generic feature are strengths of the reported system.

Researchers have explored every aspect of fuzzy philosophy and the studies reported on fuzzy expert systems in medical diagnosis covers wide spread area including the need, importance, potential and approaches for designing the expert systems for medical diagnosis.[3,4,10,13] Computer assisted applications for patient's diagnosis and treatment seems to be the more recent area of interest.[2,5,18,20,21] The Fuzzy Expert System has proved its usefulness significantly in the medical diagnosis for the quantitative analysis and qualitative evaluation of medical data, consequently achieving the correctness of results. The literature survey reveals that, the commercially available expert system shells are rigorously used to write the application specific rule-bases. It has been found that the frameworks are developed for generation of a fuzzy expert systems with respect to specific diseases, general purpose diagnostic systems as well as for counselling of personal health.[7,16,17] Design of expert system frameworks for medical treatment and prevention of high risks related with the human health widened the scope for implementation of fuzzy concept in medical field.[11] Suitability of computer systems using fuzzy methods and computerized monitoring and medical decision making systems have been reported.[6,8,9,15,19] The object oriented frameworks to construct FES are proposed.[12,14]

It has been notified that, 21% reported research is devoted towards the development of methodologies and models. The share of studies conducted at architectural development level of fuzzy expert system shells and frameworks have been also found to be significant, i.e. 14%. The neuro-fuzzy approach has been used by many researchers and developed many fuzzy expert systems incorporating artificial intelligence to it. The investigation reveals that, 13% studies are contributed to the development of neuro-fuzzy based expert systems.

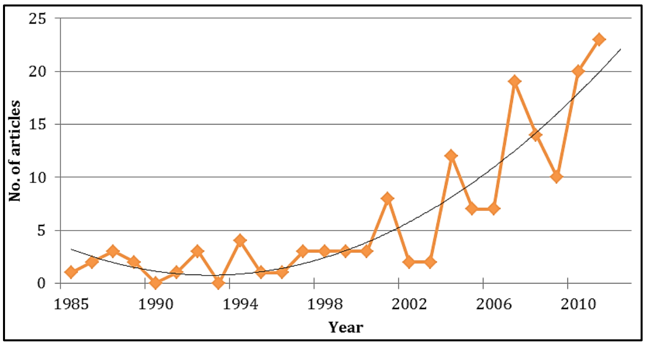

Figure-1: Trend of Research in Medical Fuzzy Expert Systems in Last Two & Half Decades

Figure 1 shows the trend of research in medical fuzzy expert systems in last two & half decades. The graph shows an exponential growth in the interests of various researchers for the development of fuzzy applications in the medical field. The penetration of fuzzy concept in medical field seems to be at par up to the year 2000. But, the recent span shows the exponential growth and more attention of researchers toward the development of fuzzy based expert systems specific to medical diagnosis. This accelerated trend intensifies the demand for focus on the development of more intelligent medical fuzzy expert systems.

Materials and Methods

The knowledgebase for developed medical fuzzy expert system contains both static and dynamic information. There are qualitative and quantitative variables, which are analyzed to arrive at a diagnostic conclusion. The fuzzy logic methodology involves fuzzification, inference engine and defuzzification as the significant steps.

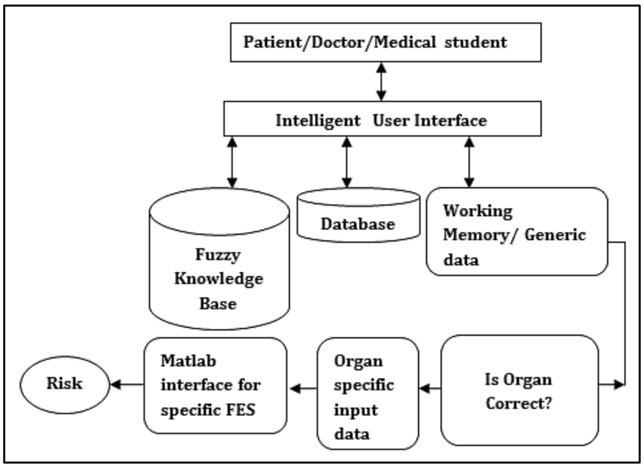

Figure-2: Flow Diagram of Generic Medical Fuzzy Expert System

A disease is usually characterized by directly observable symptoms that prompt the patient to visit a physician. A series of clinical observations are undertaken to detect the presence of a disease. The symptoms of the disease are usually expressed by the deviation of the observations from their normal state or value. The correct classification of the symptoms leads to diagnosis of the disease that enables the doctor to plan further treatment. The medical fuzzy expert system simulates the manner of expert and it is designed and developed in such a way that patient can use it himself. Figure 2 represents the basic flow of information in the medical fuzzy expert system. In the domain of heart disease risks: cholesterol, blood pressure, diabetes, gender and age are the main risk factors. There are many uncertain risk factors in the heart disease risk. So, sometimes heart disease diagnosis is hard for experts. Having so many factors to analyze to diagnose the heart disease of a patient makes the physician's job difficult. So, the diagnostic tool offers great help for an expert to consider all these risk factors and show certain results in uncertain terms.

The present work introduces simple and effective generic fuzzy expert systems for diagnosis of heart diseases. A set of 700 rules have been defined using the disease database as well as the expert knowledge on the disease domain. The designed expert system uses the rules to diagnose patient's illness based on their laboratory tests and manifested symptoms. Further, the organ specific test data is accepted from the patient. Laboratory test results are converted into fuzzy compatibility values reaching from zero to unity by consideration of the linguistic medical concepts. These fuzzified data are used to infer diagnosis with knowledge contained in a knowledgebase. Fuzzy relations were calculated for all linguistic medical concepts between test results and diagnosis by using the obtained fuzzy sets with the given set of patient data. It is necessary to obtain crisp output for the purposes of evaluation of the fuzzy model; defuzzification was used to produce crisp values on an arbitrary scale of the fuzzy output variable as the risk of heart disease. Figure 3 shows the interface screen developed in visual basic to accept the input values of symptoms and parameters. Figure 4 shows the screen for selection of more specific clinical parameters and symptoms.

In the proposed generic fuzzy expert system design, the first step is determination of input and output attributes. There are 11 input variables and one output variable considered for design of the system. The inputs are accepted through a form designed in visual basic and exported to MatLab in which fuzzy logic toolbox computes the membership function parameters that best allow the fuzzy inference system to track the given input/output data. Figure 5 shows the screen of membership functions in MatLab. The system uses Mamdani approach for design of inference mechanism and the Defuzzification process uses a centroid method to aggregate the inference of fuzzy expert system.

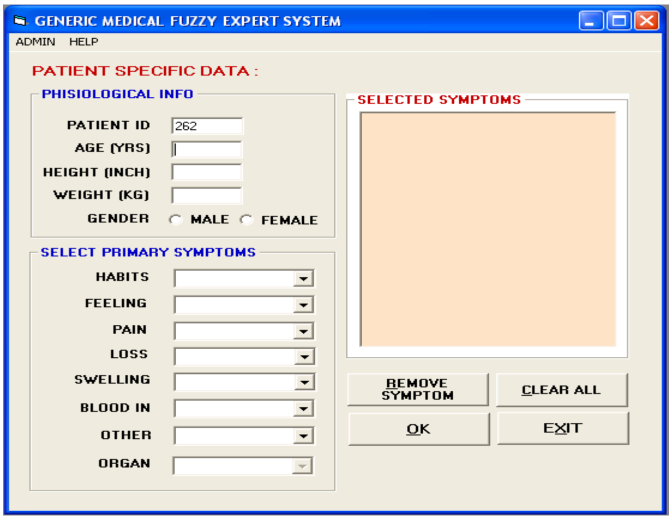

Figure-3: Selection of General Symptoms

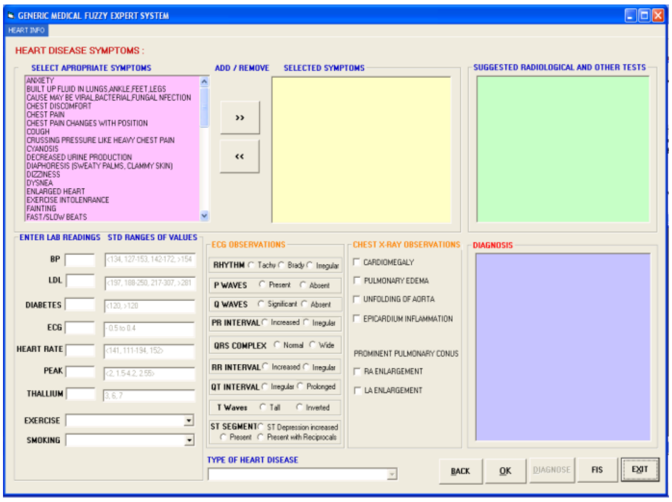

Figure-4: Selection of Clinical Parameters and Symptoms

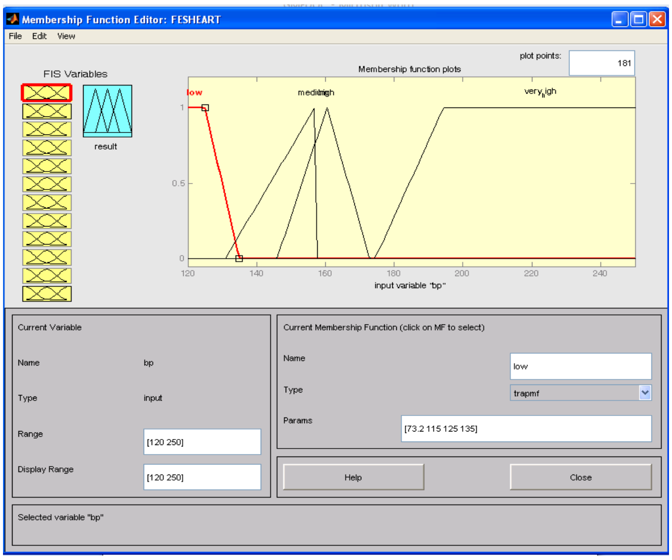

Figure-5: Membership Functions in Matlab

In the expert system, rules are required to implement the desired knowledge. In fuzzy logic the inference mechanism decides the sequence used in firing the rules to obtain the desired solution. All the rules are fired at the same time. The fuzzy rule base for this study is designed with the help of a medical doctor. The system has 700 rules building the strong rule base. Quality of the results in a fuzzy system depends on the rule base of the system. Figure 6 and Figure 7 show the screens of designed rules and extent of fired rules in MatLab respectively.

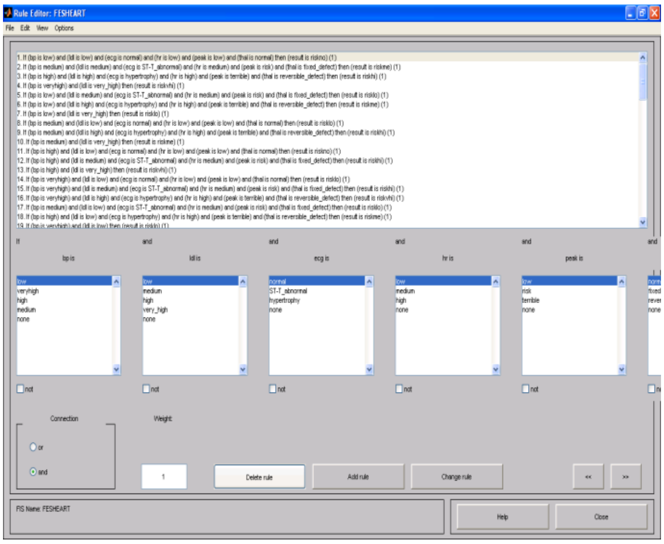

Figure-6: Rule Builder in MatLab

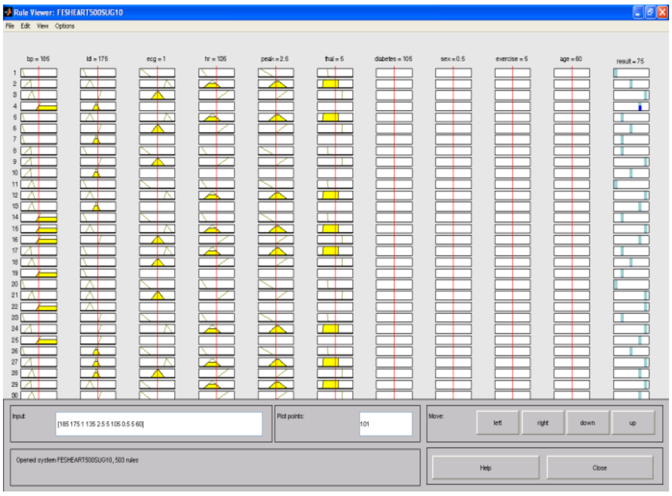

Figure-7: Rule Base in MatLab

Results

The presented system provides diagnostic assistance especially concerned with cardiac class of diseases. The system output has compared to any independent diagnoses given by physicians. The designed generic medical fuzzy expert system has been tested and found the disease risk diagnosed with accuracy. Using a given input/output data set, the toolbox function ANFIS (Adaptive Neuro-Fuzzy Inference System) constructs a fuzzy inference system whose membership function parameters are tuned with a least squares type of method. This adjustment allows fuzzy systems to learn from the modelling data. The training data set of input and output parameters considered to compute the risk of heart disease are represented in Table 1. The training data set is used to train a fuzzy system by adjusting the membership function parameters that best model this data, and appears in the plot in the center of the GUI as a set of circles as shown in Figure 8. The checking data given in Table 2 appears in the GUI plot in the form of pluses superimposed on the training data as shown in Figure 8.

Figure-8: Plot between Training Data & Checking Data

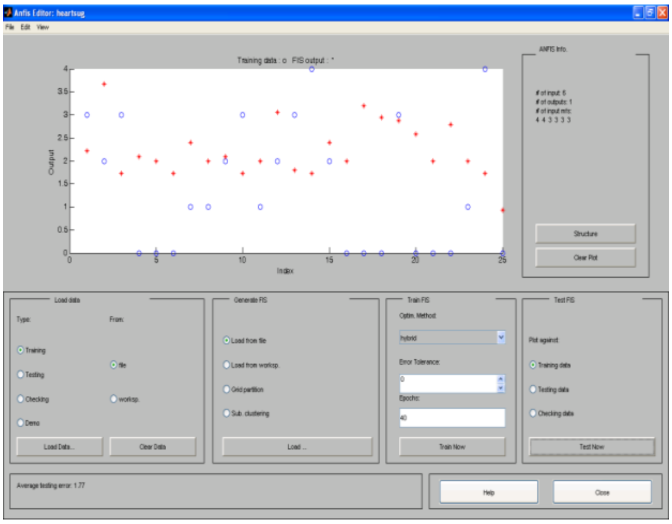

Table-1: Training Data: Input and Output Parameters

BP	LDL	ECG	HR	PEAK	THAL	RISK
147	233	2	150	2.3	6	3
163	286	2	108	2.5	3	2
124	229	2	129	2.6	7	3
134	250	0	187	0.5	3	0
128	204	2	172	1.4	3	0
124	236	0	178	0.8	3	0
142	268	2	160	1.6	6	1
120	354	0	163	2.6	3	1
134	254	2	147	1.4	7	2
144	203	2	155	3.1	7	3
146	192	1	148	0.4	6	1
144	294	2	153	1.9	3	2
132	224	2	173	3.2	7	3
136	206	2	132	2.4	7	4
140	219	1	158	1.9	3	2
120	199	1	172	0.6	3	1
146	206	1	114	1.6	3	1
155	247	1	171	1.5	3	1
150	267	2	114	2.6	6	3
144	227	1	151	1.7	3	1
160	202	1	162	0.4	3	1
150	212	1	157	1.6	3	1
132	330	2	169	1.2	3	1
120	230	2	165	2.5	7	4
120	175	0	123	0.6	3	0

Table-2: Checking Data: Input and Output Parameters

BP	LDL	ECG	HR	PEAK	THAL	RISK
120	175	0	123	0.6	3	0
156	283	2	168	2.8	7	4
140	196	1	141	1.8	3	0
135	197	1	142	1.2	3	0
130	205	2	155	3	3	1
160	272	2	165	1.6	3	0
172	256	2	140	3.4	7	3
155	231	0	147	3.6	3	2
150	269	0	148	1	3	0
128	254	0	163	2.9	7	3
128	267	0	199	1.8	7	2
120	248	2	158	0.6	6	2
130	197	2	177	0	3	1
178	198	2	151	0.8	3	0
135	258	2	141	2.8	7	3
130	208	2	142	1.5	3	0
135	245	2	180	1.8	3	1
160	270	2	111	0.8	7	3
120	208	2	148	3	3	0
130	204	2	143	0.4	3	0
140	321	2	182	0	6	2
178	274	2	150	1.6	7	3
140	201	0	158	0.8	3	0
130	222	1	186	0.4	3	0
120	260	1	185	0.7	3	0

Discussion

The focus of development of first generation expert systems was upon simulating the human knowledge and reasoning strategy of inference engine. The expert systems were designed for specific task and did not offer the solution for other tasks. Whereas, the second generation expert systems are generic in nature, in which common frameworks are suggested for development of the expert systems. Development of modelling methodologies, shells and frameworks are the major areas where key contributions of fuzzy technology has been observed. The limitations of medical decision making systems do not result from their limited computational power, but lies in the unavailability of intellectual interface between medical practitioners and computers. Till date, almost 100% medical practitioners are using computers, but many of them still do not prefer to use the expert systems as a diagnostic aid. It proved its usefulness significantly in the medical diagnosis for quantitative analysis and qualitative evaluation of medical data, consequently achieving the correctness of results. The computer based diagnostic tools and knowledgebase certainly helps for early diagnosis of diseases. To bridge the gap, more intelligent software embedded with intelligent interfaces can use the full potential of fuzzy technology in medical diagnosis segment. The computers and software are not capable enough to resolve entirely issues pertaining to human logical thinking and perceptions.

Conclusion

The generic fuzzy expert system has been designed for the diagnosis of heart diseases. The fuzzy expert system proves to be an effective diagnostic tool for the user and predicts appropriate risk by yielding accurate finding with scaled certainty of heart disease. An extensive rule base is the strength of the developed system and derives the accurate output. The interface between visual basic and MatLab is another powerful feature of the developed system that offers user friendly graphical user interface for one who uses the system. Need to arrive at the most accurate medical diagnosis in a timely manner is the main outcome that may reduce the further complications. A generic fuzzy expert system for the diagnosis of various heart diseases yields better result than the classic designed systems, because this system simulates the manner of an expert in true sense.

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