A Fuzzy Expert System Design for Diagnosis of Diseases

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Abstract

Fuzzy logic approach, rather than a certain or binary logic, uses a logic and decision mechanism which does not have certain boundaries like human logic. With this concept coined, one of its most common implementation was in fuzzy logic-based control mechanisms. Fuzzy logic control systems do not require complete model knowledge as in the other known control systems like proportional integral. For this purpose, many design methods have been derived. Making use of medicine expert's knowledge and experience uncertain sensual data fuzzy systems are being developed currentl . An expert system (ES) is a knowledge-based system that employs knowledge about its application domain and uses an inferencing (reason) procedure to solve problems that would otherwise require human competence or expertise. The power of expert systems stems primarily from the specific knowledge about a narrow domain stored in the expert system's knowledge base. In this article, by using the estimation of the membership functions of the fuzzy system, an attempt has been made to improve the prediction of some diseases by the fuzzy system.

Keywords: Medical diagnosis, fuzzy system, Expert system , fuzzy logic.

1.Introduction

Technology has shown to be very valuable for the improvement of workflow, data management, customer experience, and overall processes in the healthcare industry. The ongoing digital transformation in the healthcare space has the potential to enhance patient care, improve operational efficiency, and drive innovation. As we move into the new millennium it is becoming increasingly clear that the biomedical sciences are entering the most exciting phase of their development. Paradoxically, medical practice is also passing through a phase of increasing uncertainty, in both industrial and developing countries. Industrial countries have not been able to solve the problem of the spiraling costs of health care resulting from technological development, public expectations, and—in particular—the rapidly increasing size of their elderly populations. The people of many developing countries are still living in dire poverty with dysfunctional health care systems and extremely limited access to basic medical care. Transformation in the health industry through the single goal of "How do health organizations reduce costs and increase quality and remain competitive?" goes on and this category is always considered a big challenge. Quality improvement in the healthcare industry can be best defined by the driving forces that affect it. One of the driving forces is health data; In other words, in any type of patient-centered quality improvement program, data is the heart of that program. In today's age, i.e. the information age, data has been the most important asset for health organizations, and the success of health organizations depends on their collection, storage and analysis. Despite this, collecting and storing a large amount of data can be considered a kind of waste, unless the data is used in a beneficial way and becomes a financial source for the organization. With the advancement of technology in advanced European, American and even third world societies, many efforts have been made and are being made in various scientific fields by thinkers and researchers of different sciences. Despite these studies, we still have ambiguities in some scientific fields. Due to the complexity of medical decisions, the use of information systems to support these decisions has increased. Therefore, the role of intelligent systems in helping doctors is outstanding. One of these intelligent systems is the expert system. The strength of an ES derives from its knowledge base - an organized collection of facts and heuristics about the system's domain. An ES is built in a process known as knowledge engineering, during which knowledge about the domain is acquired from human experts and other sources by knowledge engineers. The accumulation of knowledge in knowledge bases, from which conclusions are to be drawn by the inference engine, is the hallmark of an expert system. To be more precise, the expert system examines different situations of a topic by means of a set of "if-then" rules and finally reaches a suitable result. This type of approach to diseases can actually be modeled mathematically under the title of fuzzy mathematics. In recent decades, a number of experts have conducted research on infectious diseases using the theory of fuzzy sets. The fuzzy expert system is a newer version of the expert system that uses fuzzy logic for processing.

2.What are the components of an expert system?

An Expert System (ES) is a methodology and programming approach that attempts to provide answers for complicated problems, or clarify uncertainties where human domain experts would need to be consulted. In a general definition, it can be said that expert systems are computer programs that simulate the way of thinking of an expert in a specific field. In fact, these softwares identify the logical patterns based on which an expert makes decisions, and then they make decisions based on those patterns, just like humans. Expert systems are a branch of artificial intelligence. It is an intelligent computer program that uses knowledge and inference to solve complex problems that require human expertise and experience. So the use of Expert Systems (ES) became popular because it is capable of representing and reasoning knowledge rich domain with a view to solve problems and giving advice [3]. The main advantage of ES over any other conventional software applications is its effective reasoning capability as they process knowledge instead of data or information [2]. On the other hand the application of fuzzy set theory in uncertainty handling has become one of the strongest tool to design any framework .
There are four main components of an expert system:

- The knowledge base. This is where the information the expert system draws upon is stored. Human experts provide facts about the expert system's particular domain or subject area are provided that are organized in the knowledge base. The knowledge base often contains a knowledge acquisition module that enables the system to gather knowledge from external sources and store it in the knowledge base.

- The inference engine. This part of the system pulls relevant information from the knowledge base to solve a user's problem. It is a rules-based system that maps known information from the knowledge base to a set of rules and makes decisions based on those inputs. Inference engines often include an explanation module that shows users how the system came to its conclusion.
- The user interface. This is the part of the expert system that end users interact with to get an answer to their question or problem.
- The knowledge acquisition : Knowledge acquisition is responsible for entering new rules to the rule-base, and updating the existing rules [9]. Expert system needs a complete development environment called shell to build KB applications and maintaining them. This will help human expert to construct the suitable KB without any help from expert system designer [1].

3. Fuzzy Logic

The main contribution of fuzzy mathematics is its ability to represent vague information. It has been used to model systems that are difficult to define precisely [5]. As a methodology, fuzzy set theory incorporates vagueness and subjectivity. Fuzzy decision-making includes the uncertainties of human behaviour in decision-making. Fuzzy set theory emerges as a powerful way to quantitatively represent and manipulate imprecise decision-making problems [6]. Since the vague parameters are treated as imprecise rather than precise values, the process is more powerful and results are more credible. Fuzzy mathematics emerges as a tool to model processes that are too complex for traditional techniques (such as probability theory) and when process information is qualitative, inaccurate, or unclear; for these cases the concept of membership function properly represents this type of knowledge [7]. Fuzzy logic captures an inherent property of most human communications: they are not accurate, concise, perfectly clear, and crisp [8]. The meaning of the word (natural language) is diffused because a word can be applied perfectly to some objects or events, clearly excluding others, and can be applied to a certain extent, in part, to other objects or events. Language statements are inherently vague; this fact could be addressed with fuzzy set theory [9]. Fuzzy logic resembles the way that humans make decisions and inferences [7]. In fuzzy processing there are basically three components [7]: (1) fuzzification, (2) fuzzy inference, and (3) de-fuzzification . Fuzzification is the process by which the input variables are transformed into fuzzy numbers sets. Fuzzy inference is a set of fuzzy if-then-else rules used to process diffuse inputs and generate fuzzy conclusions; that is, fuzzy inference interprets input vector values and, based on a rules set, generates an output vector. De-fuzzification is the process of weighing and averaging out all fuzzy values into a single output signal or decision. Fuzzy logic is a type of logic that replaces the various methods of conclusion in the human brain with simpler machine patterns. Fuzzy logic is a multi-valued logic which is similar to human thinking and interpretation. It has the potential of combining human heuristics into computer-assisted decision making, which is applicable to individual patients as it takes into account all the factors and complexities of individuals. Fuzzy logic has been applied in all disciplines of medicine in some form and recently its applicability in neurosciences has also gained momentum. Each type of statement of reality is not a series of true or false, their truth is something between complete truth and complete falsehood, something between one and zero, i.e. a multi-valued concept. In fact, fuzzy is something between black and white, i.e. gray, which is opposite to the binary or Aristotelian logic that sees everything in only two black and white forms, yes and no and zero and one. This logic is in the range between zero and one and discusses the value of a member's belonging to the set by avoiding absolutism (only zero or one). Fuzzy logic is a method to implement imprecise or approximate human inference and reasoning.

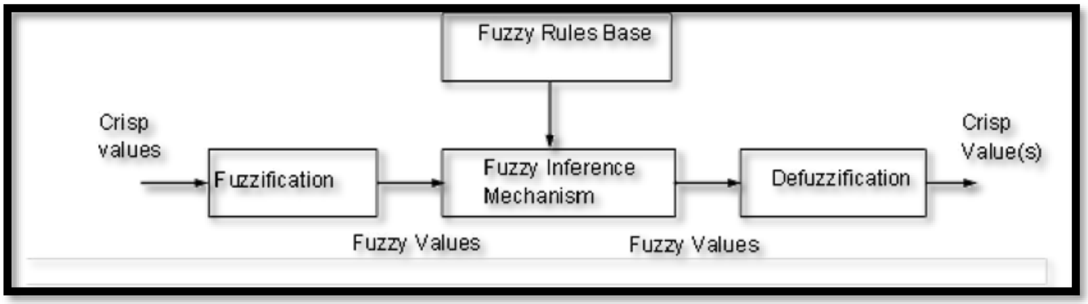

Figure 1. Fuzzy expert system with fuzzification and defuzzification

4. Fuzzy sets

The foundation of fuzzy logic is based on the theory of fuzzy sets. This theory is a generalization of the classical theory of sets in mathematics. In classical set theory, an element is either a member of the set or not. In fact, the membership of the elements follows a zero and one and binary pattern.

But the theory of fuzzy sets expands this concept and proposes graded membership. Fuzzy sets are sets with uncertain boundaries. In fact, the transition from inclusion to non-inclusion is done gradually. This gradual transition is organized by the membership function. This concept makes fuzzy sets have good flexibility for modeling linguistic concepts.

5. Fuzzy expert system

Our real world is much more complicated than it is possible to get a precise description and definition, so it should be introduced for a model, an approximate description that is acceptable and analyzable. By moving towards the information age, knowledge and human knowledge become very important .Therefore, we need a hypothesis that can formulate human knowledge in a systematic way and put it together with other mathematical models in engineering systems. These systems are a combination of an expert system and a fuzzy logic system, which were previously discussed about both systems separately. Fuzzy systems have the ability to create the ability to make decisions and control a system using the knowledge of an expert. They are most commonly used in modeling relationships in complex environments or anywhere a clear model of the system is not available, and based on a number of inputs and their results, they draw conclusions and make decisions for the system. The reasons for using the fuzzy system are:

a) The excessive complexity of the real world that ultimately leads to an approximate description or a fuzzy system to model.
b) b) The need for a model to formulate human knowledge in a legal way and place it in real systems [2].

6. Types of fuzzy systems

- **A Mamdani**-type fuzzy inference system is used in the majority of investigations. was designed to control a steam engine and boiler combination by a set of linguistic control rules obtained from the experienced human operators. In Mamdani inference system, the output of each rule to be a fuzzy logic set. A Mamdani-type fuzzy inference system is used in the majority of investigations. An experienced designer, heuristic algorithms, or combinations develop the rules base after partitioning the input and output domains into a specific number of subdomains. Thus, the best design is chosen to regulate the PV system. However, there are two types of fuzzy logic systems: Mamdani and Sugeno. The sole difference between these systems is their defuzzification process. Mamdani fuzzy inference was initially proposed to develop a control system by synthesizing a set of linguistic control rules collected from experienced human operators. Mamdani systems are well-suited to expert system applications where the rules are developed from human expert knowledge since their rule bases are more intuitive and easier to understand. Each rule's output is a fuzzy set produced from the FIS's output membership function and implication technique. These fuzzy output sets are aggregated into a single fuzzy set using the FIS's aggregation mechanism, and a final crisp output value is applied to the system through the defuzzification process [6].

- **Sugeno fuzzy** was proposed by Takagi, Sugeno, and Kang to develop a systematic approach for generating fuzzy rules from a given input-output dataset. A typical fuzzy rule in a first-order Sugeno fuzzy model has the form: IF x is A and y is B THEN z = f(x, y) where

- A and B are fuzzy sets in the antecedent
- z = f(x, y) is a crisp function in the consequent.

Sugeno fuzzy inference employs singleton output membership functions that are either constant or a linear function of the input values. A Sugeno system's defuzzification process is more computationally efficient than a Mamdani system because it employs a weighted average of a few data points rather than computing the centroid of a two-dimensional area. Because each rule is linearly dependent on the input variables, the Sugeno approach is excellent for acting as an interpolating supervisor of several linear controllers that will be applied to distinct operating states of a nonlinear dynamic system [7]. For example, a PV's performance might vary dramatically depending on the light intensity and the temperature. Linear controllers, while simple to implement and adaptable to any weather situation, must be updated frequently and seamlessly to keep up with the changing state of the PV system. Sugeno inference systems are adapted to smoothly interpolating the linear gains applied over the input space; they are a natural and efficient gain scheduler [28], while the output surface of Mamdani systems is discontinuous. As a result, while

Sugeno systems, unlike Mamdani systems, lack a clear external description, they perform well with linear, optimization, and adaptive techniques. It also adapts itself well to mathematical analysis. Considering the conducted study and obtained results, in this study, two main features in designing a controller for updating the duty cycle of present converters in the MPPT section are analyzed. First and most importantly, the performance of fuzzy-Mamdani and fuzzy-Sugeno is compared to pave the way for picking the best type used in PV systems. Secondly, the influence of input membership functions is examined by suggesting 3 and 5 membership functions for each. Consequently, four initial controllers are designed and, in the next stage, are optimized by employing a genetic algorithm.

- **Tsukamoto fuzzy** models, the result of each fuzzy if-then rule is presented in the form of a fuzzy set. As a result, the output deduced from each rule is defined as a non-fuzzy value of the degree of perfection of each rule. The final output is equal to the weighted average of the output of each rule. Since each rule leads to a non-fuzzy output, Tsukamoto's model avoids the time-consuming de-fuzzification process by calculating the sum of the outputs of each rule by calculating the weighted average. This model does not have sufficient transparency like Mamdani and Sogno methods, it is not very useful.

7.The constituent parts of the fuzzy system

Fuzzy systems are systems based on knowledge or rules. The heart of a fuzzy system is a knowledge base that consists of fuzzy if-then rules. This system has three general parts:

A) Fuzzification: In fuzzy sets, it is easy to use language words instead of definite numbers. Words make it possible to make a model clear and correct with vague expressions. To convert linguistic words into mathematical form, we use the fuzzy membership function. The fuzzy membership function is a generalization of normal (definite) numbers. Several mathematical functions have been proposed for this purpose, among them, triangular or Gaussian functions are used more. The advantage of the triangular function is that if it is used, more theoretical arguments can be cited to prove theories. The main feature of Gaussian functions is that it is closer to human thinking [2].

B) Fuzzy inference engine : It consists of numerically finding numerical inputs based on a fuzzy rule. The fuzzy inference engine combines the fuzzy rules into a mapping from the fuzzy sets in the input space to the fuzzy sets in the output space based on the principles of fuzzy logic. The main problem with pure fuzzy systems is that their inputs and outputs are fuzzy sets. While in engineering systems, inputs and outputs are variables with real values. In order to use pure fuzzy systems in engineering systems, a simple method is to add a fuzzifier to the input, which transforms real-valued variables into a fuzzy set, and to add a defuzzifier, which transforms a fuzzy set into a Convert variable with real value in output. The basic structure of fuzzy inference systems consists of three conceptual parts : The first part is rules that include a selection of fuzzy rules. The second part is the database in which membership functions used in fuzzy rules are defined. Finally, the third part is the inference mechanism by which the inference procedure is carried out with the help of existing rules and facts to reach a reasonable output.

C) De-fuzzification: Converts a fuzzy set to a real-valued variable. In other words, the input information is often complex values and these numbers are converted into fuzzy sets. Models are interpreted based on fuzzy logic including if-then rules. The truth is that after the statement if a prior logic is expressed, based on that we examine the other truth that comes after that and in which the result of the work is explained. In fact, fuzzy logic puts human experience and knowledge in the form of a combination of numbers and enables to make a decision based on mathematics and logic.

8. Applications of fuzzy expert systems in medicine

Expert system for prescribing medical treatment: Due to the wide range of diseases and available drugs, and the limitation of the doctor to remember all types of drugs and pay attention to the different conditions of the patient in terms of age, weight and disease records, the designed expert system has responded to all these limitations.

- Using fuzzy logic in providing a fuzzy expert system to diagnose animal diseases with neurological manifestations: types of animal neurological diseases that are not easy to diagnose based on clinical symptoms. By the fuzzy logic approach, a model has been presented in which the presence and absence of neurological diseases can be calculated and determined.

- Diagnosis of human diseases using fuzzy expert system: The purpose of designing this system is to develop a web-based expert system to overcome various problems in order to improve the quality of life. In this system, the user specifies her problem area and then answers the questions related to her symptoms and the result of the disease is determined using fuzzy inference rules :

- Fuzzy expert system to evaluate the severity of asthma attack. Fuzzy expert system design is designed to evaluate the severity level of an asthma attack. The input variables of this system include breathing intensity, wheezing condition, level of consciousness, breathing rate, heart rate condition, and the output of this system is the degree of asthma attack severity.
- Designing an expert system to diagnose and recommend the treatment of leukemia: This system diagnoses the disease using the knowledge of a specialist doctor and provides the appropriate treatment method using the VP-EXPERT shell.
- A fuzzy expert system for identifying kidney failure: a decision support system for kidney patients is designed to reduce the errors of doctors in their diagnoses, which diagnoses acute and chronic kidney failure.
- Determining the optimal dose of atorvastatin to patients using fuzzy intelligent system: Diagnosing the appropriate dose of atorvastatin for patients with coronary artery stenosis, considering the co-existence of several diseases with several other diseases and the side effects of atorvastatin on the patient's normal functions, should help doctors in making decisions.

9. Conclusion

Fuzzy laws are of interest because they can be interpreted by an expert. In fact, the knowledge considered by the doctor can be considered as a fuzzy rule base that is improved during the data mining process and with the help of an optimization algorithm according to criteria such as accuracy and interpretability. An important group of problems in medical science is related to the diagnosis of diseases, which is performed on the basis of various tests on the patient. This has led to the fact that during the last few decades, computer diagnostic tools have been introduced to help the doctor to somehow remove the irregularity and inconsistency from the data. Data mining plays a vital role in health by creating evidence-based medicine and leads to the discovery of new, useful and lasting knowledge in the databases of health organizations, because in order to achieve evidence-based medicine, it is necessary to identify gaps and knowledge gaps in health care processes. The current one started and then looked for the best evidence, in the next step, one should check the correctness and validity of the measures identified in the best evidence, and in the last step, implement this evidence on the affected patients. Finally, with these systems, the speed of analysis and access to recommendations increases at any time and place, which is very important for medical decisions. Intelligent medical systems have a structure, components, and improve decision-making capabilities, for this reason, they have been used in many cases in medicine.

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