Journal of the Nigerian Association of Mathematical Physics
***Volume 31*, (July, *2015*), pp 123 – 128**

Fuzzy Logic Diagnostic System for Disease Detection

[1]Daodu S. S., [2]Ukaoha K. C., [3]James T. R. and [4]Amadin I. F.

[1,2,4]Department of Computer Science, University of Benin, Benin City, Nigeria
[3]Department of Computer Science, College of Education, Igueben, Edo State, Nigeria.

Abstract

A major problem in medical diagnosis is precision and accuracy. The traditional medical diagnosis method is characterized with the aforementioned problem. The advent of computers has led to the development of several algorithms and technologies to ensure accuracy and precision. One such technology is fuzzy logic- an integral part of Artificial Intelligence. In this work, we proposed a medical diagnostic system using fuzzy logic which would enhance the accuracy and precision of the entire system. The focus of the work is on malaria diagnosis and the system was developed using Visual Prolog Programming Language.

Keywords: Fuzzy Logic, Expert System, Medical diagnosis, Artificial Intelligence, Soft Computing.

1.0 Introduction

Nowadays the use of computer technology in the fields of medical diagnosis, treatment of ailments and management of hospital patients has increased. Artificial Intelligence methods have significantly been used in medical applications, and research efforts have been concentrated on medical expert systems and other computer-based techniques for healthcare delivery.

The diagnosis of diseases involves several levels of uncertainty and imprecision. Patients cannot tell exactly how they feel, doctors and nurses might not be able to state exactly their observations and laboratory results could be fraught with errors in some cases. All these complexities in medical practice makes the traditional quantitative approaches methods inappropriate. Diagnosis is concerned with the development of algorithms and techniques that are able to determine the correct behaviour of a system, and should determine accurately the part of the system that is not functioning well and the nature of the fault. Computation is based on observations which provide information on the current behaviour.

Among all the soft computing techniques, we adopted the concept of fuzzy logic in this work due to its capability to make decisions in an environment characterized by imprecision, uncertainty, and incomplete information. Fuzzy logic also mimics the human decision making process due to its ability to work from approximate reasoning to finding a precise solution. Fuzzy expert systems on the other hand, 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.

2.0 Related Work

Malaria has been a major health problem in the world with about 2 to 3 million new cases arising every year. The direct costs of malaria include huge personal and public expenditures in both prevention and treatment, and the indirect costs are the human sufferings and deaths recorded [1]. Several works have shown that malaria remains a major public health problem in Africa [2]. However concerted efforts are continually made to control malaria spread and transmissions within and between communities.

While good attempts have been made at designing systems for diagnosing tropical diseases, some drawbacks experienced necessitated the use of soft computing techniques with a need to arrive at the most accurate diagnosis. The design of a fuzzy logic controller for medical devices based on software using fuzzy logic was proposed in [3] while a description of how fuzzy logic was used in human health care system and the medical data of patients was given in [4]. The use of fuzzy logic in the neuro-medical field for the evaluation of facial expressions and human behaviours and the use of data analysis in the survey of different fuzzy techniques was reported in [5] with Hata et al. [6] working on a scheme to concentrate medical diagnosis and health management and describing the practical application of management system for health.

Corresponding author: Daodu S. S, E-mail: sege.daodu@gmail.com, Tel.: +2349023508022

Description of the immune system on the basis of an immune algorithm using a flowchart and fuzzy cognitive map has been carried out [7]. Also, a survey related to fuzzy logic, fuzzy sets, and relations, fuzzy control and their applications in medical science with an explanation on patient glucose data setting, fuzzy automata concept was the focus of a survey carried out in [8].
A good number of expert systems have been designed for the diagnosis and treatment of some diseases. Apurba and Anupam [9] developed a fuzzy expert system approach using multiple experts for dynamic follow-up of endemic diseases in which they discussed some applications of fuzzy logic concepts to medical diagnosis of some diseases.
Abraham and Nath [10] proposed a medical expert system for managing tropical diseases and assisted medical doctors in the diagnosis of symptoms related to a given tropical disease, suggesting likely ailments and advancing possible treatments based on the medical expert system diagnosis. The expert system's inference engine used forward chaining mechanism to search the knowledge base for symptoms and its associated therapy which matched the query supplied by the patient. The authors noted that the proposed system is useful for people without access to medical facilities and those requiring first-aid solution before approaching a medical consultant. Our present work is a medical diagnostic system that uses fuzzy logic techniques to diagnose patients using so

3.0 Methodology
Irrua Specialist Teaching Hospital, Irrua in Edo State, Nigeria was used for data collection and involved secondary data collection using direct interview of consultants in general medicine. Data collected included various malaria diagnosis methods, their signs and symptoms while previous research works and texts in the subject area were consulted. These were used to design and implement the software via Visual Prolog.
The proposed system is a medical diagnostic system using the fuzzy logic techniques and will allow patients to be diagnosed using a software-based technique. The patients are expected to input their symptoms, then the system uses a fuzzy logic algorithm to infer the likely ailment or disease while the diagnosis would be done at the click of a mouse.

4.0 Design and Implementation
We describe the approach adopted in developing the overall framework for the fuzzy medical diagnosis system for malaria fever. The framework is made up of four major components;
- The User Interface
- Information Manager
- Knowledge Base and
- Fuzzy Inference System

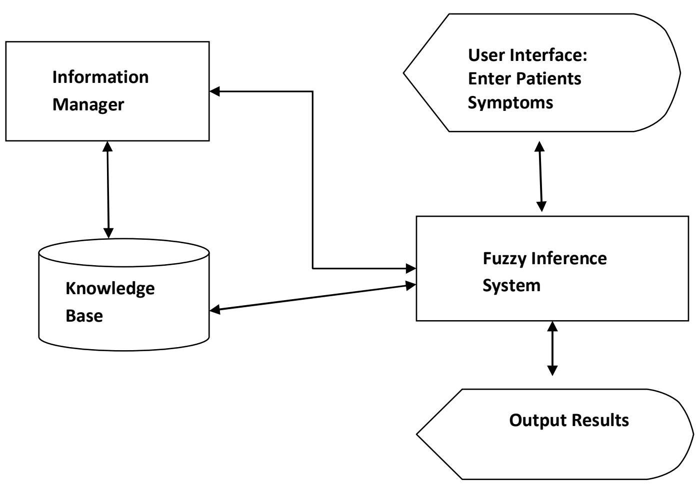

Fig. 4.1: Fuzzy Medical Diagnostic System

4.1 User Interface: provides a graphical interface showing the symptoms considered and their respective acronyms. An interactive interface where patients can enter their symptoms in relation to its intensity during knowledge acquisition is also provided.

4.2 Information Manager: this is used for the creation and manipulation of information in the knowledge base, for maintaining the patient's history. It uses time series forecasting method for predicting the future using past and present data.

4.3 Knowledge Base: the symptoms of the patient is keyed into the system and based on the weights of the symptoms stored in the knowledge base, the symptoms are fuzzified. Rules related to patients' symptoms and diseases are also stored here. The Knowledge Base maintains two tables for each entity set to store the current data and historical data separately.

4.4 **Fuzzy Inference System**: the Inference Engine has two components namely a scheduler for scheduling the rules to be fired and an interpreter that fires the rules using forward chaining inference technique. It applies fuzzy rules to make decisions on diseases.

The result is displayed which shows the diagnosis of the patient.

4.5 Algorithm for the Proposed System

i. *Input signs and symptoms of patient's complaint into the system. Set n = number of signs and symptoms.*
ii. *Search the knowledge-base for the disease d, which has the identified signs and symptoms.*
iii. *Get the weighting factors (wf) (the associated degree of intensity) wf = 1, 2, 3, 4 where 1 = mild, 2 = moderate, 3 = severe and 4 = very severe.*
iv. *Apply fuzzy rules*
v. *Map fuzzy inputs into their respective weighting factors to determine their degree of membership*
vi. *Determine the rule base evaluating (non-minimum values)*
vii. *Determine the firing strength of the rules R*
viii. *Calculate the degree of truth R, of each rules by evaluating the nonzero minimum value*
ix. *Compute the intensity of the disease*
x. *Output fuzzy diagnosis*

Fig4.2: Algorithm for proposed Fuzzy System

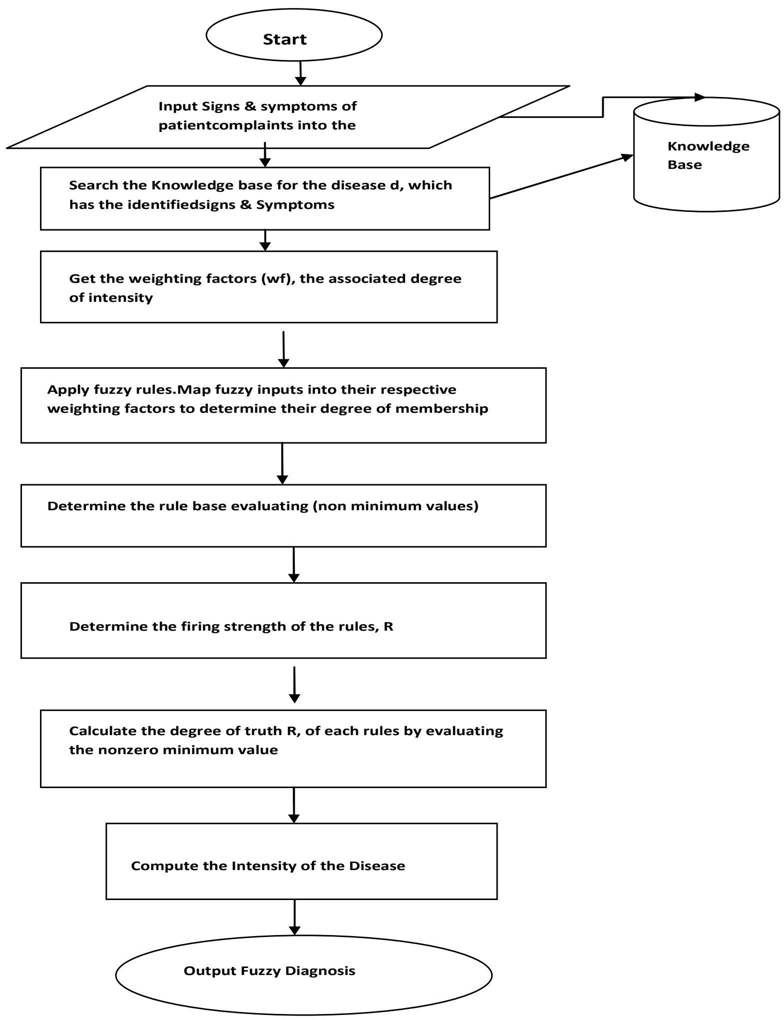

Fig. 4.3: Flowchart for the Medical Diagnosis System

4.6 **Unified Modeling Language:** The Unified Modeling Language (UML) analysis of the proposed system could be done using the following:

a. Class diagram
b. Use Case diagram

4.6.1 **Class Diagram:** the class diagram in the UML is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among object.

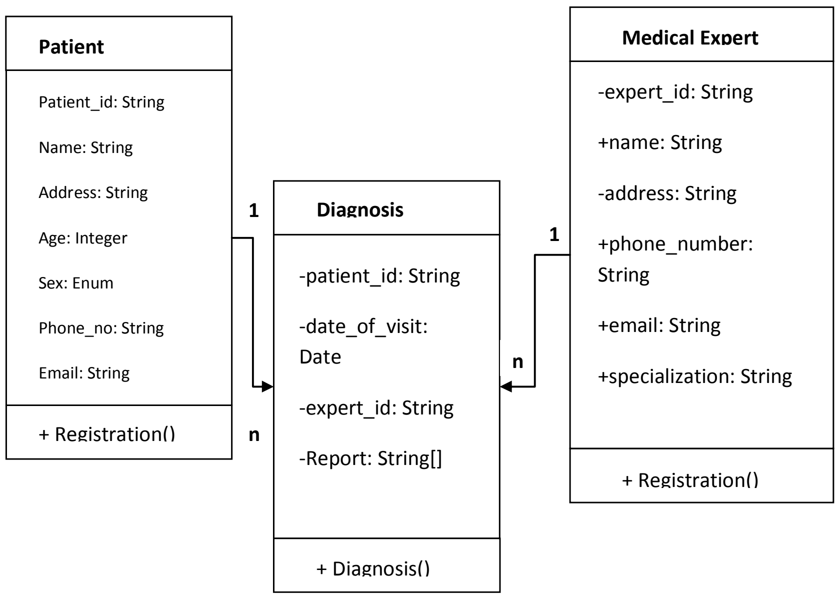

Fig. 4.4: Class diagram for the Proposed System

4.6.2 **Use Case Diagram:** A use case diagram at its simplest is a representation of a user's interaction with the system and depicts the specifications of a use case. It can portray the different types of users of a system and the various ways they interact with the system. This type of diagram is typically used in conjunction with the textual use case and will often be accompanied by other types of diagrams as well.

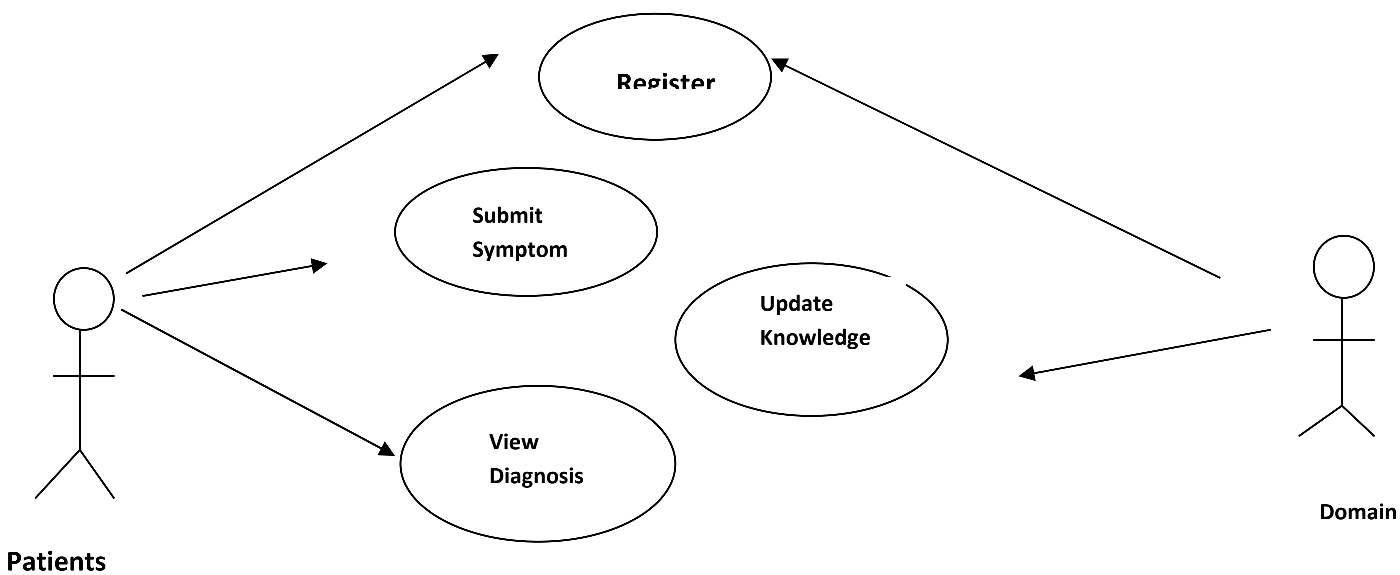

Fig. 4.5: **Use Case diagram for the proposed system**

4.6.3 Knowledge Base Design: The Knowledge Base consists of rules for 11 symptoms in which each rule has symptoms and corresponding weight with the number of symptoms ranging from 3 to 10 depending on the option selected by the user. Moreover, there are many rules for the 11 symptoms that are created for making decisions. Each rule has a symptom and their corresponding conditions based on its weight. The total number of conditions in each rule base varies from 10 to 110. Along with it, there are separate rules for common and general symptoms and conditions. For every symptom the user is selecting, the rule base generates the possible conditions from equations 4.1 - 4.4.

4.6.4 Fuzzy Logic: Fuzzy logic plays an important role in medicine. Fuzzy logic is a method that renders precise what is imprecise in the world of medicine using natural language. Fuzzy logic systems are excellent in handling ambiguous and imprecise information prevalent in medical diagnosis. The basic aim of the fuzzy logic and fuzzy set theory is exploitation of the tolerance that exists in imprecise, vague or partially truth data for obtaining more robust and cheaper solutions [11].

4.6.5 Fuzzification: the first step in the development of fuzzy logic expert system is to construct fuzzy sets for the parameters. This is shown in equations (4.1) to (4.3) below. On the basis of domain experts' knowledge, both input and output parameters selected for this research were described with four linguistic variables (mild, moderate, severe and very severe). The range of fuzzy value for each linguistic is given as:

Linguistic Variables	**Fuzzy Values**
Mild	$0.1 \leq x < 0.3$
Moderate	$0.3 \leq x < 0.6$
Severe	$0.6 \leq x < 0.8$
Very Severe	$0.8 \leq x \leq 1.0$

Fuzzification begins with the transformation of the raw data using the functions that are expressed in equations (4.1) to (4.3) below. During the process, linguistic variables are evaluated using triangular membership function are accompanied by associated degree of membership ranging from 0 to 1 as shown in the equations below. These formulas are determined by aid of both the expert doctors in the field.

$$mild\ (x) = \begin{cases} 0 & if\ x < 0.1 \\ \frac{x-0.1}{0.2} & if\ 0.1\ \leq x\ \leq 0.2 \\ \frac{0.2-x}{0.2} & if\ 0.1\ \leq x\ \leq 0.2 \\ 0 & if\ x\ \geq 0.2 \end{cases} \quad (4.1)$$

$$moderate\ (x) = \begin{cases} 0, & if\ x < 0.3 \\ \frac{x-0.3}{0.2}, & if\ 0.3\ \leq x\ \leq 0.40 \\ \frac{0.45-x}{0.15}, & if\ 0.41\ \leq x\ \leq 0.44 \\ 0, & if\ x\ \geq 0.45 \end{cases} \quad (4.2)$$

$$severe\ (x) = \begin{cases} 0, & if\ x\ \leq 0.5 \\ \frac{x-0.6}{0.2}, & if\ 0.6\ \leq x\ \leq 0.8 \\ \frac{0.7-x}{0.2}, & if\ 0.6\ \leq x\ \leq 0.7 \\ 0, & if\ x\ \geq 0.7 \end{cases} \quad (4.3)$$

$$very\ severe\ (x) = \begin{cases} 0 & if\ x\ \leq 0.8 \\ \frac{x-0.8}{0.2} & if\ 0.8\ \leq x\ \leq 1.0 \\ \frac{0.2-x}{0.1} & if\ 0.1\ \leq x\ \leq 0.2 \\ 0 & if\ x\ \geq 0.2 \end{cases} \quad (4.4)$$

The next step in the fuzzification process is the development of fuzzy rules. The fuzzy rules for this research were developed with the assistance of domain experts (five medical doctors). The knowledge base of Fuzzy Expert System for Malaria Management (FESMM) has so many fuzzy rules designed with the aid of combination theory- only valid rules were chosen by the domain experts. A rule is said to fire if any of the precedence parameters (mild, moderate, severe, very severe) evaluate to true (1); otherwise, if all the parameters evaluate to false (0), it does not fire.

5.0 Conclusion

The use of fuzzy logic for medical diagnosis provides an efficient way to assist inexperienced physicians to arrive at the final diagnosis of malaria more quickly and efficiently. The developed fuzzy logic based medical diagnostic system provides a decision support platform to assist malaria researchers, physicians and other health practitioners in malaria endemic regions. We believe that the approach proposed in this study, if used intelligently, could be an effective technique for diagnosing malaria. Furthermore, implementation of the system would reduce doctors' workload during consultation and ease other problems associated with hospital consultations.

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