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MEDICAL DIAGNOSIS OF MALARIA USING FUZZY APPROACH

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Abstract: Malaria embodies major public health problems in the world. One of the chief hitches that both the developed and under-developed countries including India are facing is the difficulties of treating malaria. The harmful effects of malaria parasites to the human body cannot be undervalued. Deadly and life-threatening vivax malaria is increasingly reported from India. This paper talks about the development of a medical diagnostic system for malaria using "Fuzzy expert system for the management of malaria (FESMM)" so as to enhance the accuracy and meticulousness of medical diagnosis of malaria and was presented for providing decision support platform to malaria researchers, physicians and other healthcare practitioners in malaria endemic regions. The established FESMM comprises of four main components, which include the "Knowledge base", "Fuzzification", "Inference engine" and "Defuzzification" components. The fuzzy inference procedure engaged in this research is the "Root Sum Square (RSS)" method. The Root Sum Square of drawing inference was engaged to infer the data from the fuzzy rules developed. The degree of participation of each input parameter and the defuzzification procedure engaged in this research is the Centre of Gravity (CoG) which is shown by using triangular membership function. The fuzzy expert system was designed based on clinical observations, medical diagnosis and the expert's knowledge and the data collected from other researchers.

Index Terms **- Malaria, Fuzzy Expert system, Knowledge base, Fuzzification, Root sum square, Defuzzification, Medical Diagnosis.**

I. INTRODUCTION

Malaria has always tested humanity by bearing the burden on socio-economic stability of a community. Plasmodium falciparum. P. falciparum along with three other p. vivax, p.ovale, and p. malariae are the main cause of the parasitic disease Malaria, they are mainly diffused by around 30 to 40 species of Anopheles mosquitos. In the research done by the WHO, out of about 1.4 billion people living in 11 countries (land area 8,466,600 km2 , i.e. 6% of global area), 1.2 billion are bare to the risk of malaria and most of whom live in India (Kondrachine 1992).Conversely, the southeast Asia contributed only 2.5 million cases to the global burden of malaria. Of this, India alone contributed 76% of the total cases. Taking into account clinical episodes, it has now been estimated with the help of epidemiological models, geographical and demographic data that P. falciparum estimates outside Africa, especially in south-east Asia are 200% higher than that reported by the World Health Organization, i.e. 118.94 million out of global estimations of 515 million cases (Snow et al 2005). In toting to this, affliction of P. vivax malaria in the world has been evaluated at 71–80 million cases of which south-east Asia and western pacific countries contributed 42 million cases (Mendis et al 2001). The development of disorder prognosis and management is complex due to the numerous variables involved. It is made greater so because of a lot of imprecision and uncertainties. Patients cannot describe precisely how they feel, docs and nurses cannot tell exactly what they observe, and laboratories outcomes are dotted with some mistakes brought on either by the carelessness of technicians or malfunctioning of the instrument. Medical researchers are liable to making choice errors, due to high complexity of medical issues and due to perceptive limitations. Making up expertise is required even to remedy reputedly simple troubles. A physician is required to recall and apply understanding of a massive array of entities like sickness presentations, diagnostic parameters, drug combos and guidelines. However, the physician's cognitive capabilities are restricted due to factors like multi-tasking, limited reasoning and memory capacity. All those complexities in medical practice make traditional quantitative approaches of evaluation inappropriate. Computer tools assist to prepare, store data and retrieve appropriate medical knowledge needed by the practitioner in in addressing each hard case and suggesting appropriate diagnosing, prognosis, therapeutic choices and decision-making technique.

An Expert System (ES) is an intelligent pc application that uses the knowledge -base of one or extra experts and inference methods for trouble solving. Figure 1 below depicts a typical ES architecture. Human professionals solve problems by using a combination of factual knowledge and reasoning capacity. In the expert system, these two essentials are contained in two separate however related components: a knowledge base and an inference engine. The knowledge base affords specific information and guidelines about the subject and the inference engine affords the reasoning capability that permits the expert system to shape conclusions.

Expert systems also provide additional tools in the shape of consumer interface and rationalization facilities. User interfaces, as with any utility, allow humans to shape queries, offer information and engage with the device. Explanation facilities, a fascinating part of expert system, permit the system to give an explanation for or justify their conclusions, and they allow developers to check at the operation of the system themselves. The concept of fuzzy logic is followed in this research due to its ability to makes 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 human decision making with its 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.

In this research, we developed a fuzzy expert system for the management of malaria (FESMM). FESMM was design based on clinical observations, medical diagnosis and the expert's knowledge. The objective of the system is to provide a decision support platform to malaria researchers, physicians and other healthcare practitioners in malaria endemic regions. In addition, the system will assist medical personnel in the tedious and complication task of diagnosing and further provide a scheme that will assist medical personnel especially in rural areas, where there are shortages of doctors, thereby, offering primary health care to the people.

I. RESEARCH METHODOLOGY

3.1 What is Fuzzy logic?

Fuzzy logic is a system that extracts specific from what is obscure inside the world of medicine from the records accumulated from research using natural language. It is determined as set of mathematical principles for understanding representation based totally on stages of membership rather than on crisp membership of classical binary logic. Fuzzy logic systems are first rate in taking care of ambiguous and imprecise statistics customary in medical and to stepped forward tractability, robustness and low-cost solutions for actual world problems. Fuzzy set and fuzzy logic founded by using makes it viable to outline inexact medical entities as fuzzy set. Fuzzy logic methodology gives a simple way to reach at a specific conclusion from vague, imprecise and ambiguous clinical statistics. Medical analysis of malaria is an incredible instance of vagueness and uncertainty. Fuzzy set theory is a response to the call for thoughts and approaches for dealing with nonstatistical uncertainty. The procedure of fuzzification required two fundamental levels which consist of derivation of the membership functions for both the input and the output variables along the linguistic representation of their functions. Membership function chosen for this research is triangular membership functions because of the variation in the statistics of data representing the enter or input variables. Input variables used for development of the fuzzy logic model for malaria danger prediction used some of triangular membership functions that become proportional and same to the wide variety of values of each respective variable taken into consideration for threat of malaria.
The fuzzy set is represented by a membership function, defined as follows:

$$\alpha_{A}: X \rightarrow [0,1] \quad \text{..........(1)}$$

$$\alpha_A(X) = 1 \quad \text{if x is totally in A}$$

$$\alpha_A(X) = 0 \quad \text{if x is not in A}$$

$$0 < \alpha_A(X) < 1 \quad \text{if x is partially in A.}$$

$\alpha_A(X)$ expresses to which the value x belongs to the fuzzy set A. The value of corresponds to the absolute non-membership and the value 1 corresponds to the absolute membership. Therefore, a fuzzy membership function $\alpha_A(X)$ indicates the degree of belonging to some element z of the universe of discourse Y. It maps each element of Y to a membership grade between 0 and 1 in various shapes such as Triangular, Trapezoidal, Sigmoid and Gaussian. Triangular membership function which is widely used will be used in this research. Triangular membership function can be calculated as follows:

$$\alpha_A(X) = \begin{cases} 0 & \text{if } z \leq l \\ \frac{z-l}{n-l} & \text{if } z \in [l, n] \\ \frac{m-z}{n-m} & \text{if } z \in [m, n] \end{cases}$$

if $z \geq n$

where l, m, and n have been defined by experts' doctors. Figure 2 below shows a crisp and a fuzzy representation of a fuzzy set defined by triangular membership function of the attribute age of a patient.

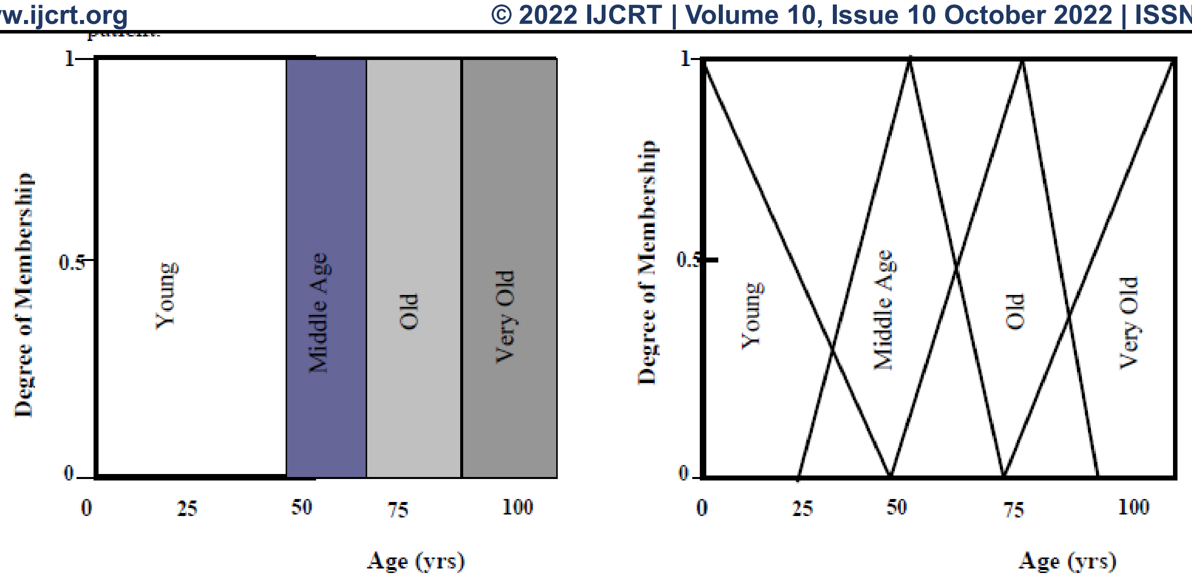


Figure 2: Crisp (left) and fuzzy (right) sets of Young, Middle Age, Old and Very Old (Crisp and Fuzzy set of Patients' Age with their Linguistics Variables)

It is common to describe fuzzy variables as linguistic variables. The linguistics variables that we will use in this research are mild, moderate, severe and very severe for both the input and output parameters in the fuzzy model. By using those linguistic variables, fuzzy if-then rules which are the main output of the fuzzy system would be set up: generally presented in the form of: if x is A then y is B where x and y are linguistic variables and A and B are linguistic values, determined by their fuzzy sets. The first part of the rule is called the antecedent, and can consist of multiple parts with the operators AND or OR between them. The latter part is called the consequent, and can also include several outputs.

3.2 FUZZY EXPERT SYSTEM

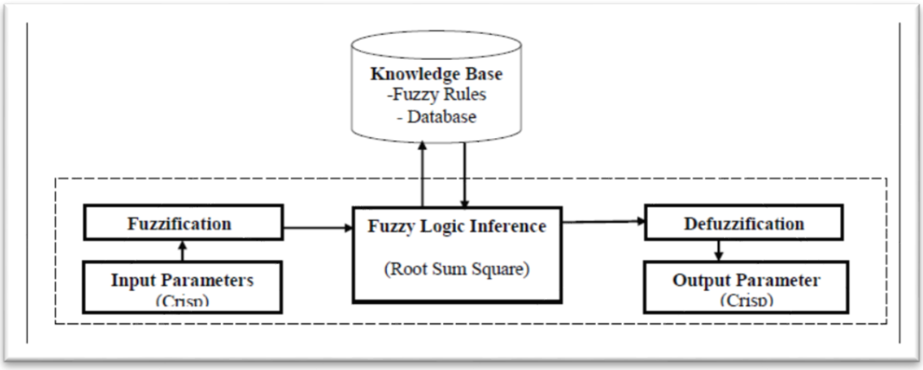
The achievement of a Fuzzy Expert System relies upon upon the opinion of the domain specialists on various troubles related to the study. The domain experts recognized have been from Specialist health center Gombe and Specialist medical institution Yola in Nigeria. The developed device, christened "Fuzzy Expert System for the Management of Malaria (FESMM)" has an architecture supplied in figure three below. The improvement FESMM includes fuzzification, inference engine and defuzzification. FESMM is a rule-based gadget that uses fuzzy (approximate) logic as an alternative for that Boolean logic. It turned into developed based on the subsequent key components:

• Knowledge Base component: Knowledge is a key factor in the overall performance of sensible systems. The knowledge-base of FESMM consists of established and concise representation of the understanding of domain specialists of tropical medicine. The structured knowledge is concerned with facts, regulations and occasions of tropical diseases, which were generally agreed upon through experts within the discipline of tropical medicine. For the cause of this research, malaria as a recognized tropical ailment is considered.

• Fuzzification Component: Fuzzification is the technique of changing an actual scalar value right into a fuzzy value. This is accomplished with different styles of fuzzifiers. There are typically four sorts of fuzzifiers, which might be used for the fuzzification technique. They are: Trapezoidal fuzzifier, Triangular fuzzifiers, Singleton fuzzifier, and Gaussian fuzzifier [30]. Triangular fuzzifier which is broadly used is going to be used on this research. Fuzzification of information is executed by choosing input parameters into the horizontal axis and projecting vertically to the upper boundary of membership function to decide the degree of membership.

• Inference Engine Component: The technique of drawing end from existing records is referred to as inference. Fuzzy inference is the manner of mapping from a given input to an output by the usage of the theory of fuzzy sets [30]. The center of decision-making output is technique through the inference engine the use of the policies contained in the guideline base. The fuzzy inference engine makes use of the rules in the knowledge-base and derives conclusion base on the guidelines. FESMM inference engine uses a forward chaining mechanism to go looking for and the understanding for the signs and symptoms of a disease. For each rule, the inference mechanism appears up the club values in the situation of the rule. Fuzzy inputs are mapped into their respective weighting elements and their related linguistic variables to determine their degree of membership. The aggregation operator is used to calculate the degree of achievement or firing strength of a rule.

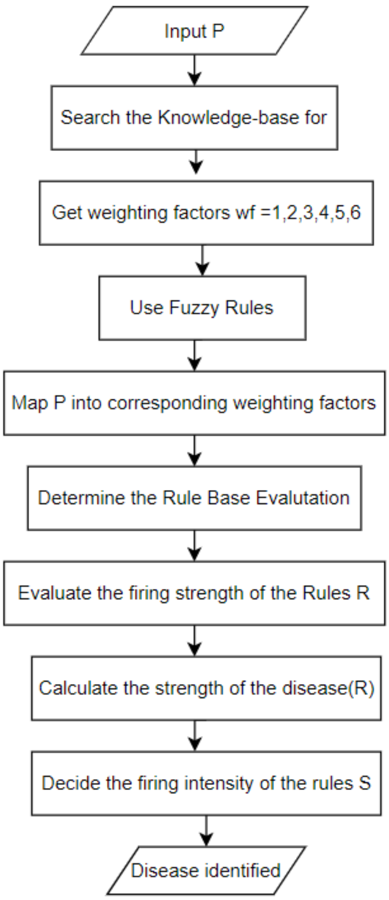
• Defuzzification Component: The defuzzification technique translates the output from the inference engine into crisp output. This is due to the reason that, the output from the inference engine is mostly a fuzzy set even as for maximum scientific medical applications, crisp values are required. The input data to the defuzzification process is a fuzzy set at the same time as the output of the defuzzification technique is a single number (crisp output). Many defuzzification techniques are proposed and four common defuzzification strategies are: center of- area (gravity), center-of-sums, max-criterion and imply of maxima



3.3 Theoretical framework THE ALGORITHM FOR FUZZY DIAGNOSIS:

- Step 1: Input parameters and signs of patient complaint is taken into the system. Where p = number of signs and symptoms.
- Step 2: Search the knowledge-base for the disease K, which has the signs and symptoms identified.
- Step 3: Get the weighing factors (wf) (the associated degree of intensity) wf = 1, 2, 3, 4,5,6. Where 1= No effect, 2 = Very mild, 3 = Mild, 4 = Moderate, 5 = Severe, 6 = Very severe.
- Step 4: Apply fuzzy rules as stated above.
- Step 5: Map the fuzzy inputs into their respective weighing factors to determine their degree of membership.
- Step 6: Determine the rule base evaluating (non-minimum values).
- Step 7: Determine the firing strength of the rules R.
- Step 8: Calculate the degree of truth R, of each rule by evaluating the nonzero minimum value.
- Step 9: Compute the intensity of the disease.
- Step 10: Output fuzzy diagnosis.

3.4 Flow Chart



3.4.1 Mathematical Equations

Descriptive Statics has been used to find the maximum, minimum, standard deviation, mean and normally distribution of the data of all the variables of the study. Normal distribution of data shows the sensitivity of the variables towards the periodic changes and speculation. When the data is not normally distributed it means that the data is sensitive towards periodic changes and speculations which create the chances of arbitrage and the investors have the chance to earn above the normal profit. But the assumption of the APT is that there should not be arbitrage in the market and the investors can earn only normal profit. Jarque bera test is used to test the normality of data.

1. THE KNOWLEDGE-BASE OF FESMM

For the purpose of this research, malaria as a known tropical disease is considered.

2. Fuzzification

The first step in the advancement of fuzzy logic based expert system is to construct fuzzy sets for the parameters. On the basis of domain experts' knowledge, both input and output parameters selected for this research were described with six linguistic variables (no effect, very mild, mild, moderate, severe and very severe). The range of fuzzy value for each linguistic is shown in table 1 below:

Table 1: Range of Fuzzy Values

Linguistic Variables	Fuzzy Values
No effect	$0 \leq x < 0.16$
Very mild	$0.16 \leq x < 0.32$
Mild	$0.32 \leq x < 0.48$
Moderate	$0.48 \leq x < 0.64$
Severe	$0.64 \leq x < 0.82$
Very severe	$0.82 \leq x \leq 1$

Fuzzification begins with the transformation of the raw data using the functions that are expressed in equations (3) to (6) below. During the process, linguistic variables are evaluated using triangular membership function and are accompany by associated degree of membership ranging from 0 to 1 as shown in equations (3) to (6) below. These formulas are determined by aid of both the expert doctors in the field of tropical medicine and literature.

$$\Phi_{\text{no effect}}(X) \begin{cases} 0 & \text{if } x \leq 0 \\ \frac{x}{0.16} & \text{if } 0 \leq x < 0. \\ \frac{0.08-x}{0.08} & \text{if } 0.08 \leq x < 0.16 \\ 0 & \text{if } y \geq 0.08 \end{cases} \quad \text{---------------------- (3)}$$

$$\Phi_{\text{very mild}}(X) \begin{cases} 0 & \text{if } x \leq 0.16 \\ \frac{x-0.16}{0.16} & \text{if } 0.16 \leq x < 0.32 \\ \frac{0.24-x}{0.08} & \text{if } 0.24 \leq x < 0.32 \\ 0 & \text{if } y \geq 0.24 \end{cases} \quad \text{-----------------------(4)}$$

$$\Phi_{\text{mild}}(X) \begin{cases} 0 & \text{if } x \leq 0.32 \\ \frac{x-0.32}{0.16} & \text{if } 0.32 \leq x < 0.48 \\ \frac{0.40-x}{0.08} & \text{if } 0.40 \leq x < 0.48 \\ 0 & \text{if } y \geq 0.40 \end{cases} \quad \text{-----------------------(5)}$$

$$\Phi_{\text{moderate}}(X) \begin{cases} 0 & \text{if } x \leq 0.48 \\ \frac{x-0.48}{0.16} & \text{if } 0.48 \leq x < 0.64 \\ \frac{0.56-x}{0.08} & \text{if } 0.56 \leq x < 0.64 \\ 0 & \text{if } y \geq 0.56 \end{cases} \quad \text{----------------------(6)}$$

$$\Phi_{\text{severe}}(X) \begin{cases} 0 & \text{if } x \leq 0.64 \\ \frac{x-0.64}{0.18} & \text{if } 0.64 \leq x < 0.82 \\ \frac{0.73-x}{0.09} & \text{if } 0.73 \leq x < 0.82 \\ 0 & \text{if } y \geq 0.73 \end{cases} \quad \text{----------------------(7)}$$

$$\Phi_{\text{very severe}}(X) \begin{cases} 0 & \text{if } x \leq 0.82 \\ \frac{x-0.82}{0.18} & \text{if } 0.82 \leq x < 1.0 \\ \frac{0.91-x}{0.09} & \text{if } 0.91 \leq x < 1.0 \\ 0 & \text{if } y \geq 0.91 \end{cases} \quad \text{----------------------(8)}$$

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 FESMM has so many fuzzy rules designed with the aid of combination theory: only the valid rules were chosen by the domain experts. Table 2 shows some of the sample fuzzy rules for malaria

IV. RESULTS AND DISCUSSION

4.1 Fuzzy Inference

For this research, we have determined to use fuzzy logical AND to assess the composite firing strength of the guidelines. In practice, the fuzzy regulations set typically have several antecedents which might be combined using fuzzy logical operators, including AND, OR and NOT, although their definitions generally tend to vary: AND simply makes use of minimal weight of all of the antecedents, while OR makes use of the maximum value. There is also the NOT operator that subtracts a membership function from 1 to offer the "complementary" function. The IF a part of a rule is called the "antecedent" and the THEN component is called the "consequent".

For the purpose of this research, the AND operator is used to mix the antecedent parts of the rules. The degree of truth (R) of the rules are decided for every rule through comparing the nonzero minimal values the use of the AND operator. The inference engine evaluates all the policies inside the rules base and combines the weighted effects of all of the relevant (fired) into a single fuzzy set. The inference engine method hired in this research is the Root Sum Square (RSS). RSS is given by means of the formulation in equation:

$$\sqrt{\sum R^2} = \sqrt{(R1^2 + R2^2 + R3^2 \ldots\ldots + Rn^2)} \qquad \text{----------------------(9)}$$

Where $R1^2 + R2^2 + R3^2 \ldots\ldots + Rn^2$ are strength values (truth values) of different rules which share the same conclusion. i.e R = value of firing rule. RSS procedure combines the consequences of all relevant rules, scales the functions at their respective magnitudes and compute the "fuzzy" centroid of the composite area. This approach is more complex mathematically than other methods, but decided on for this research due to the fact that it offers the first-rate weighted affect to all firing guidelines.

4.2 Defuzzification

The CoG is an averaging technique. The CoG defuzzification method is similar to the formula for calculating the center of gravity in physics. The difference is that, density of mass is replaced by the membership values. The CoG formula is given as:

$$\text{CoG (Y)} = \frac{\Sigma\Phi_y(x_i)x_i}{\Sigma\Phi_y(x_i)}$$

Where, $\Phi_y(x_i) =$ Membership value in the membership function and

x_i= center of membership function

The approach is adopted in this research because it is computationally simple and intuitively plausible.

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