FUZZY EXPERT SYSTEM FOR IDENTIFYING AND ESTIMATING THE LEVEL OF VERY SEVERE AND UNCOMPLICATED PLASMODIUM FALCIPARUM MALARIA DISEASE (VSUPFMD)

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Abstract: Plasmodium falciparum malaria causes the most serious form of the disease, and is common in the tropical areas. Infections with this parasite can be fatal in the absence of prompt recognition of the disease and its complications, and also due to the people negligence of their common silly symptom like fever, and urgent appropriate patient treatment. The situation is complicated by the increasing occurrence of P-Falciparum parasites that are resistant to chloroquine and antimalarial drugs. Prompt action is especially important for high-risk groups such as young children and pregnant women. Very-Severe malaria is caused by Plasmodium falciparum infection and usually occurs as a result of delay in treating an uncomplicated attack of falciparum malaria. Sometimes, however, especially in children, very severe malaria may develop very rapidly. Recognizing and promptly treating uncomplicated P-falciparum malaria is therefore of vital importance. Identifying and Estimating the level of Very-Severe malaria complicated P-Falciparum disease patients groups Datas collected by the different Hospitals and symptoms Analyzes of patients different Age-groups and their study by using fuzzy expert system under the guidance of four Expert physicians. Fuzzy logic technology provides a simple way to arrive at a definite conclusion from vague, ambiguous and imprecise data. Our proposed knowledge based diagnosis system can be used to find a permanent solution to the effective and efficient treatment of this disease. The system facilitates the experts, doctors and lab technicians to determine his/her patient's probable diseases very quickly with the aid of a knowledge base expert system.

Key Words: Fuzzy Logic, Simple Fuzzy Models, Fuzzy expert system, Fuzzy Inferance System, Triangular Fuzzifier, Trapezoidal Fuzzifier, Linguistic Variables, Root Sum Square (RSS) Method.

Introduction: Fuzzy Expert System Model

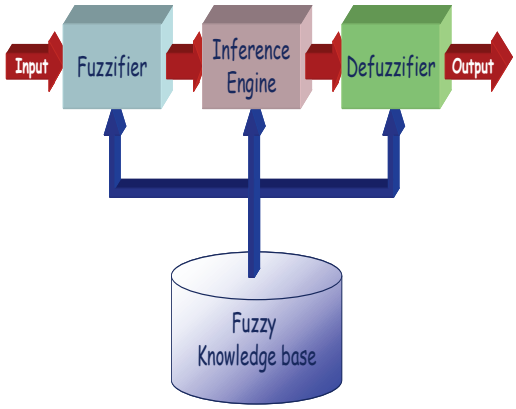

Figure-01:- Architecture of an Expert System

The Data base and the CETD-Matrix method are jointly referred to as the Fuzzy knowledge base system

- a rule base containing a number of fuzzy IF–THEN rules;
- a database which defines the membership functions of the fuzzy sets used in the fuzzy rules
- The steps of fuzzy reasoning (inference operations upon fuzzy IF–THEN rules) performed by FISs are:- Compare the input variables with the membership functions on the antecedent part to obtain the membership values of each linguistic label. (This step is often called fuzzification.)
- Combine (usually multiplication or min) the membership values on the premise part to get firing strength (deree of fullfillment) of each rule.
- Generate the qualified consequents (either fuzzy or crisp) or each rule depending on the firing strength.
- Aggregate the qualified consequents to produce a crisp output.

Very-Severe malaria is caused by Plasmodium falciparum infection and usually occurs as a result of delay in treating an uncomplicated attack of falciparum malaria. Sometimes, however, especially in children, very severe malaria may develop very rapidly. Recognizing and promptly treating uncomplicated P-falciparum malaria is therefore of vital importance.

Uncomplicated Malaria: The presentation of uncomplicated p-falciparum malaria is very variable and mimics that of many other diseases. Although fever is common, it is absent in some cases. The fever is initially persistent rather than tertian (Spikes of fever on alternate days). The expectation that p-falciparum malaria should have a tertian fever may lead to the diagnosis of malaria being missed with a consequent delay in treatment. The fever may or may not be a complicated by rigors. True regors are relatively unusual in acute falciparum malaria.

Fuzzy Sets and Membership Function: Zadeh introduced the term *fuzzy logic* in his seminal work "Fuzzy sets," which described the mathematics of

fuzzy set theory (1965). Plato laid the foundation for what would become fuzzy logic, indicating that there was a third region beyond True and False. It was Lukasiewicz who first proposed a systematic alternative to the bivalued logic of Aristotle. The third value Lukasiewicz proposed can be best translated as "possible," and he assigned it a numeric value between True and False. Later he explored four-valued logic and five-valued logic, and then he declared that, in principle, there was nothing to prevent the derivation of infinite-valued logic. A fuzzy set is an extension of a crisp set. Crisp sets allow only full membership or no membership at all, whereas fuzzy sets allow partial membership. In a crisp set, membership or non-membership of element *x* in set *A* is described by a characteristic function. μ_A (X)

Where μ_A (X) = 1: if x is totally in A

μ_A (X) = 0: if x is not in A

Fuzzy set theory extends this concept by defining partial membership. A fuzzy set *A* on a universe of discourse *U* is characterized by a membership function μ_A (x) that takes values in the interval [0,1]. Fuzzy sets represent commonsense linguistic labels like *slow, fast, small, large, heavy, low, medium, high, tall,* etc. A given element can be a member of more than one fuzzy set at a time. A fuzzy set *A* in *U* may be represented as a set of ordered pairs. Each pair consists of a generic element *x* and its grade of membership function i.e, A $= \{(x, (\mu_A\ (x)) \mid x \in U\ \}$, x is called a support value μ_A (x) > 0. A linguistic variable *x* in the universe of discourse *U* is characterized by

T(x) = $\{T_x^1, T_x^2, T_x^3, - - - - T_X^k\}$

And $\mu(x) = \{\mu_x^1, \mu_x^2, \mu_x^3, - - - - \mu_X^k\}$

Where T(x) is the term set of X i.e., the set of names of linguistic values of *x*, with each *Txi* being a fuzzy number with membership function μ_x^i defined on *U*. For example, if *x* indicates height, then T(x) may refer to sets such as *short, medium,* or *tall* to describe height, we can use three term values such as *short, average,* and *tall*. In practice, the terms *short, medium,* and *tall* are not used in the strict sense. Instead, they imply a smooth transition. Various types of membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions. Figure (4) shows trapezoidal membership functions.

Triangular Membership function:-It is represented using three variables p, q and r in the hip X-axis where p and r are the lower boundary and the upper boundary respectively who membership degree is zero and q is the center where the membership degree is one. A simple triangular membership plot has been shown in fig-1.

Membership Degree (x) =

$$\mu_A\ (X) = \begin{cases} 0 & if\ x \le p \\ \frac{x-p}{q-p} & if\ x \in [p,q] \\ \frac{r-x}{r-q} & if\ x \in [r,q] \\ 0 & if\ x \ge r \end{cases} \quad \text{---------- (1)}$$

Trapezoidal curves depend on five parameters and are given by

Membership Degree (x) =

$$\mu_A\ (X) = \begin{cases} 0 & if \quad x < p \\ \frac{x-p}{q-p} & if \quad p \le x \le q \\ 1 & if \quad q \le x \le r \\ \frac{s-x}{s-r} & if\ r \le x \le s \\ 0 & if \quad x \ge s \end{cases} \quad \text{---------- (2)}$$

Fuzzy Inference System: A fuzzy inference system (FIS) essentially defines a nonlinear mapping of the input data vector into a scalar output, using fuzzy rules. FIS contains four components: the fuzzifier, inference engine, rule base, and defuzzifier. The rule base contains linguistic rules that are provided by experts. It is also possible to extract rules from numeric data. Fuzzy sets that represent the output of each rule are combined into a single fuzzy set. Fuzzy rules are fired in parallel, which is one of the important aspects of an FIS

Algorithm for Fuzzy Expert Diagnosis (AFED): The proposed expert system assist by expert Doctors in the diagnosis of the diseases the patient might have, in a fuzzy way. Based on the patient complaints, the signs and symptoms are input into the system, according to the selection the fuzzy expert system diagnosis diseases based on its knowledge. The algorithm for the proposed system is adapted from following steps.

Flow chart of FDOM

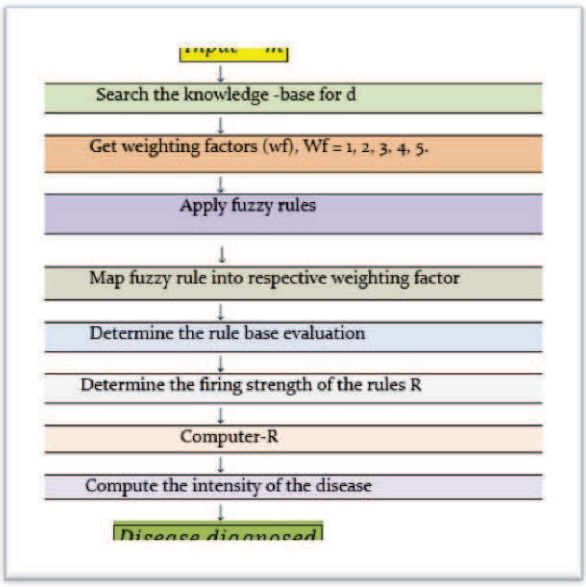

Figure-4: Flow Diagram of Fuzzy Diagnosis of Malaria.

Step 1: Input signs and symptoms of patient complaint into the system. Where P = number of signs and symptoms.
Step 2: Search the knowledge-base for the disease malaria whether it matches the signs and symptoms identified.
Step 3: Get the associated degree of intensity (weighing factor) degree = 1, 2, 3, 4, and 5. Where 1 =Very- Mild, 2 = Mild, 3 = Moderate, 4 = Severe, 5 = Very-Severe.
Step 4: Apply fuzzy rules.
Step 5: Map 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 rules by evaluating the nonzero minimum value.
Step 9: Compute the intensity of the disease.
Step 10: Output fuzzy diagnosis. (Non-zero minimum values)

Fuzzification: Fuzzification is a process that determines the degree of membership to the fuzzy set based on fuzzy membership function. This is achieved with different types of fuzzifiers. Usually there are four types of fuzzifiers,

1. Triangular fuzzifier
2. Trapezoidal fuzzifier

Triangular fuzzifier is widely used in research.
The first step is to create a fuzzy set of the parameters. This is shown by an equations (3) to (6) below. On the basis of domain experts' knowledge both input and output parameters selected for this research. The parameters will be described with four linguistic variables (mild, moderate, severe and very severe which range shown in table below). The degree of membership for a fuzzy system is of the range [0,1]. A range of the fuzzy value using the linguistic variables will be determined by the expert. Range of fuzzy values shown in table-01 below.

Table-01: Range of Fuzzy values

Linguistic Variables	Fuzzy Values
Very-Mild Sever Malaria	$0.1 \le X < 0.3$
Mild Severe Malaria	$0.3 \le X \le 0.5$
Moderate Severe Malaria	$0.5 \le X \le 0.7$
Severe Malaria	$0.7 \le X \le 0.9$
Very-Severe Severe Malaria	$0.9 \le X < 1.0$

The fuzzy rule will be developed with the assistance of the domain expert. Fuzzification process begins with the transformation of the raw data using the functions that are expressed in equations (3) and (6) below During the process, Linguistic variables are evaluated using Trapezoidal membership function and are accompany by associated degree of membership ranging from [0.1] as shown in equation (3) to (6) below. These formulas are determined by aid of both expert doctors in the field of tropical medicine and literature.

$$\mu_{Very\ mild}(X) = \begin{cases} 0 & if\ 0 \le x < 0.1 \\ \frac{x-p}{q-p} & if\ 0.1 \le x \le 0.15 \\ 1 & if\ 0.15 \le x \le 0.2 \\ \frac{s-x}{s-r} & if\ 0.2 \le x \le 0.25 \\ 0 & if\ 0.25 \le x \le 0 \end{cases} \quad \text{---- (3)}$$

$$\mu_{mild}(X) = \begin{cases} 0 & if\ 0.25 \le x < 0.3 \\ \frac{x-p}{q-p} & if\ 0.3 \le x \le 0.35 \\ 1 & if\ 0.35 \le x \le 0.4 \\ \frac{s-x}{s-r} & if\ 0.4 \le x \le 0.45 \\ 0 & if\ 0.45 \le x \le 0 \end{cases} \quad \text{------ (4)}$$

$$\mu_{Moderate}(X) = \begin{cases} 0 & if\ 0.45 \le x < 0.5 \\ \frac{x-p}{q-p} & if\ 0.5 \le x \le 0.55 \\ 1 & if\ 0.55 \le x \le 0.6 \\ \frac{s-x}{s-r} & if\ 0.6 \le x \le 0.65 \\ 0 & if\ 0.65 \le x \le 0 \end{cases} \quad \text{---- (5)}$$

$$\mu_{Severe}(X) = \begin{cases} 0 & if\ 0.65 \le x < 0.7 \\ \frac{x-p}{q-p} & if\ 0.7 \le x \le 0.75 \\ 1 & if\ 0.75 \le x \le 0.8 \\ \frac{s-x}{s-r} & if\ 0.8 \le x \le 0.85 \\ 0 & if\ 0.8 \le x \le 0 \end{cases} \quad \text{------ (6)}$$

$$\mu_{Very-Severe}(X) = \begin{cases} 0 & if\ 0.85 \le x < 0.9 \\ \frac{x-p}{q-p} & if\ 0.9 \le x \le 0.95 \\ 1 & if\ 0.85 \le x \le 1.00 \\ \frac{s-x}{s-r} & if\ 0.95 \le x \le 1.00 \\ 0 & if\ 0.95 \le x \le 0 \end{cases} \quad (7)$$

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 (four-medical doctors). The knowledge base of (VSUPFMD) 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.

Table 02: Fuzzy Rule Base for Very-Severe Malaria

Rule No	Fever	H-Fever	Headache	Nausea	Enlarge Liver	Jaundice	Joint pain	Dizziness	Conclusion
01	V-Severe	Moderate	Mild	Severe	V-Severe	Moderate	Severe	Moderate	Moderate
02	Severe	Mild	Moderate	Moderate	Severe	V-Severe	Severe	V-Mild	Severe
03	V-Mild	Mild	Moderate	Moderate	V-Severe	Severe	V-Severe	V-Severe	Severe
04	Severe	Moderate	Severe	Severe	Moderate	Severe	V-Mild	Moderate	V-Severe
05	Moderate	Severe	V-Severe	Mild	V-Mild	Mild	Severe	Mild	Severe
06	Severe	V-Mild	Severe	Moderate	Moderate	Severe	V-Severe	Moderate	Moderate
07	V-Severe	Severe	V-Severe	Severe	Severe	V-Severe	Moderate	Moderate	V-Severe
08	Mild	V-Severe	Mild	Moderate	Severe	Severe	Mild	V-Mild	V-Severe
09	Moderate	Mild	V-Severe	Mild	Moderate	Mild	Moderate	V-Severe	Moderate
10	Severe	Severe	Severe	Mild	Moderate	Severe	Moderate	Severe	Severe
11	Moderate	V-Mild	Severe	Moderate	Moderate	Moderate	Moderate	Mild	Moderate
12	Severe	V-Severe	V-Mild	Severe	Moderate	Severe	Severe	Severe	V-Severe
13	Moderate	V-Mild	Severe	Moderate	V-Severe	Moderate	V-Severe	Severe	V-Severe
14	Mild	Moderate	Moderate	V-Severe	Severe	Moderate	Moderate	V-Severe	Severe
15	Mild	Moderate	V-Mild	Moderate	Moderate	Moderate	Severe	Mild	Moderate
16	Severe	V-Severe	V-Mild	Moderate	Severe	V-Severe	Moderate	V-Severe	V-Severe
17	Mild	Moderate	V-Severe	Severe	Moderate	Severe	Moderae	V-Severe	Moderate
18	Mild	V-Mild	Moderate	Mild	Mild	Severe	V-Severe	Moderate	Mild
19	Severe	V-Severe	Mild	V-Severe	Mild	Moderate	Mild	Severe	V-Severe
20	Mild	Severe	V-Severe	Severe	Moderate	Severe	V-Severe	Moderate	V-Severe

Next step in the fuzzification process is the development of fuzzy rules. The fuzzy rules for this research where developed with the assistance of domain experts four-medical doctors. Table-2 above shows sample fuzzy rules base for complicated-uncomplicated malaria some sample of the rule.

1. Very-Mild Sever Malaria: Rule-Numbers-(NIL)
2. Mild-Malaria Rule-Numbers are (Rule-18)
3. Moderate-Malaria (Rule-01, 06, 09, 11, 15, 17)
4. Severe-Malaria (Rule-02, 03, 05, 10, 14,)
5. Very-Severe-Malaria (Rule-4, 07, 08, 12, 13, 16, 19, 20)
6. Very-Mild severe malaria-Nil

Mild-Malaria: Rule-18: If fever =mild, and H-fever = V-mild, Headache = moderate, Nausea = mild, Enlarge liver =mild, Jaundice=severe, joint-pain=V-severe, Dizziness=moderate. Then conclusion-Mild.

Moderate-Malaria:

1. Rule-01: If fever = very-mild, and H-fever = moderate, headache = mild, Nausea = severe,

Enlarge liver = very-severe, Jaundice = moderate, joint-pain = severe, Dizziness = moderate. Then conclusion, Severe- Malaria = moderate.

2. Rule-06: If fever = severe, and H-fever = V-mild, Headache = severe, Nausea = moderate, Enlarge-Liver = moderate, Jaundice= sever, joint-pain= v-severe, Dizziness= moderate, Then conclusion, Severe- Malaria = moderate.
3. Rule-09: If fever = moderate, and H-fever = mild, Headache = Very-severe, Nausea = mild, Enlarge-Liver = moderate, Jaundice = mild, joint-pain = moderate, Dizziness = V-Severe, Then conclusion, Severe-Malaria = moderate.
4. Rule-11: If fever = moderate, and (H-fever = V-mild, Headache = severe, Nausea = moderate, Enlarge-liver = moderate, Jaundice = moderate, joint-pain = moderate, Dizziness = mild, Then conclusion, Malaria = moderate.
5. Rule-15: if Fever = mild, H-Fever = moderate, Headache = V-Mild, Nausea = moderate, Enlarge-Liver = moderate, Jaundice = moderate, Joint pain = Severe, Dizziness = Mild. Then conclusion = Moderate.

Severe-Malaria:

1. Rule-2: If fever = Severe, and H-fever = mild, Headache = moderate, Nausea = moderate, Enlarge-liver = Severe, Jaundice = very-sever, joint-pain = severe, body Dizziness = V-mild, Then conclusion, Malaria = severe.
2. Rule-3: If fever = Very-mild, and H-Fever = Mild, headache = moderate, nausea = Moderate, Enlarge-liver = Very-sever, Jaundice = severe, joint-pain = V-severe, dizziness = V-severe. Then conclusion, Malaria = severe.
3. Rule-5: If fever = v-severe, and H-Fever = sever, headache = V- severe, nausea = mild, vomiting = mild, Enlarge liver = Very-mild, cough = mild, joint-pain = Severe, dizziness = Mild, Jaundice = Mild, Then conclusion, Malaria = severe.
4. d) Rule-10: If fever = severe, H-Fever = Severe, headache = Severe, nausea = Mild, Liver-enlarge = Moderate, Jaundice = sever, =mild, Joint pain=moderate, dizziness = severe. Then conclusion, Malaria = severe.

Very-Severe-Malaria: Rule-04: Fever = severe, H-Fever = Moderate, Headache = Severe, Nausea = Severe, Enlarge-Liver = moderate, Jaundice = severe, Joint pain = V-mild, Dizziness = moderate etc.

Fuzzy Inference: The inference engine controls how the rules are applied towards facts. This is the part of rule-based expert system that makes inferences. It decides which rules are satisfied by facts and controls overall execution. Also, it matches the facts against the rules to see what rules are applicable. VSUPFMD Inference engine uses a forward chaining mechanism to search the knowledge for the symptoms of a disease. For each rule, the inference mechanism looks up the membership values in the condition of the rule. Fuzzy inputs are mapped into their respective weighting factors and their associated linguistic variables to determine their degree of membership. Therefore the system will make use of forward chaining reasoning; it would make use of the facts given by the patient to diagnose the problem. Rules are used in the knowledge-base by the fuzzy inference engine to derive conclusion based on the rules.

The inference engine evaluates all the rules in the rule base and combines the weighted consequences of all the relevant (fired) in to a single fuzzy set. The inference engine technique employed in this research is the Root Sum Square (RSS). RSS is given by the formula

$$\sqrt{\sum R^2} = \sqrt{(R_1^2 + R_2^2 + R_3^2 + R_4^2 + \cdots + R_n^2 + R_{n+1}^2)} \quad (7)$$

Where

$R_1^2 + R_2^2 + R_3^2 + R_4^2 + \cdots\cdots\cdots + R_n^2 + R_{n+1}^2$

are strength values (truth values) of different rules which share the same conclusion, i.e. R= Values of firing rules. RSS combines method the effects of applicable rules, scales the functions at their respective magnitudes and compute the "Fuzzy" centered of the composite area. This method is more complicated mathematically then other methods, but selected for this research since it gives best weighted influence to all firing rules. Examples of the rule base evaluation for patient NO-03 and patient No-20 are presented in section table 6 and 7 below. The RSS of drawing inference was found to be the most suitable technique to infer data from the rules developed.

Defuzification: A task of defuzzification is to map a fuzzy output to crisp-output of the system. A number of defuzzification strategies exist, and it is not hard to invent more. Each provide a means to choose a single output (which is denoted as Zj) based on the implied fuzzy sets. The input for defuzzification is the fuzzy set (the aggregate output fuzzy set) and the output is a crisp number. Defuzzification can be obtained using three known ways:

1. The mean of maximum method
2. The maximizing decision method
3. The center of gravity method

The defuzzification process translates the output from the inference engine in to crisp output. This is due to the fact that, the output from the inference engine is usually a fuzzy set while for most medical applications, crisp values are required. The input to the defuzzification process is a fuzzy set while the output of the defuzzification process is single number (crisp output). Many defuzzification techniques the above 3- methods proposed and four common defuzzification technique are as follows:

1. Centre of area (gravity)

2. Centre of sums
3. Max-criterion and
4. Mean of maxima.

The center of area: [also referred as center - of-gravity (COG) or the centroid method] is the most widely used technique because when it is used, the defuzzified values tend to move smoothly around the fuzzy output region, thus giving a more accurate representation of fuzzy set of any shape. The center of gravity (COG) often uses discrete variables so that COG, Z_K can be approximated to overcome its disadvantage as shown in equation (8) whereas *the max-criterion* produces the point at which the possibility distribution of the action reaches a maximum value and it is simplest to implement. Below which uses weighted average of the centers of the fuzzy set instead of integration. The COG is an averaging technique.

Popular method is used for defuzzification. A crisp output Z j is chosen using the center of area and area of each implied fuzzy set and is given by

$$Z_K = \frac{\sum_{j=1} W_{jk} Y_j}{\sum_{j=1} Y_j} \text{ ---------- (8)}$$

Where, Z_K is determined by means of a gravity center of the area under the membership function curve of the Fuzzy output and Y_j is a membership grade.

Research-Experiment: Patients states of health with respect to severe-malaria was evaluated by the domain experts based on signs, symptoms and investigations. The intensity of signs, symptoms and investigation was rated as Very-Mild = 1, Mild = 2, Moderate = 3, Severe = 4 and Very-Severe = 5.

Table-03 below shows the weights assigned to patients after an interactive session with the expert doctors.

Table-03: Fuzzy Rule Base for Very-Severe Malaria.

Rule No	Fever	H-Fever	Head ache	Nausea	Enlarge Liver	Jaundice	Joint pain	Dizziness	Conclusion
01	1	3	2	4	5	3	4	3	3
02	4	2	3	3	4	5	4	1	4
03	1	2	3	3	5	4	5	5	5
04	4	3	4	4	3	4	1	3	5
05	3	4	5	2	1	2	4	2	4
06	4	1	4	2	2	4	5	3	3
07	5	4	5	4	4	5	3	3	5
08	2	5	2	3	4	4	2	1	5
09	3	2	5	2	3	2	3	5	3
10	4	4	4	2	3	4	3	4	4
11	3	1	4	3	3	3	3	2	3
12	4	5	1	4	3	4	4	4	5
13	3	1	4	3	5	3	5	4	5
14	2	3	3	5	4	3	3	5	4
15	2	3	1	3	3	3	4	2	3
16	4	5	1	3	4	5	3	5	5
17	2	3	5	4	3	4	3	5	3
18	2	1	3	2	2	4	5	3	2
19	4	5	2	5	2	3	2	4	5
20	2	4	5	4	3	4	5	3	5

From the above table- 03, Implies that the linguistic variable (Very-Mild, Mild, Moderate, Severe, and Very-severe) respective symptoms are still Vague and Ambiguous to have a patient has Fever → mild or moderate, Headache → severe or very-severe, Joint-pain → mild or severe etc. It is of supreme importance to define the degree to which one can say that Sign/symptom is Very-mild, Mild, Moderate, Severe, and very-severe. This is done with the help of a fuzzifier employed in this research is the Trapezoidal fuzzifier see equation (2) above.

In Table-04 below that the expert Doctor applied weighing factors rated as 1,2,3,4 and 5 for Very-Mild, Mild, Moderate, Severe and Very-severe linguistic variables of Sever-malaria patients. i.e. The intensity of signs/ symptoms and their investigation was rated as {Very-Mild = 1, Mild = 2, Moderate = 3, Severe =4 and Very-Severe = 5 these are known as Trapezoidal Fuzzy values from Table-03}. Now evaluate the Trapeziodal - fuzzy numbers, by simple fuzzy technique. Since we denoted as Trapezoidal Fuzzy Number = M, Trapezoidal Fuzzy value = P, Total Number of Weighing factors = N.

Equation of Triangular Fuzzy Number is constructed as

Trapezoidal fuzzy numbers

$$= \frac{\text{(Trapezoidal fuzzy Values) - 1}}{\text{Total Number of Weighing Factors}} \text{ ---------- (9)}$$

i.e. $M = \frac{P-1}{N}$ ---------- (10)

For example a patient No-04 he/she has Liver-enlarge and Joint pain So a medical doctor Assigned weighing factors 4 (out of 5) value to these symptoms. Now evaluate the Intensity (Degree) of Very- severe and moderate malaria of patient No-04 from equation (10) above

$M = \frac{5-1}{5} = 0.8$ and $M = \frac{4-1}{5} = 0.6$

Very-Severe = 0.8, and Severe = 0.6, Moderate = 0.4, Mild = 0.2 and Very-Mild = 0.0 respectively, hence Trapezoidal Fuzzy numbers as shown in Table- No-04 using Table-No-03.

Table-04: Trapezoidal Fuzzy Numbers for Severe-malaria.

Rule No	Fever	H-Fever	Headache	Nausea	Enlarge Liver	Jaundice	Joint pain	Dizziness	Conclusion
01	0.0	0.4	0.2	0.6	0.8	0.4	0.6	0.4	0.4
02	0.6	0.2	0.4	0.4	0.6	0.8	0.6	0.0	0.6
03	0.0	0.2	0.4	0.4	0.8	0.6	0.8	0.8	0.8
04	0.6	0.4	0.6	0.6	0.4	0.6	0.0	0.6	0.8
05	0.4	0.6	0.8	0.2	0.0	0.2	0.6	0.2	0.6
06	0.6	0.0	0.6	0.2	0.2	0.6	0.8	0.4	0.4
07	0.8	0.6	0.8	0.6	0.6	0.8	0.4	0.4	0.8
08	0.2	0.8	0.2	0.4	0.6	0.6	0.2	0.0	0.8
09	0.4	0.2	0.8	0.2	0.6	0.2	0.4	0.8	0.4
10	0.6	0.6	0.6	0.2	0.4	0.6	0.4	0.6	0.6
11	0.4	0.0	0.6	0.4	0.4	0.4	0.4	0.2	0.4
12	0.6	0.8	0.0	0.6	0.4	0.6	0.6	0.6	0.8
13	0.4	0.0	0.6	0.4	0.8	0.4	0.8	0.6	0.8
14	0.2	0.4	0.4	0.8	0.6	0.4	0.4	0.8	0.6
15	0.2	0.4	0.0	0.4	0.4	0.4	0.6	0.2	0.4
16	0.6	0.8	0.0	0.4	0.6	0.8	0.4	0.8	0.8
17	0.2	0.4	0.8	0.4	0.4	0.6	0.4	0.8	0.4
18	0.2	0.0	0.4	0.2	0.2	0.6	0.8	0.4	0.2
19	0.6	0.8	0.2	0.8	0.2	0.4	0.2	0.6	0.8
20	0.2	0.6	0.8	0.6	0.4	0.6	0.8	0.4	0.8

Table-05: The interactive session entered for patient No- 03 is as follows

Symptoms	Linguistic variable	Trapezoidal Fuzzy Numbers
Fever	Very-Mild	0.0
H-Fever	Mild	0.2
Headache	Moderate	0.4
Nausea	Moderate	0.4
Enlarge-Liver	Very-Severe	0.8
Jaundice	Severe	0.6
Joint pain	Very-Severe	0.8
Dizziness	Very-Severe	0.8
Conclusion	Severe Malaria	0.8

These values will result in the Fuzzy Transcript as shown in Table-05 below using the Rule-base for very-severe malaria as presented in Table-No-02 above. An example for rule base evaluation for patient number 03, in Table-No-05 below

Table-06: Rule Base Evaluation for Patient number-03

Rule	Fever	H-	Head	Nausea	Enlarge	Jaundice	Joint	Dizziness	Non Zero Minimum

No		Fever	ache		Liver		pain		Values And Conclusion
01	0.0	0.4	0.2	--------	---------	0.4	------	0.4	0.4 ⇒ Moderate
02	0.6	------	------	0.4	0.6	----------	0.6	---------	0.6 ⇒ Severe
03	0.0	------	------	0.4	0.8	----------	0.8	0.8	0.8 ⇒ Severe
04	------	------	0.6	0.6	0.4	----------	0.0	0.6	0.8 ⇒ V-Severe
05	------	0.6	0.8	--------	0.0	----------	0.6	---------	0.6 ⇒ Severe
06	------	------	0.6	--------	--------	0.6	------	0.4	0.4 ⇒ Moderate
07	------	------	0.8	0.6	0.6	0.8	------	----------	0.8 ⇒ Severe
08	------	0.8	------	0.4	0.6	0.6	------	----------	0.8 ⇒ V-Severe
09	0.4	------	0.8	--------	0.6	----------	0.4	0.8	0.4 ⇒ Moderate
10	------	0.6	0.6	--------	----------	0.6	------	0.6	0.6 ⇒ Severe
11	0.4	------	0.6	0.4	----------	0.4	0.4	---------	0.4 ⇒ Moderate
12	------	0.8	------	0.6	----------	----------	0.6	0.6	0.8 ⇒ V-Severe
13	0.4	------	0.6	0.4	0.8	----------	0.8	----------	0.8 ⇒ V-Severe
14	0.2	------	------	0.8	0.6	----------	------	0.8	0.6 ⇒ Severe
15	------	0.4	------	0.4	0.4	0.4	0.6	----------	0.4 ⇒ Moderate
16	0.6	0.8	------	--------	0.6	0.8	------	0.8	0.8 ⇒ V-Severe
17	------	0.4	------	0.4	0.4	0.6	0.4	----------	0.4 ⇒ Moderate
18	0.2	------	------	0.2	0.2	0.6	------	----------	0.2 ⇒ Mild
19	0.6	0.8	------	0.8	----------	0.4	------	0.6	0.8 ⇒ V-Severe
20	------	0.6	0.8	0.6	----------	0.6	0.8	---------	0.8 ⇒ V-Severe

Above Table-05 shows that (20) rules, first we choose patient numbers 01-20 where fired out for the patient -No-03 i.e. where 19 rules generated non-zero minimum values from the fuzzy rule base for Severe-malaria in table-No-02. For each of the linguistic variables Very-Mild, Mild, Moderate, Severe and Very-Severe. The respective output membership function strength [range: 0-1] from the possible rules ($R_1 - R_{20}$) are computed using Root Sum Square (RSS) inference technique as shown in equation (11) below.

Mild = $\sqrt{R_{03}^2} = \sqrt{0.2^2} = 0.2$

Moderate

$= \sqrt{R_1^2 + R_6^2 + R_9^2 + R_{11}^2 + R_{15}^2 + R_{17}^2}$

$= \sqrt{0.4^2 + 0.4^2 + 0.4^2 + 0.4^2 + 0.4^2 + 0.4^2}$

$= \sqrt{0..96} = 0.9797$

Severe = $\sqrt{R_2^2 + R_5^2 + R_{10}^2 + R_{14}^2}$

$= \sqrt{0.6^2 + 0.6^2 + 0.6^2 + 0.6^2}$

$= \sqrt{1.44} = 1.2$

Very-Severe

$= \sqrt{R_4^2 + R_7^2 + R_8^2 + R_{12}^2 + R_{13}^2 + R_{16}^2 + R_{19}^2 + R_{20}^2}$

$= \sqrt{0.8^2 + 0.8^2 + 0.8^2 + 0.8^2 + 0.8^2 + 0.8^2 + 0.8^2 + 0.8^2}$

$= \sqrt{5.12} = 2.2627$

$$\left.\begin{array}{rcl} Mild & = & 0.2 \\ Moderate & = & 0.9797 \\ Severe & = & 1.3416 \\ VerySevere & = & 2.2627 \end{array}\right\} \text{---------- (11)}$$

The defuzzification process translates the output from the inference engine in to crisp-output. This is due to the fact that, the output from the inference engine is usually a Fuzzy-Set while for most medical applications, CRISP – Values are required.

The in-put to the defuzzification process is a Fuzzy-Set, while the out-put of the defuzzification process is a single number (CRISP-OUTPUT)

Therefore above equation (11) is the defuzzification output (Fuzzy-Set) from RSS is then defuzzified to obtain the crisp out-put. For defuzzifying using centre of gravity (Discrete-CoG) technique as follows by an equation (8) above as show in equation (12) below.

Crisp out-put

$$= \frac{sum\ of\ membership\ value\ in\ membership\ function * membership\ grade}{membership\ grade W_{jk}}$$

Crisp output

$$= \frac{(0.2 * 0.2) + (0.9797 * 0.4) + (I.2 * 0.6) + (2.2627 * 0.8)}{0.2 + 0.9797 + 1.2 + 2.2627} \text{--(12)}$$

$$= \frac{2.96204}{4.6424} = 0.64 = 64\%$$

⇒ the patient No-03 has severe malaria with 64% possibility.

Conclusion for Very-Severe Malaria, Here Trapezoidal fuzzy Numbers (Mild=0.2) is taken by expert Doctor Decision. These values will result in the fuzzy transcript as shown in Table-No-06 below using the rule base for Very-Severe- malaria as presented in Table-No-02 above. An example for rule base evaluation for patient number- 19 is presented in Table-No-06 below

Table-07: The interactive session entered for patient No - 20 is as follows

Symptoms	Linguistic variable	Trapezoidal Fuzzy Numbers
Fever	Moderate	0.2
H-Fever	Very-severe	0.6
Headache	Mild	0.8
Nausea	Very-severe	0.6
Enlarge-Liver	Mild	0.4
Jaundice	Severe	0.6
Joint pain	Mild	0.8
Dizziness	Severe	0.2
Conclusion	Very-Severe Malaria	0.8

Table-08: Rule Base Evaluation for Patient number-20

Rule No	Fever	H-Fever	Head ache	Nausea	Enlarge Liver	Jaundice	Joint pain	Dizziness	Non Zero Minimum Values And Conclusion
01	0.0	0.4	0.2	--------	---------	0.4	------	0.4	0.4 ⇒ Moderate
02	0.6	----------	-------	0.4	0.6	----------	0.6	---------	0.6 ⇒ Severe
03	0.0	---------	-------	0.4	0.8	----------	0.8	0.8	0.8 ⇒ Severe
04	------	----------	0.6	0.6	0.4	----------	0.0	0.6	0.8 ⇒ V-Severe
05	------	0.6	0.8	--------	0.0	----------	0.6	---------	0.6 ⇒ Severe
06	------	----------	0.6	--------	--------	0.6	------	0.4	0.4 ⇒ Moderate
07	------	-------	0.8	0.6	0.6	0.8	------	----------	0.8 ⇒ Severe
08	------	0.8	-------	0.4	0.6	0.6	------	----------	0.8 ⇒ V-Severe
09	0.4	----------	0.8	--------	0.6	----------	0.4	0.8	0.4 ⇒ Moderate
10	------	0.6	0.6	--------	----------	0.6	------	0.6	0.6 ⇒ Severe
11	0.4	---------	0.6	0.4	----------	0.4	0.4	---------	0.4 ⇒ Moderate
12	------	0.8	-------	0.6	----------	----------	0.6	0.6	0.8 ⇒ V-Severe
13	0.4	---------	0.6	0.4	0.8	----------	0.8	----------	0.8 ⇒ V-Severe
14	0.2	---------	-------	0.8	0.6	----------	------	0.8	0.6 ⇒ Severe
15	------	0.4	-------	0.4	0.4	0.4	0.6	----------	0.4 ⇒ Moderate
16	0.6	0.8	-------	--------	0.6	0.8	------	0.8	0.8 ⇒ V-Severe
17	------	0.4	-------	0.4	0.4	0.6	0.4	----------	0.4 ⇒ Moderate
18	0.2	---------	-------	0.2	0.2	0.6	------	----------	0.2 ⇒ Mild
19	0.6	0.8	-------	0.8	----------	0.4	------	0.6	0.8 ⇒ V-Severe
20	------	0.6	0.8	0.6	----------	0.6	0.8	---------	0.8 ⇒ V-Severe

Table No-06 above shows that 18-Rules with Rule-No-19, so 18-Rules were fired out for patient No-19 that is 19-Rules generated non- zero minimum values from the fuzzy rule base for Severe- malaria in Table-No-03. For each of the linguistic variables [Very-Mild, Mild, Moderate, Severe and Very-severe], the respective output membership function strength Range: [0, 1] from the possible rules (R_1 – R_{20}) are computed using RSS inference technique as shown in equation (13) below

Very-Mild = 0.0

Mild = $\sqrt{R_{18}^2} = \sqrt{0.4^2} = 0.4$

Moderate = $\sqrt{R_1^2 + R_6^2 + R_9^2 + R_{11}^2 + R_{15}^2 + R_{17}^2}$

$= \sqrt{0.6^2 + 0.6^2 + 0.6^2 + 06^2 + 0.6^2 + 0.6^2}$

= 1.4697

Severe = $\sqrt{R_2^2 + R_3^2 + R_5^2 + R_{10}^2 + R_{14}^2}$

$= \sqrt{0.8^2 + 0.8^2 + 0.8^2 + 0.8^2 + 0.8^2}$

= 1.7888

Very-Severe = $\sqrt{R_4^2 + R_7^2 + R_8^2 + R_{12}^2 + R_{13}^2 + R_{16}^2 + R_{20}^2}$

$= \sqrt{0.9^2 + 0.9^2 + 0.9^2 + 0.9^2 + 0.9^2 + 0.9^2 + 0.9^2}$

= 2.3812

$$\left.\begin{array}{ll} Very-Mild & = 0.0 \\ Mild & = 0.4 \\ Moderate & = 1.4697 \\ Severe & = 1.7888 \\ Very-Severe & = 2.3812 \end{array}\right\} \text{---------- (13)}$$

Therefore above equation (13) is the defuzzification output (Fuzzy-Set) from RSS is then defuzzified to obtain the crisp out-put. For defuzzifying using center of gravity (Discrete-CoG) technique as follows by an equation (8) above as shown in equation (14) below

Crisp Output

$$= \frac{(0.4 * 0.2) + (1.4697 * 0.4) + (1.7888 * 0.6) + (2.3812 * 0.8)}{0.1 + 1.4697 + 1.7888 + 2.3812}$$

-------- (14)

$$= \frac{3.6461}{6.2711} = 0.60 = 60\ \%$$

⇒ The patient No-20 has Very-Severe malaria with 60% possibility.

Similarly, we computed the results of all fired rules for the other 18 patients and may get results that were in the range of predefined limits by the domain experts.

Results and Discussion: We have made humble attempt to implement the concept of Fuzzy Rule Based Systems that incorporated fuzzy techniques in simplifying the diagnosis of malaria. A fuzzy expert system for diagnosis malaria was developed. In the fuzzy logic implementation, the selection of fuzzifier, Rule base and inference engine determined the output of VSUFMD We choose triangular fuzzifier, the rule base was designed based on knowledge of domain experts (Four medical Physicians), and the inference technique we employed was RSS. Fuzzy logic was utilized to remove uncertainty, ambiguity and vagueness inherent in medical diagnosis.

The study evaluated the diagnosis of twenty patients using fuzzy methodology and the results gotten were in the range of the pre-defined limits by the domain experts. The essence of the study was to ascertain the degree to which fuzzy methodology represents the exact diagnosis of the patient as compared with those of medical doctors. From the study, apart from assigning linguistics variables such as mild, moderate, severe and very severe to the diagnosis, the degree of mildness, intensity or severity are also evaluated as shown in the two cases cited. Table-No- 5 and Table-No-6 show the rule evaluation for patient number 03 and patient number 19. Patient number -03 was diagnosed for *severe malaria with 64%* possibility and patient number -20 was diagnosed for *Very-Severe malaria with 60%* possibility. This will enable the medical practitioner to assign different doses of treatment to each of the two patients according to their degree of diagnosis. As seen in the results, one advantage fuzzy diagnosis has over other soft computing techniques is that it resembles human decision making with its ability to work from approximate reasoning and ultimately find a precise solution. The other patients' data were similarly computed and results for the 20 patients are presented in the appendix.

Table-09: Appendix: Fuzzy Results

Patient Number	Malaria % Possibility	Diagnosis
01	61	Moderate
02	64	Severe
03	64	Severe
04	48	Very-severe
05	59	Severe
06	63	Moderate
07	59	Very-Severe
08	74	Very-Severe
09	64	Moderate
10	48	Severe
11	64	Moderate
12	62	Very-Severe
13	71	Very-Severe
14	66	Severe
15	58	Moderate
16	59	Very-Severe
17	48	Moderate
18	35	Mild
19	77	Very-Severe
20	60	Very-Severe

Conclusions:

1. On the basis of the all presented, it can be concluded that there is no doubt whether Fuzzy Expert Systems should be applied for medical purpose. 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 VSUPFMD provides decision support platform to assist malaria researchers, physicians and other health practitioners in malaria endemic and epidemic regions. The authors believe that the approach proposed in this study, if used intelligently, could be an effective technique for diagnosing malaria. Furthermore, implementation of VSUPFMD will reduce doctors' workload during consultation and ease other problems associated with hospital consultations.
2. Fuzzy logic technology provides a simple way to arrive at a definite conclusion from vague, ambiguous and imprecise data. Our proposed knowledge based diagnosis system can be used to find a permanent solution to the effective and efficient treatment of this disease. The system facilitates the experts, doctors and lab technicians to determine his/her patient's probable diseases very quickly with the aid of a knowledge base expert system.
3. This study has clearly shown the use of fuzzy logic in medical diagnosis. The complexity of medical practices makes traditional approaches of diagnosis inappropriate. Fuzzy logic approach for diagnosis provides an efficient way to assist doctors in the diagnosis of Fuzzy Expert System for Identifying and Estimating the Level of Very Severe and Uncomplicated Plasmodium falciparum Malaria Disease (VSUPFMD). Fuzzy logic technology provides a simple way to arrive at

a definite conclusion from vague, ambiguous and imprecise data (as found in medical data).

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