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# Medical Diagnosis System Using Fuzzy Logic

**J.B. Awotunde[1], O.E. Matiluko[2], O.W Fatai [3]**
Computer Science Department, Faculty of CIS, University of Ilorin, Ilorin, Nigeria[1,3],
Center for Systems and Information Services, Landmark University, Omu-Aran, Nigeria[2]
jabonnetbylinks@gmail.com[1], matiluko.opeyemi@lmu.edu.ng[2], fataholawale@yahoo.com [3]
08062644218[1],07068450495[2],08032310132[3]

**ABSTRACT**
One of the major problems that both the developed and under-developed countries are facing is the difficulties of treating ill-health people. There is shortage of medical expertise in various hospitals, most of these countries are spending affluence of their resources to meet this challenge but still they are unable to meet the demands of providing good medical services for their people. It has become of great concern to find a lasting solution to the problem of traditional method of medical diagnostic which is characterized by inaccuracy and imprecision. Many researchers have developed several algorithms and technologies (including Fuzzy Logic, Genetic Algorithms and even Artificial Neural Network) to ensure accuracy and precision in the field of medicine which are branches of Artificial Intelligence. This paper covers the development of a medical diagnostic system using fuzzy logic; so as to enhance the accuracy and precision of medical diagnosis. The proposed medical diagnostic system was developed using Visual Prolog Programming language. The proposed system proffers solution to the enormous responsibilities of the diagnostic process carried out by medical personnel using fuzzy logic. More advance medical diagnosis system can be designed to help in the area like drugs prescription, registering of patients as well as keeping of patients' details and records in the medical sector.

**Keyword:** Algorithms, Expert system, Fuzzy logic, Affluence, Diagnostic system.

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## 1. INTRODUCTION

One of the problems that characterized the traditional method of medical diagnostic is inaccuracy and imprecision which has cause many life. The advent of computer has led to the development of several algorithms, models and technologies to ensure accuracy and precision and this has greatly reduced the numbers of patients that dead daily in the hospitals and one of such technologies is fuzzy logics which is a branch of artificial intelligence.

Nowadays, medical diagnostic processes are carried out with the aid of computer-related technologies, which are on the increase daily. These systems are mostly based on the principles of artificial intelligence and are designed not just to diagnose based on symptoms but also prescribe treatments based on such. According to [1], "in the medical field, many decision support systems (DSSs) have been designed, such as Aaphelp, Internist I, Mycin, Emycin, Casnet/Glaucoma, Pip, Dxplain, Quick Medical Reference, Isabel, Refiner Series System and PMA which assist medical practitioner in their decisions for diagnosis and treatment of different diseases".

The proposed Medical Diagnostic System (MDS) is meant to diagnose various diseases in an expert system such as this. Fuzzy logic is chosen as the artificial intelligence tool employed in the proposed system because it is one of most efficient qualitative computational methods.

Fuzzy logic has been proven to be one of the effective methods to bring clarity in the world of medicine. In the words of [1], "it has been used in many areas of medical applications such as in CADIAG, MILORD, DOCTORMOON, TxDENT, MedFrame / CADIAG-IV, FuzzyTempToxopert and MDSS".

According to an article by [2], "automated systems based on fuzzy logic have been used widely in control systems, household appliances, decision making systems, the medical and automobile industries. Terminologies used in fuzzy logic include but not limited to fuzzification, defuzzification, membership function, rules, domains, linguistic variables and so on". While Boolean algebra set values only include {0, 1} or {False, True}, it is believed through fuzzy logic that there are other values between 0 and 1 or False and True, which are sometimes referred to as in-between values. In other words, Boolean logic engages the principles of totally inclusive and exclusive rules on its set of {0, 1} while the principles of totally inclusive, exclusive and 'in between values' rules is engaged in fuzzy logic [3].

Fuzzy logic control systems and expert system are designed to be used in handling difficult and complex tasks but the strength of fuzzy logic control system over an expert system is in its ability to handle ambiguity. To handle ambiguity, linguistic rules are engaged which assist in decision making thereby emulating a human operator. This decision making ability is time saving and reduces or totally eliminates the need for human factor as employed in the old control models [3].

**Motivation**
The traditional method of medical diagnostic is characterized with the problem of precision and accuracy. This negative impact this imprecision and inaccuracy have on the populace geared this research.

**Contribution**
The major contribution of this paper is to develop fuzzy logic based medical diagnostic system. The reason for choosing fuzzy logic is to address uncertainty and vagueness that characterized traditional medical diagnostic practice. The system is tailor to be used in diagnose of malaria.

## 2. RELATED WORK

**Fuzzy Logic**
The diagnostic decisions taken by medical experts depend upon familiarity, experience, expertise, knowledge, capability and perception of the medical scientist. As the complexity of system increases, it is not easy to follow a particular path of diagnosis without any mistake. Fuzzy logic presents powerful reasoning methods that can handle uncertainties and imprecision. An aggregation of the knowledge, observation and experience of medical experts serves as the backbone of a fuzzy models based medical diagnostic system. The novel methodologies are presented for physician's decisions in medical informatics, medical problems solving and for the assessment of treatment planning decision process in diseases and therapies [4]. [5] Problem solving algorithms are proposed for data handling, pattern recognition, fuzzy segmentation of MRI data and diagnosis of diseases using genetic algorithm fuzzy approach.

A number of medical diagnostic systems have been developed based on fuzzy logic model and have been employed in the diagnosis and treatments of diabetes, cancer and many more [6]. For example, a system called DIAGAID has been developed by Turku University Hospital and the system is based on fuzzy logic [6]. Fuzzy logic has been used variously in the field of medicine; some of the recent research works in the area of medicine using fuzzy logic is as follows;1. Fuzzy logic controller (FLC): This is used in medical devices as the control unit [7] 2. Fuzzy logic has also been used in data analysis to evaluate facial expression and the behaviour of human [8].

In [3] Fuzzy Cognitive Map was used along with algorithms designed to investigate the immune system of human [9].
Expert system based on fuzzy logic employed in medical diagnosis has proved to be of great importance, providing a clear and impressive evaluation report of medical data. They have also provide a quick and easy means of medical condition diagnosis even at the absence of an expert or medical personnel based on the knowledge base built into it and acquire from experts in the field. The development of web based applications and interfaces enabled the medical practitioners to share their experiences and expertise across the world [10]

**Malaria**
There are a number of factors especially environmental that affects the spread of malaria; this includes but not limited to season, climate etc. The *Anopheles gambiae* complex which is a complex of about seven species of mosquitoes is the major and the most effective vector for the transmission of malaria. They are majorly in Africa and temperate regions because they cannot withstand frost [11]. *Plasmodium falciparum*, a species of *Plasmodium* is a protozoan and a parasite that is carried by the female Anopheles mosquitoes and the major causative parasite of malaria. Temperature affects the transmission cycle of P. falciparum in many different ways, but the effects on the duration of the sporogonic cycle of the parasite and vector survival are particularly important. At temperatures below about 22$^{o}$C the determining factor is the number of mosquitos surviving the parasite's incubation period, which takes 55 days at 18$^{o}$C [12] and ceases at around 16$^{o}$C. After 55 days the proportion of a cohort of mosquitos that survives is only 0.003 [13].

Epidemic malaria tends to occur along the geographical margins of the endemic regions, when the conditions supporting the equilibrium between the human, parasite and mosquito vector populations are disturbed. This leads to a sharp but temporary increase in disease incidence. More than 124 million Africans live in such areas and experience epidemics causing around 12 million malaria episodes and up to 310,000 deaths annually Worrall, [14]. Malaria is an ancient disease having a huge social, economic, and health burden. It is predominantly present in the tropical countries. Even though the disease has been investigated for hundreds of years, it still remains a major public health problem with 109 countries declared as endemic to the disease in 2008. There were 243 million malaria cases reported, and nearly a million deaths - primarily of children under 5 years [15]. Several related work have shown that malaria remains a major public health problem in Africa [16]. However, concerted efforts are continually been made to control malaria spread and transmissions within and between communities. In the work carried out by [17], it was reported that monthly malaria incidence rates and vector densities were used for surveillance and adaptive tuning of the environmental management strategies; which resulted in a high level of performance. Within 3-5 years, malaria-related mortality, morbidity and incidence rates were reduced by 70-95% [17].

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In a recent study, it was concluded that malaria control programmes that emphasized environmental management were highly effective in reducing morbidity and mortality Keiser, Singer, & [17]. The great failure of malaria control in Africa, from a district perspective in Burkina Faso was highlighted in the work carried out by [18].An integrated approach to malaria control was presented by [19]. In the scientific commentary delivered by [20], he stressed the need for a new global commitment to disease control in Africa. In the commentary, malaria was among the diseases highlighted [20]. However, in the work carried out by [21], it was observed that malarial control strategies consisted majorly of chemotherapy directed against the malaria parasite and prevention of mosquito vector/human contact using insecticide-impregnated bed nets. This control strategy achieved minimum results [21].

Another research was carried out on the island of Bioko (Equatorial Guinea). The purpose of this study was to access the impact of the two control strategies (insecticide treated nets (ITNs) and indoor residual spraying (IRS) on the island of Bioko (Equatorial Guinea), with regards to Plasmodium infection and anaemia in the children under five years of age. The results obtained showed that IRS and ITNs have proven to be effective control strategies [22].Recently, a research was conducted to determine the cost effectiveness of selected malaria control interventions. It was concluded that on cost effectiveness grounds, in most areas in sub-Saharan Africa, greater coverage with highly effective combination treatments should be the cornerstone of malaria control [23].Therefore, there is a pressing need to research into the best methods of deploying and using existing approaches, such as rapid methods of diagnosis, to have effective control over malaria transmissions [24].

## 3. RESEARCH METHODOLOGY

Collection of data was carried out at Irrua Specialist Teaching Hospital (ISTH), Irrua, Edo State. The data will be collected using secondary data collection method which involves direct interview of consultants in general medicine. The data to be collected include various methods for diagnosing malaria and the various signs and symptoms. In addition, previous research works and texts in the subject area will be consulted, which will be used to design and implement the program using Visual Prolog.

## 4. DISCUSSION AND RESULT

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. Fuzzy set and fuzzy logic founded by makes it possible to define inexact medical entities as fuzzy set [2]. Fuzzy logic technology provides a simple way to arrive at a definite conclusion from vague, imprecise and ambiguous medical data [25]. Theory of fuzzy sets and fuzzy logic is efficient method for treating the uncertain and imprecise data of any kind. It has such characteristics that enable researchers to provide the high rationality when modeling the uncertain, incomplete and fuzzy data that exist in clinical practice. The basic aim of the fuzzy sets theory and fuzzy logic is exploitation of the tolerance that exists in imprecise, vague or partially truth data for obtaining the more robust and cheaper solutions [25].

**Fuzzification**

Fuzzification is a process that determines the degree of membership to the fuzzy set based on fuzzy membership function. This is done by selecting input parameters into the horizontal axis and projecting vertically to the upper boundary of membership function to determine the degree of membership.

The first step in the development of fuzzy logic based expert system is to construct fuzzy sets for the parameters. This is shown in equations (1) to (3) below. On the basis of domain experts' knowledge, both input and output parameters selected for this research were described with four linguistic variables (minor, moderate, severe and very severe). The range of fuzzy value for each linguistic is shown in table 1 below:

| **Linguistic Variables** **Fuzzy Values** | |
|---|---|
| Minor | $0.1 < x < 0.3$ |
| Moderate | $0.3 < x < 0.6$ |
| Severe | $0.6 < x < 0.8$ |
| Very Severe | $0.8 < x < 1.0$ |

Fuzzification begins with the transformation of the raw data using the functions that are expressed in equations (1) to (3) 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 (1) to (3) below. These formulas are determined by aid of both the expert doctors in the field [26].

$$\mu_{mild}(x) = \begin{cases} 0 & if \quad x \leq 0.1 \\ \frac{x-0.1}{0.2} & if \quad 0.1 \leq x \leq 0.3 \\ \frac{0.2-x}{0.2} & if \quad 0.2 \leq x \leq 0.3 \\ 0 & if \quad x \geq 0.2 \end{cases} \tag{1}$$

$$\mu_{moderate}(x) = \begin{cases} 0 & if \quad x \leq 0.3 \\ \frac{x-0.3}{0.2} & if \quad 0.3 \leq x \leq 0.6 \\ \frac{0.45-x}{0.15} & if \quad 0.45 \leq x \leq 0.6 \\ 0 & if \quad x \geq 0.45 \end{cases} \tag{2}$$

$$\mu_{severe}(x) = \begin{cases} 0 & if \quad x \leq 0.5 \\ \frac{x-0.6}{0.2} & if \quad 0.6 \leq x \leq 0.8 \\ \frac{0.7-x}{0.2} & if \quad 0.7 \leq x \leq 0.8 \\ 0 & if \quad x \geq 0.7 \end{cases} \tag{3}$$

$$\mu_{very\,severe}(x) = \begin{cases} 0 & if \quad x \le 0.8 \\ \frac{x-0.1}{0.2} & if \quad 0.8 \le x \le 1.0 \\ \frac{0.2-x}{0.1} & if \quad 0.9 \le x \le 1.0 \\ 0 & if \quad x \le 1.0 \end{cases} \quad (4)$$

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 FESMM has so many fuzzy rules designed with the aid of combination theory: only the 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); other, if all the parameters evaluate to false (0), it does not fire[26].

**Table 1 Fuzzy Rule Base for Malaria [26]**

| Rule No | Fever | Headache | Nausea | Vomiting | Jaundice | Enlarge Liver | Joint Pain | Body Weakness | Dizziness | Loss of Appetite | MP | Conclusion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mild | Mild | Mild | Mild | Mild | Mild | Mild | Mild | Severe | Mild | Mild | Mild |
| 2 | Moderate | Mild | Mild | Mild | Mild | Mild | Moderate | Moderate | Severe | Severe | Moderate | Moderate |
| 3 | Severe | Moderate | Mild | Mild | Mild | Mild | Mild | Severe | Severe | Severe | Moderate | Severe |
| 4 | Very Severe | Mild | Mild | Mild | Mild | Mild | Severe | Severe | Mild | Mild | Severe | Very Severe |
| 5 | Moderate | Mild | Mild | Moderate | Mild | Mild | Moderate | Moderate | Moderate | Severe | Moderate | Moderate |
| 6 | Mild | Moderate | Moderate | Mild | Mild | Mild | Mild | Mild | Moderate | Mild | Mild | Mild |
| 7 | Mild | Mild | Moderate | Moderate | Mild | Mild | Severe | Severe | Moderate | Moderate | Moderate | Severe |
| 8 | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate |
| 9 | Moderate | Mild | Moderate | Moderate | Mild | Severe | Moderate | Moderate | Severe | Moderate | Moderate | Moderate |
| 10 | Mild | Mild | Moderate | Moderate | Mild | Moderate | Mild | Mild | Mild | Mild | Mild | Mild |
| 11 | Severe | Severe | Severe | Severe | Severe | Severe | Severe | Very Severe | Severe | Severe | Moderate | Very Severe |
| 12 | Moderate | Severe | Moderate | Severe | Moderate | Severe | Moderate | Severe | Moderate | Mild | Moderate | Severe |
| 13 | Mild | moderate | Moderate | Moderate | Mild | Mild | Mild | Moderate | Mild | Moderate | Moderate | Moderate |
| 14 | Severe | Severe | Moderate | Severe | Severe | Severe | Severe | Severe | Moderate | Moderate | Severe | Severe |
| 15 | Mild | Mild | Mild | Moderate | Mild | Mild | Mild | Severe | Mild | Severe | Moderate | Severe |
| 16 | Very Severe | Moderate | Mild | Moderate | Severe | moderate | Mild | Very Severe | Severe | Mild | Moderate | Very Severe |
| 17 | Mild | Very Severe | Moderate | Moderate | Mild | moderate | Mild | Moderate | Very Severe | Mild | Moderate | Very Severe |
| 18 | Moderate | Very Severe | Very Severe | Mild | Severe | Severe | Moderate | Severe | Very Severe | Very Severe | Severe | Very Severe |
| 19 | Moderate | Moderate | Moderate | Moderate | Mild | Mild | moderate | Moderate | moderate | Moderate | Moderate | Moderate |
| 20 | Very Severe | Severe | Severe | Severe | Severe | Severe | Severe | Severe | Severe | Severe | Moderate | Very severe |

L=A rule is said to fire if any of the precedence parameters (minor, moderate, severe, very severe) evaluate to true (1); other, if all the parameters evaluate to false (0), it does not fire [26].

**Defuzzification**

The defuzzifier translates the output from the inference engine into crisp output. The input to the defuzzification process is a fuzzy set while the output of the defuzzification process is a single number (crisp output). This is due to the fact that the output from the inference engine is usually a fuzzy set, while for most real life applications, crisp values are often required. The three common defuzzification techniques are: max criterion, center-of gravity and the mean of maxima.

Though the max criterion is the simplest to implement because it produces the point at which the possibility distribution of the action reaches a maximum value [26].

$$CoG(Y^n) = \frac{\sum \mu_Y(x_i)x_i}{\sum \mu_Y(x_i)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where $\mu_Y(x_i)$ = Me

$x_i$ = center

**Inference Engine**

The process of drawing conclusion from existing data is called inference. The inference engine is the knowledge processor which is modeled after the expert's reasoning. Fuzzy inference is the process of mapping from a given input to an output using the theory of fuzzy sets [27].

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The inference engine is the knowledge processor which is modeled after the expert's reasoning. The core of decision making output is process by the inference engine using the rules contained in the rule base. There are two types of inference techniques;

**Forward chaining:** Inference strategy that begins with a set of known facts, derives new facts using rules whose premises match the known facts, and continues this process until a goal state is reached or until no further rules have premises that match the known or derived facts. [1]

**Backward chaining:** Inference strategy that attempts to prove a hypothesis by gathering supporting information.
The fuzzy inference mechanism employed in this research is the Mamdani Inference type. The fuzzy inference engine uses the rules in the knowledge-base and derives conclusion base on the rules. This inference engine uses a forward chaining mechanism to search the knowledge for the symptoms of malaria. The inference engine technique employed in this research is the Root Sum Square (RSS). RSS is given by the formula in equation (6):

$$\sqrt{\sum R} = \sqrt{(R_1^2 + R_2^2 + R_3^2 + \dots .. + R_n^2)} \quad \dots \quad (6)$$

Where $R_1^2 + R_2^2 + R_3^2 + \dots .. + R_n^2$ are strength values (truth values) of different rules which share the same conclusion.

The decision making process is initiated by the inference engine whenever it receives user queries. The weight for the inputs is generated by the Inference engine.

## 5. MEDICAL DIAGNOSIS SYSTEM DESIGN INTERFACE

The first page show is the welcome interface which consists of File menu, Exit menu, Window menu and the Help menu.

1. **File Menu:** This consists of the New Diagnosis button, Open button, Save button, Save As button, and Exit button fig. 1.
2. **Symptoms Interface:** This consists of the degree of symptoms. This is where you can select the degree of the symptoms Fig. 2.
3. **Diagnosis Result:** This consist the page where the result is been display after select the symptoms fig. 3.
4. **Result Interface:** This display the final result of the nature of the malaria whether is Mild, Moderate, Severe or Very Severe Malaria fig. 4.

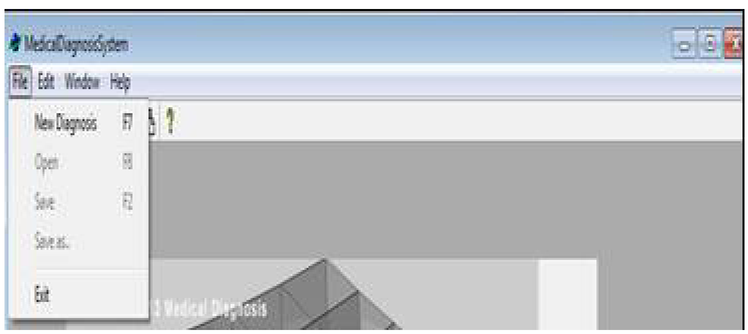


**Fig. 1: The File Menu Button**

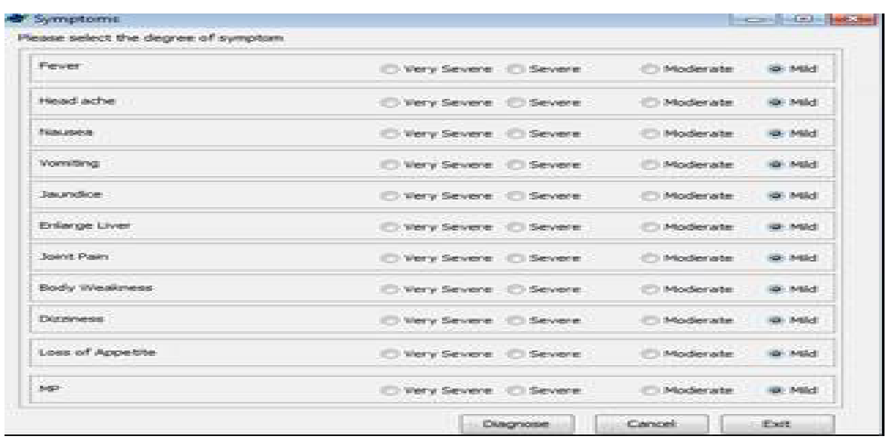

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**Fig. 2: The Symptoms Interface**

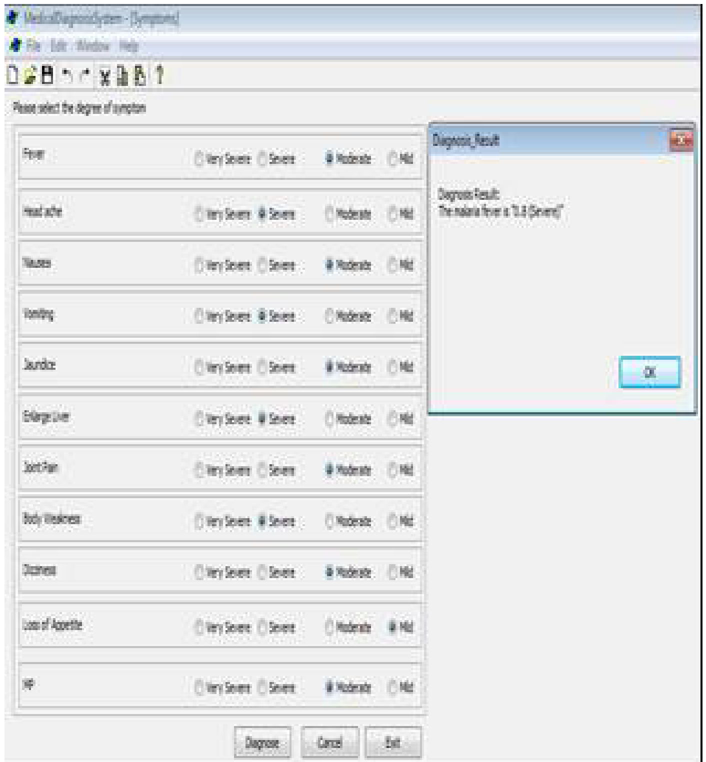

**Fig. 3: Diagnosis_Result Interface**

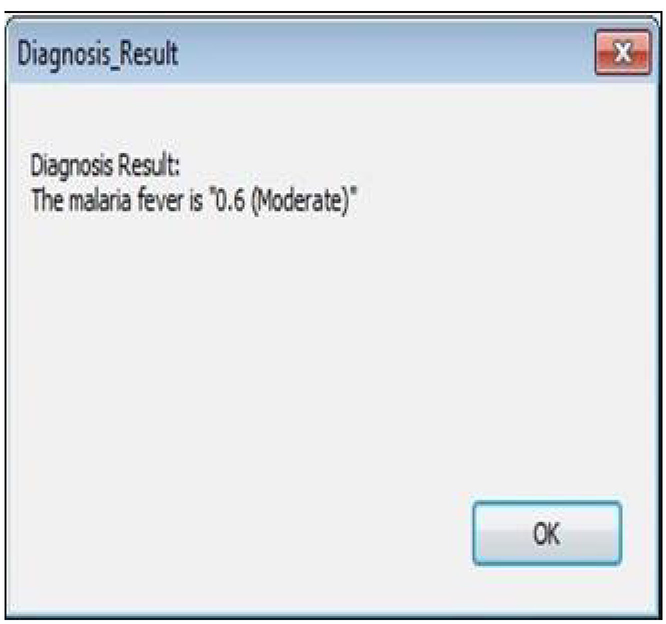


**Fig. 4: Final Result Interface**

## 6. DISCUSSION

The authors considered a set of five diseases **D**, and the expert doctors defined a set of signs and symptoms **M** relevant to malaria disease.

S = {$d_1$, $d_2$, $d_3$, $d_4$, $d_5$} where $d_1$, $d_2$, $d_3$, $d_4$, $d_5$ represents the five malaria diseases under consideration.

M = {$m_1$, $m_2$, $m_3$, $m_4$ . . . $m_n$} where $m_1$, $m_2$, $m_3$, $m_4$ . . . $m_n$ represents the signs and symptoms of malaria disease.
To specify the signs/symptoms intensity for a particular patient, the expert doctors applied weighing factors to the set **M**, thereby assigning fuzzy values to the signs/symptoms.

The fuzzy values are selected from the fuzzy set:
{ Mild (1), Moderate (2), Severe (3), Very Severe (4)}
Several patients were consulted by medical experts during a few consultation sessions and they were reviewed based on signs and symptoms to determine if they had malaria. The severity of the malaria related signs and symptoms were placed on a scale of 1 to 4 i.e. mild from to very severe.

*Where* 1 is mild, 2 is moderate, 3 is severe and 4 is very/extremely severe.

## CONCLUSION AND FUTURE WORK

Apart from prescription and treatments, diagnosis of the ailments remains a primary duty of medical personnel and the creation of an automated diagnostic system assist in decision making and easy and fast discovery of ailment affecting a patient. The adoption of fuzzy logic in the design of such automated system gives an innovative and professional means of malaria diagnosis especially in the part of world where malaria is in wide spread. The use of fuzzy logic in the design of the diagnostic system proposed in this paper is believed to serve as a dependable and cheap means of treating malaria. Furthermore, implementation of Fuzzy logic based medical diagnostic system will reduce doctors' job during consultation and ease other problems associated with hospital consultations. More advance medical diagnosis system can be designed to help in the area like drugs prescription, registering of patients as well as keeping of patients' details and records in the medical sector.

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## Authors' Briefs

**Bamidele Joseph, AWOTUNDE** is currently a Computer Science Teacher at the University School, University of Ilorin, Ilorin, Kwara State, Nigeria. He holds OND Statistics at The Federal Polytechnic, Bida, Niger State, B.Tech. Mathematics/Computer Science at Federal University of Technology, Minna, Niger State, Nigeria in 2007, and M.Sc. Degree in Computer Science at the University of Ilorin, Ilorin, Kwara State, Nigeria in 2014. His research interests are Information Security, Bioinformatics, Artificial Intelligence, Software Engineering and Biometrics. He can be reached by phone on +2348062644218 and through E-mail jabonnetbylinks@gmail.com or awotunde.jb@unilorin.edu.ng

**Opeyemi Emmanuel MATILUKO** is the System Analyst/Developer at the Centre for Systems and Information Services, Landmark University, Omu-Aran, Kwara State, Nigeria. He obtained a B.Tech. Computer Science degree at Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria in 2008 and M.Sc. Degree in Computer Science at the University of Ilorin, Kwara State, Nigeria in 2014. He is a member of IEEE, Computer Society and he is specialized in Web and Computer application development, and his research interests include artificial intelligence, software engineering and bioinformatics. He can be reached by phone on +2348059463559 and through E-mail matiluko.opeyemi@lmu.edu.ng or opmat01@yahoo.com

**Olawale Waheed, FATAI** is currently with Microswitch Technology, Port-Harcourt, Cross Rivers State, Nigeria. He holds B.Sc. Computer Science at University of Ilorin, Kwara State, Nigeria in 2006, and M.Sc. Degree in Computer Science at the University of Ilorin, Ilorin, Kwara State, Nigeria in 2014. His research interests are Network and Network Security, Software Engineering and Project Management. He can be reached by phone on +2348032310132, +2348052477500 and through E-mail fataholawale@yahoo.com