Journal of King Saud University – Computer and Information Sciences 30 (2018) 185–197

Contents lists available at ScienceDirect

Journal of King Saud University – Computer and Information Sciences

journal homepage: www.sciencedirect.com

Malavefes: A computational voice-enabled malaria fuzzy informatics software for correct dosage prescription of anti-malarial drugs

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ARTICLE INFO

Article history:
Received 9 October 2016
Revised 9 February 2017
Accepted 7 April 2017
Available online 11 April 2017

Keywords:
Informatics
Bioinformatics
Fuzzy
Anti-malaria
Voice computing
Dosage prescription

ABSTRACT

Malaria is one of the infectious diseases consistently inherent in many Sub-Sahara African countries. Among the issues of concern are the consequences of wrong diagnosis and dosage administration of anti-malarial drugs on sick patients; these have resulted into various degrees of complications ranging from severe headaches, stomach and body discomfort, blurred vision, dizziness, hallucinations, and in extreme cases, death. Many expert systems have been developed to support different infectious disease diagnoses, but not sure of any yet, that have been specifically designed as a voice-based application to diagnose and translate malaria patients' symptomatic data for pre-laboratory screening and correct prescription of proper dosage of the appropriate medication. We developed *Malavefes*, (a malaria voice-enabled computational fuzzy expert system for correct dosage prescription of anti-malarial drugs) using Visual Basic.NET., and Java programming languages. Data collation for this research was conducted by survey from existing literature and interview from public health experts. The database for this malaria drug informatics system was implemented using Microsoft Access. The Root Sum Square (RSS) was implemented as the inference engine of *Malavefes* to make inferences from rules, while Centre of Gravity (CoG) was implemented as the defuzzification engine. The drug recommendation module was voice-enabled. Additional anti-malaria drug expiration validation software was developed using Java programming language. We conducted a user-evaluation of the performance and user-experience of the *Malavefes* software.

1. Introduction

One of the tropical diseases inexplicably inherent in most English-speaking Sub-Sahara African countries despite concerted effort and interventions by different government agencies and research institutions is Malaria. Among the issues of concern are wrong diagnosis, error in or wrong dosage prescription of anti-malaria drugs by pharmacy store attendants, counterfeit pharmaceuticals, fake pharmacies and untrained pharmacists (Chaudhry and Stumpf, 2013;Gyasi, 2013;Kaona and Tuba, 2003). In addition, some patients, on their own volition, result to administering wrong dosage of self-prescribed anti-malarial tablets; these have resulted into diverse degrees of complications ranging from severe headaches, stomach and body discomfort, high body temperatures, blurred vision, dizziness, balance loss, depression, hallucinations, sores of the throat and mouth, vomiting, adverse effects on the development of fetus, fainting and in extreme cases, death.

Recently, the FDA (United States Food and Drug Administration), precisely on the 29th of July, 2013, issued a warning and called the attention of the public to the possible neurologic and psychiatric side effects of administering the anti-malarial drug Mefloquine Hydrochloride (FDA, 2013). The aim of this research is to develop a voice-enabled computational system, which can help diagnose and predict the extent of malaria infection in a patient's body and the intensity rate based on symptoms keyed-in and appropriately recommends correct dosage of malaria drugs to the patients concerned.

We have developed *Malavefes*, (a malaria voice-enabled computational fuzzy expert system for correct dosage prescription of

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksuci.2017.04.003
1319-1578/

malaria drugs). *Malavefes* was implemented in Visual Basic.NET programming language within an integrated development environment. This software will assist health institutions, health professionals, pharmacists, care givers, and individuals, to correctly prescribe malaria drugs not only to pregnant women but the general populace at large. This will help guarantee a drastic reduction in the complications that result from the wrong administration and usage of malaria drugs. This will ultimately reduce mortality rate especially among pregnant women and children.

2. Related works

Relevant and related literatures were consulted and reviewed. In a study an expert system for malaria environmental diagnosis was developed (Oluwagbemi et al., 2009). Oluwagbemi and colleagues developed a very useful expert system that will serve the medical and public health communities (Oluwagbemi et al., 2009). The expert system was developed in the quest of seeking alternative control strategies towards the reduction of the spate of malaria. The system developed by Oluwagbemi and colleagues, however, focused on developing an expert system that centred on seeking environmental strategy and intervention towards controlling malaria. It is different from the current study, in that it does not cater for the correct dosage administration of malaria drugs, neither does it take care of diagnosing the intensity of malaria infection among humans and human bodies.

Data collation was accomplished by thorough scrutiny of prescriptions made by pediatric health personnel and from questionnaires administered to parents of over 400 outpatient children (Karande et al., 2005); necessary recommendations were made accordingly. Insight was also gained from the World Health Organization (WHO) "core drug use indicator" report (WHO,1993), which highlighted general drug usage patterns by different categories of people and corresponding drug dispensing patterns. The study; however, only focused mainly on children health.

Djam and colleagues, also conducted an interesting study on malaria management (FESMM) (Djam et al., 2011). They proposed the architecture of FESMM (a fuzzy expert system). The RSS (Root Sum Square) was applied as the fuzzy inference method. A triangular membership function was applied to reveal to what degree each input parameter are involved. Center of Gravity was employed as the defuzzification technique. FESMM, however, had some limitations. FESMM lacked notable features present in *Malavefes*. For instance, (i) FESMM does not have a programmed voice-enabled mechanism (ii) FESMM also lacked a programmed graphical statistical facility to adequately depict the disparity between complicated and uncomplicated cases of malaria based on the severity level (iii) FESMM lacked a comprehensive database that accommodates more disease-symptom data, and malaria drug-correct dosage data (iv) FESMM lacked a flexible feature that allows both administrator (a health practitioner such as a medical Doctor or Nurse, edits and updates the system (v) FESMM also does not make adequate provision for patients to view their data and updates (vi) FESMM lacked email notification feature that enables uninterrupted communication between administrators and patients (vii) FESMM does not make any provision for pregnant women diagnosis and drug recommendation (viii) FESMM only made provision for 13 symptoms which is different from *Malavefes* which made provision for more disease symptoms (23 disease symptoms) and more rule-based system evaluation (*Malavefes* contains 45 fuzzy-related rules). However, *Malavefes* was developed based on extended literature survey, medical diagnosis, and clinical observations and knowledge. In *Malavefes*, we have been able to address the limitations that exist in FESMM and some other existing expert systems.

Several other expert systems have been previously developed. Phuong and Kreinovich described the formalism of fuzzy based systems in medicine and real-life applicability (Phuong and Kreinovich, 2000). Besides these, so many forms of systems have been built and applied to health related issues. Allahverdi and Yaldiz developed a pre-diagnosis expert system against cancer disease. The system makes it possible to diagnose and treat patients' cancer tumour (Allahverdi and Yaldiz, 1998). In their system (ONCO-HELP), personal data of patients are collated, laboratory parameters and a comprehensive knowledge-base of patients' prognosis-score are also integrated in order to generate and evaluate a therapy concept. Allahverdi discussed the significance of expert systems and the various applications of artificial intelligence (Allahverdi, 2002). Doukidis and colleagues discussed the role of medical expert system for developing countries. They specifically described ESTROPID (an Expert System for Tropical Diseases) and its evaluation. ESTROPID was designed to provide diagnostic support for paramedical staff in clinical settings. The evaluation of ESTROPID showed that there was an increase in time spent by clinical officer with patients. The evaluation also revealed that more symptoms were generated or obtained from patients at the commencement of consultations. It was a small study with limited statistical data. The study produced a 24% scale of disagreement of patient between the CO (clinical officer) and the doctor when computer was adopted, while it produced a 14% scale of disagreement of patient with normal practice (Doukidis et al., 1994).

Boyom presented a work on expert systems adopted on endemic tropical diseases (Boyom, 1990); Fatumo and colleagues developed a simple expert system to manage some complications of malaria and typhoid fever. They developed XpertMalTyph by using the Java Expert System Shell (JESS) programming. Clinical and laboratory data were obtained from the literature (Fatumo et al., 2013);

Uzoka and Famuyiwa presented a report on an intelligent, user-friendly, knowledge-based system which analyzes complaints of patients in order to make inferences. The focus of the system is on tropical diseases (Uzoka and Famuyiwa, 2004);

Akinyokun and Adeniji conducted a study on a computer aided diagnosis and therapy system (Akinyokun and Adeniji, 1991). Akinyokun and colleagues (Akinyokun et al., 2015) also recently developed a web and fuzzy logic-based expert system on the diagnosis of heart failure disease. The system was implemented using PHP, Javascript and HTML, while the database was implemented using MySql.

Useful systems have been built in the area of medical diagnosis in times past. Obot conducted an experimental study on the diagnosis and therapy for typhoid fever using a knowledge-based system (Obot, 1999, 2006).

Devlin and Devlin developed a decision support system to assist clinicians in the diagnosis and treatment of patients (Devlin and Devlin, 2007); Yan and colleagues (Yan et al., 2006), adopted the multi-layer perceptron neural network to develop a decision support system in order to diagnose heart diseases. They used a back propagation algorithm to train the system. 352 relevant patient records were used to train the system. Three assessment methods were used to assess the system namely: bootstrapping, cross validation and holdout. Pietka presented a report on the preliminary study of an expert system that will be useful to patients, in diagnosing some selected blood circulatory and respiratory diseases (Pietka, 2008). Fathi-Torbaghan and Meyer developed a fuzzy-based expert system for the diagnosis of abdominal pain. (Fathi-Torbaghan and Meyer, 1994);

Those with specific applications to the medical and biomedical fields, include the works of: Street (Street, 2007); Abdod and colleagues conducted a comprehensive survey of the applications of fuzzy tecnhnology in healthcare and medicine (Abdod et al., 2001); Saritas and colleagues described a fuzzy expert system that diagnoses and analyzes prostate cancer disease. The system predicts prostate cancer risk as its ouput (Saritas et al., 2003); Apurba and colleagues adopted a fuzzy expert system approach in the appropriate follow-up of endemic diseases (Apurba et al., 2007); Obot and colleagues developed a fuzzy-rule-based framework which can be very instrumental in managing tropical diseases. (Obot et al., 2008); Obot and colleagues also conducted a comprehensive experimental comparative analysis of fuzzy logic and analytic hierarchy for decision support systems used in the medical field (Obot et al., 2010);

Innocent and John (2004) developed a computer aided medical diagnostics system. Oluwagbemi et al. (2016) developed a fuzzy expert system for the diagnosis of the possible intensity of the Ebola Virus Disease (EVD). The system also has the capability of providing useful recommendations to the management of EVD in West Africa and other affected regions of the world. The system was developed using the Root Sum Square (RSS) as its fuzzy inference method, fuzzy logic as its inference mechanism, and the Centre of Gravity (CoG) as its defuzzification technique.

Developing complementary drug-informatics software for correct dosage prescription of anti-malaria drugs is a task and study worth researching. This is because there are numerous cases of non-adherence, inappropriate and wrong usage of anti-malaria drugs among inhabitants of English-speaking developing and malaria endemic countries and this has led to serious complications which in extreme cases, has resulted to death. In the next phase of literature review, as shown in the table below, we highlighted (as obtained from scientific literature), factors responsible for the non-adherence to dosage prescription of anti-malaria medication and usage (See Table 4).

3. Materials and methods

3.1. Implementation

3.1.1. Data collation

Data and information collation for this research was conducted by survey from existing literature (WHO, 2010), by personal interviews with public health personnel, pharmacists and from medical personnel from relevant health institutions.

Furthermore, extra data was collated by administering performance evaluation questionnaire for *Malavefes* software to thirty-five anonymous individuals which consists of medical professionals, and individuals from other disciplines. The performance evaluation questionnaire consists of nineteen (19) comprehensive questions to test and get feedback on the performance of *Malavefes* software.

3.1.2. Methodology

Malavefes was developed using Visual Basic.NET programming within the Microsoft Visual studio integrated development environment. The database for this malaria drug informatics system was implemented using Microsoft Access. The architecture of *Malavefes* is specified in Fig. 1. The inference engine for this system was implemented by incorporating some fuzzy-based rules. The algorithm for *Malavefes* is displayed as shown section 3.1.4. The Root Sum Square (RSS) (Obot and Uzoka, 2008) was implemented in VB.NET as the inference engine of *Malavefes* to infer data from rules, while Centre of Gravity (CoG) (Whitby, 1993; Van Leekwijck et al., 1999; Runkler, 1996) was implemented as the defuzzification technique (engine) (Van Broekhoven and De Baets, 2004; Runkler, 1997) in our software. We also implemented the triangular membership function (Van Broekhoven and De Baets, 2006; Juang et al., 2008; Pedrycz, 1994) in VB.NET programming to reveal the extent to which input parameters keyed into our software participated or is ranked. The anti-malaria expiration validation was implemented in order to help patients avoid taking-in expired anti-malaria drugs. The implementation was done in Java programming language

3.1.3. Internal support mechanism for Malavefes

3.1.3.1. Knowledge base. The allocation of memory is done for the storage of decision variables during the diagnosis of the intensity of malaria. The database and fuzzy logic provide a storage platform that acts as a data bank for data waiting to be processed.

3.1.3.2. Malavefes database. The database of *Malavefes* contains facts and established rules which centers on the diagnosis of malaria intensity. These consist of signs and symptoms of malaria. Deductions are drawn from the rules. The database contains disease-symptoms, results and diagnosis.

3.1.3.3. Fuzzification of input variables into Malavefes. Diagnosis process within *Malavefes* leverages on the merits of fuzzy logic components. If we are given a fuzzy set C defined in Eq. (1), representing malaria diagnosis variables with elements denoted by z_1, the process of fuzzification involves converting the input value for each variable into fuzzy term from the set {*mild*, *moderate*, *severe*, *very-severe*} which are defined over the variables. The derivation of such values stems from functions that have been defined in order to determine and establish the degree of membership of the variables within the fuzzy set (See Eq. (1))

$$C = \{(z_i, \mu_C(z_i)|z_i \in V, \mu_C(z_i) \in [0, 1]\} \tag{1}$$

where V is a set which accommodates the malaria diagnosis variables denoted by z_1

The process of fuzzification is accomplished using the function defined in Eq. (2)

$$\mu_C(z_i) = \begin{cases} 0 & if\ z_i \leqslant a \\ \frac{z_i - a}{b - a} & if\ a \leqslant z_i < b \\ \frac{c - z_i}{c - b} & if\ b \leqslant z_i < c \\ \frac{d - z_i}{d - c} & if\ c \leqslant z_i < d \\ 0 & if\ d \geqslant z_i \end{cases} \tag{2}$$

where $\mu_C(z_i)$ is the membership function (MF) of z_i in C using the triangular MF, where μ_C is the degree of membership of z_i in C; a, b, c and d are parameters of MF that oversees and monitors its triangular shape and lingual terms describes each attribute.The triangular membership function can also be applied as shown in Equations (2a); (2b); (2c); (2d):

$$\mu_{Mild}(Z) = \begin{cases} 0 & if\ z \leqslant 0.1 \\ \frac{z - 0.1}{0.2} & if\ 0.1 \leqslant z < 0.3 \\ \frac{0.2 - z}{0.1} & if\ 0.2 \leqslant z < 0.3 \\ 0 & if\ z \geqslant 0.2 \end{cases} \tag{2a}$$

$$\mu_{Moderate}(Z) = \begin{cases} 0 & if\ z \leqslant 0.3 \\ \frac{z - 0.3}{0.3} & if\ 0.3 \leqslant z < 0.6 \\ \frac{0.45 - z}{0.15} & if\ 0.45 \leqslant z < 0.6 \\ 0 & if\ z \geqslant 0.45 \end{cases} \tag{2b}$$

$$\mu_{Severe}(Z) = \begin{cases} 0 & if\ z \leqslant 0.5 \\ \frac{z - 0.6}{0.2} & if\ 0.6 \leqslant z < 0.8 \\ \frac{0.7 - z}{0.1} & if\ 0.7 \leqslant z < 0.8 \\ 0 & if\ z \geqslant 0.7 \end{cases} \tag{2c}$$

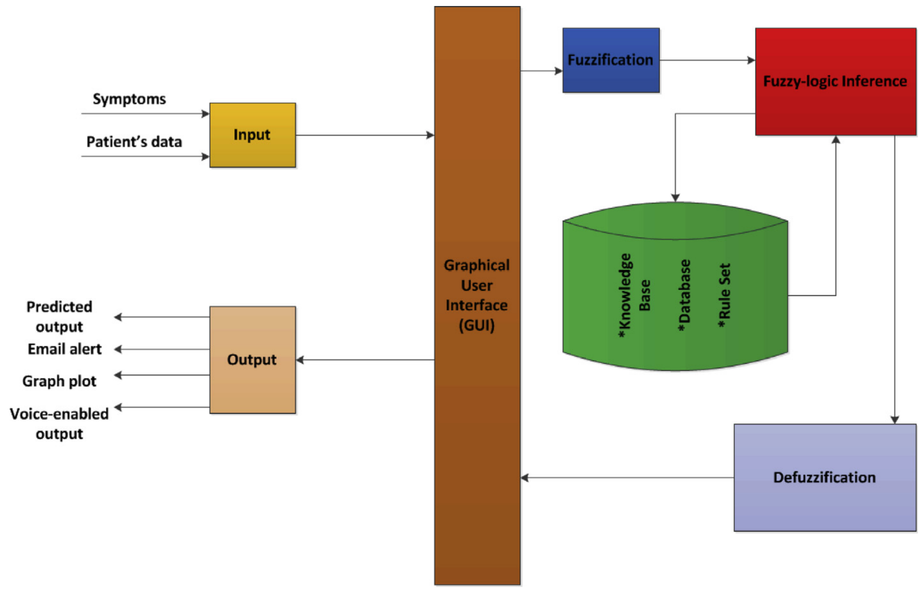


Fig. 1. Architecture of *Malavefes*.

$$\mu_{VerySevere}(Z) = \begin{cases} 0 & \text{if } z \leqslant 0.8 \\ \frac{z-0.1}{0.2} & \text{if } 0.8 \leqslant z < 1.0 \\ \frac{0.2-z}{0.1} & \text{if } 0.9 \leqslant z < 1.0 \\ 0 & \text{if } z \leqslant 1 \end{cases} \tag{2d}$$

3.1.3.4. Establishing a fuzzy rule base for Malavefes. The *Malavefes* software rule-base is patterned by a set of IF-THEN rules which consists of the IF parts and the THEN parts involving linguistic variables. A rule is acted upon if precedence parameters such as mild, moderate, severe and very severe evaluate to be TRUE; else, no action is carried out.

The inference engine processes the critical part of decision making by using the rules contained in the rule base. The fuzzy inference engine uses the rules in the knowledge-base are used by the fuzzy inference engine and conclusions are arrived at depending on the rules.

The degree of fulfillment or the firing strength of a rule is calculated by using the aggregation operator. In our research, we adopted and applied the fuzzy logical AND to evaluate the composite firing strength of the rules. What the AND simply does, was to make use of the minimum weights of antecedents, while the fuzzy logical OR uses the maximum value.

*It should be noted that knowledge of symptoms diagnosed by medical doctors and malaria experts and researchers in the malaria domain were instrumental as part of the ingredients in formulating some of the diagnosis and not for formulating the conclusion of the rules.

One of the rules in the *Malavefes* software rule-base is shown as follows:

Example

IF fever = "mild" And cold = "severe" And headache = "moderate" THEN malaria = "moderate"

The degree of truth (R) of the rules is determined for each rule by evaluating the nonzero

Minimum values using the AND operator.

The non- minimum value is gotten by checking each rule for the corresponding truth comparing it to the users input.

Example

Linguistic Variables

Mild = 0.0

Moderate = 0.25

Severe = 0.50

Very severe = 0.75

Patient's Input

Cold = mild

Headache = moderate

Fever = mild

Rigor = Severe

Rule 1

IF fever = "mild" And cold = "severe" And headache = "moderate" And rigor = "severe" THEN Malaria = "moderate"

Rule Base evaluation

Fever = 0.0 Cold = ----- Headache = 0.25 Rigor = 0.50

We can observe that in **rule 1** fever is mild, and in the patient's input, fever is mild so fever in rule is true and would be assigned the value of mild.

For cold, it is false so it is empty, for headache it is true and it is moderate so headache would be assigned 0.25 value. At the end, the non-minimum value for rule 1, is the minimum of all the antecedent that are fired, that evaluates to true.

And operator (minimum of all antecedent)

Min (0.0., -, 0.25, 0.50) = 0.25

This would be done for all the rules and at the end all the rules with the same conclusion would be brought together and the Root Sum Square inference would be performed on them

3.1.3.5. Malavefes fuzzy inference engine. The *Malavefes* fuzzy inference engine possesses mechanisms that govern or monitor decision-making process of *Malavefes*. Operations from rule-base are applied to values of inputs received. Here, RSS is applied to achieve a quality inference.

$$RSS = \sum_{x=1}^{n} R_x^2 \tag{3}$$

where R_x is a fired rule where $x\forall 1,\ldots n$ rule identifier that have been executed.

Expanding Eq. (3), we have Eq. (4) as follows:

$$\sqrt{\sum R^2} = \sqrt{R_1^2 + R_2^2 + R_3^2 + R_4^2 + R_5^2 + R_6^2 + R_7^2 \ldots R_n^2} \tag{4}$$

This method was preferred and applied because it ensured the provision of the best weighted influence on rules executed within *Malavefes*.

3.1.3.6. Defuzzification of output values in Malavefes. The translation of the inference engine results in *Malavefes*, will lead to the defuzzification of some compact values. These values complement the diagnostic process of *Malavefes*. For the purpose of defuzzification, *Malavefes* adopted center of gravity (CoG) or Centroid of Area (CoA).

Thus, in Eq. (5), we have

$$CoA = \frac{\sum_{i=1}^{m} \mu Z(z_i) z_i}{\sum_{i=1}^{m} \mu Z(z_i)} \quad (5)$$

where $\mu Z(z_i)$ is the degree of i in a membership function, while z_1 is the center value in the function. m (in Eq. (5)), is the maximum value that i can achieve or arrive at.

3.1.3.7. Malavefes range of fuzzy values as depicted in the linguistic table. Malavefes range of fuzzy values is depicted in the table below. It simply shows the range of values for each linguistic variable adopted in *Malavefes* (See Table 5).

3.1.3.8. Programmed voice computing mechanism in Malavefes. We incorporated voice computing into *Malavefes* by implementing a speech function and integrating an object API through it. The result of the fuzzy algorithm is passed as a variable to the speech function to interpret to speech. The Malaria fuzzy expert system has a glossary users can search from.

The voice API reads the search criteria searches the database and brings the text to speech result of query to the user by communicating it through speech. We chose English language for English-speaking sub-Sahara countries and other English-speaking malaria endemic countries for the purpose of these software.

3.1.4. Algorithm for Malavefes

Step1: Select signs and symptoms of patients' complaints.
Step2: Conduct a thorough search through the Disease-symptoms database.
Step3: If disease-symptoms match, select the disease and correctly diagnose it.
Step 4: Output the probability (in%) of severity and categorize the disease into either complicated category or uncomplicated category.
Step 5: Statistically depict the categorization of the complication level of malaria.
Step 6: Search the database of malaria drug-dosage prescription based on category.
Step 7: Based on the output of step 6, using voice-enabled programming, prescribe the most appropriate malaria drug and correct dosage. Recommended drugs for complicated cases of malaria are different from recommended drugs for uncomplicated cases of malaria.
Step 8: Send email notification to patients.

3.1.5. Algorithm for Malavefes drug expiration validator

Begin
Step 1: Enter manufactured_date of the anti-malaria drug
Step 2: Enter expiration_date of the anti-malaria drug
Step 3: If the expiration_date is less than the manufactured_date, then the manufactured_date and expiration_date are incorrect.
Step 4: If expiration_date of anti-malaria drug is equal to current date, then drug EXPIRES on current date.
Step 5: If expiration_date of anti-malaria drug is less than current date, then drug has EXPIRED, the drug is NOT safe for ingesting, it can lead to serious complications.
Step 6: If expiration_date of anti-malaria drug is greater than current date, then drug is still usable (NOT YET EXPIRED)
End

3.2. Results

Malavefes was designed and implemented after a comprehensive schematic architecture, as depicted in Fig. 1. From the implementation carried out, the following results were generated; Fig. 2 shows the login page of *Malavefes*, which adequately provides login slots for the patients and administrators.

Fig. 3 shows the patient profile module of *Malavefes*. This consists of the view record, diagnosis, update details and delete account sub-modules.

Fig. 4 shows the voice-enabled diagnosis module within *Malavefes*. This module depicts the possible symptoms of malaria, the possible level of severity and it allows the users to select the most applicable symptoms for the purpose of diagnosis.

Fig. 5 reveals the *Malavefes* malaria intensity prediction chart. The prediction chart of the malaria intensity-reflection section is in Fig. 5.

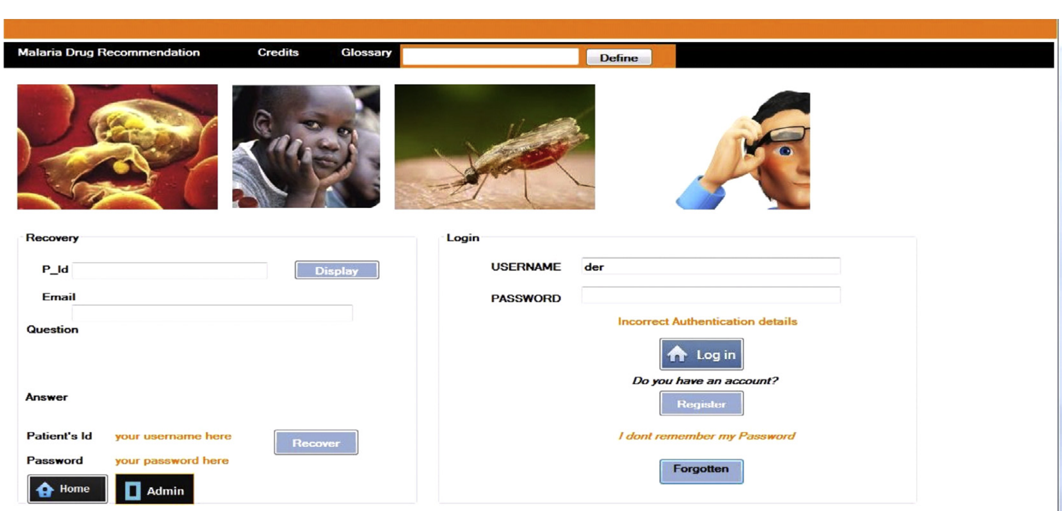


Fig. 2. Voice-enabled Login Page of *Malavefes*.

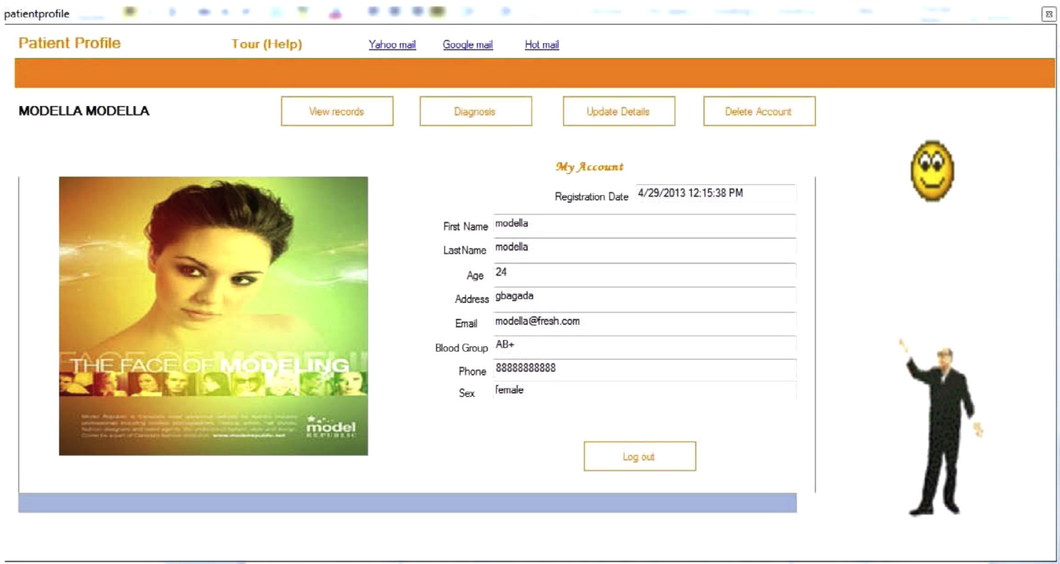


Fig. 3. The Patient profile module of *Malavefes*.

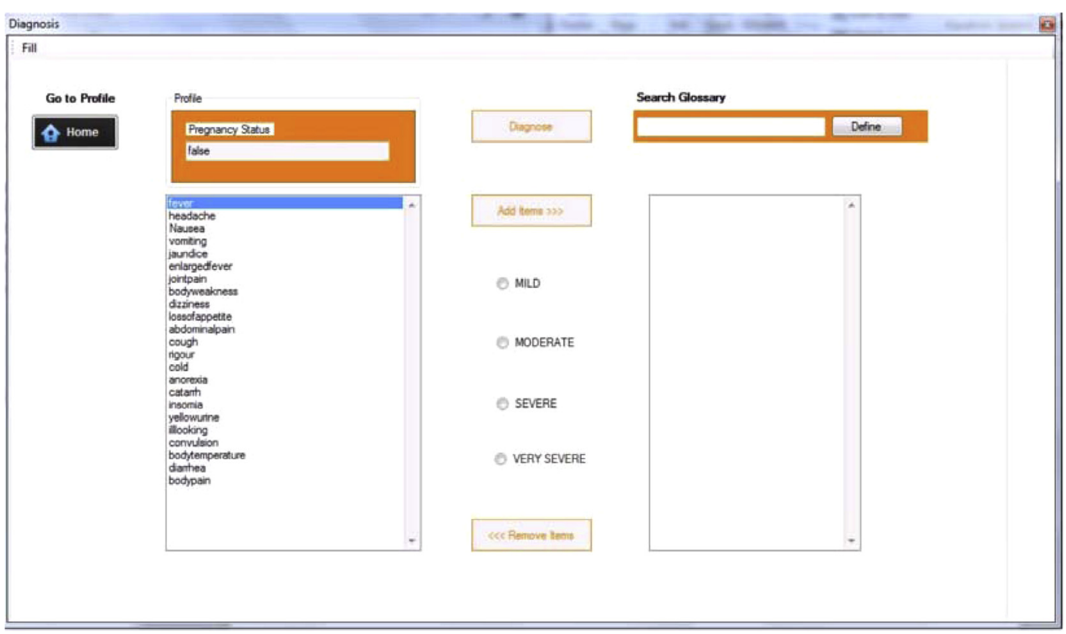


Fig. 4. Voice-enabled Diagnosis module within *Malavefes*.

The anti-malarial drug recommendation for pregnant women module within the *Malavefes* software is displayed in Fig. 6.

Malavefes email notification section is the subject of Fig. 7, where it presents the feedback or output generated by *Malavefes* to patient as an email notification. This email message carefully highlights the severity of malaria infection, malaria prediction rate, age and the blood group of the patient concerned. In addition, *Malavefes* sends a drug recommendation with the correct prescription (dosage) and also specifies the possible allergies to expect.

After developing *Malavefes*, a comprehensive performance evaluation was conducted by administering a comprehensive 19-question questionnaire to medical professionals and individuals from other disciplines (See Tables 1–3). (i) The percentage analysis revealed that 91.4% of the participants agreed and strongly agreed that *Malavefes* software has the ability to prescribe malaria drugs to patients via a voice-based feature (a voice-module), 2.9% were indifferent, while 5.8% disagreed (ii) Approximately 80% of the participants agreed and strongly agreed that the quality of the voice module in the *Malavefes* software was clear and audible enough for the purpose of understanding, while the remaining 20% were indifferent (iii) 88.6% of the participants agreed that *Malavefes* software has the ability to correctly diagnose malaria patients while 11.4% were indifferent (iv) 94.2% of the participants agreed that *Malavefes* has the ability to graphically analyze and present the intensity of malaria infection for a malaria patient based on the input data (possesses graphical depiction of malaria intensity feature), while 5.7% were indifferent (v) 77.2% agreed that the developers of *Malavefes* software have adequately modeled the software according to the operations of typical healthcare providers and pharmacists (Modeling), while 22.9% were indifferent (vi) 94.3% of the participants agreed that *Malavefes* software has the capability of generating email alert notifications for correct dosage

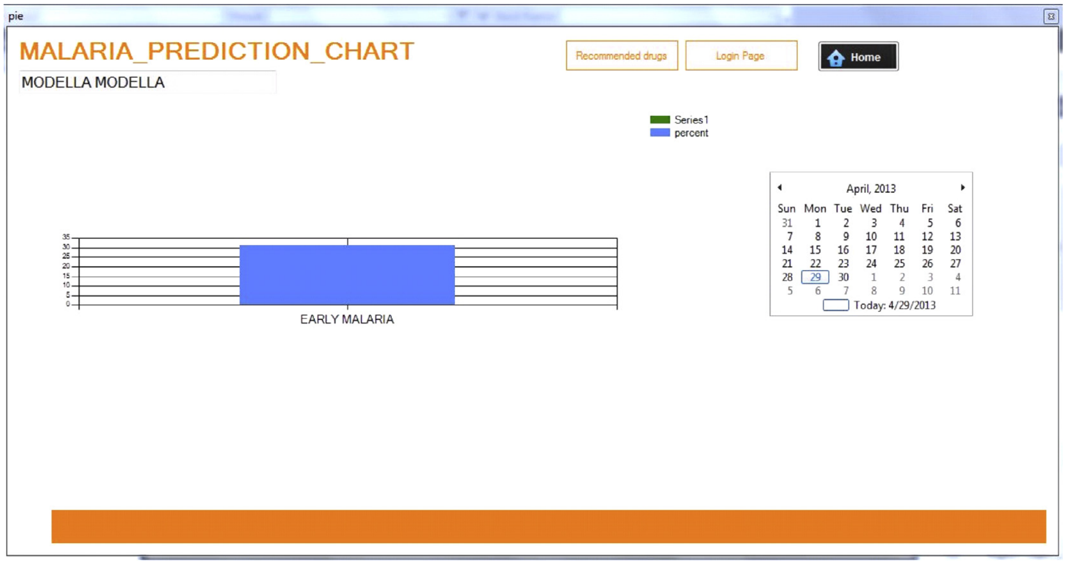


Fig. 5. Malaria intensity prediction chart module within *Malavefes*.

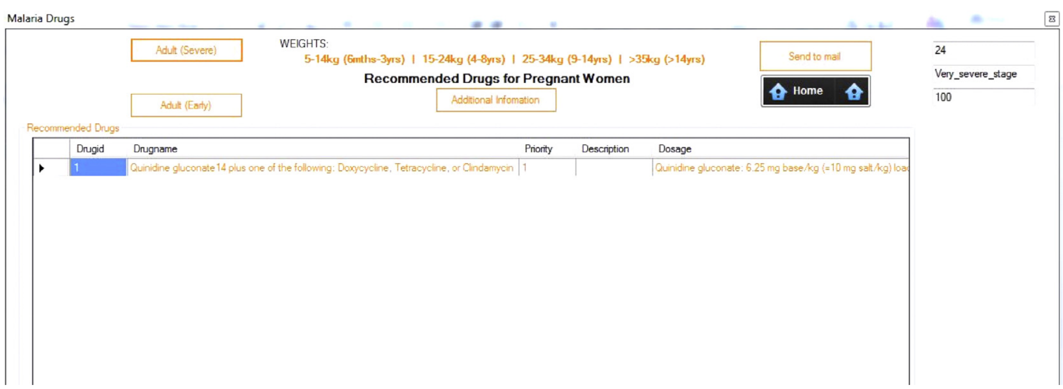
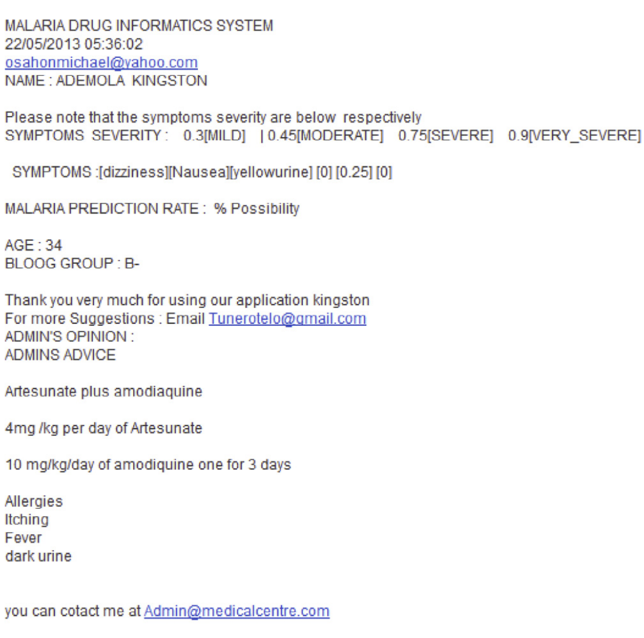


Fig. 6. Anti-malaria drug recommendation for pregnant women module within *Malavefes*.



MALARIA DRUG INFORMATICS SYSTEM
22/05/2013 05:36:02
osahonmichael@yahoo.com
NAME : ADEMOLA KINGSTON

Please note that the symptoms severity are below respectively
SYMPTOMS SEVERITY : 0.3[MILD] | 0.45[MODERATE] 0.75[SEVERE] 0.9[VERY_SEVERE]

SYMPTOMS :[dizziness][Nausea][yellowurine] [0] [0.25] [0]

MALARIA PREDICTION RATE : % Possibility

AGE : 34
BLOOG GROUP : B-

Thank you very much for using our application kingston
For more Suggestions : Email Tunerotelo@gmail.com
ADMIN'S OPINION :
ADMINS ADVICE

Artesunate plus amodiaquine

4mg /kg per day of Artesunate

10 mg/kg/day of amodiquine one for 3 days

Allergies
Itching
Fever
dark urine

you can cotact me at Admin@medicalcentre.com

for feed back

Fig. 7. Email notification module within *Malavefes*.

prescription of anti-malarial drugs prescribed as long as there is internet connectivity (vii) 94.3% of the participants agreed that *Malavefes* software accepts appropriate data type for each field during the symptom-diagnosis phase, while 5.7% were indifferent (viii) 74.3% of the participants agreed that *Malavefes* software was able to prescribe the correct dosage of anti-malarial drugs to be administered to infected patients based on the predicted intensity of malaria (ix) 65.8% agreed that *Malavefes* software prompts error messages whenever wrong data is supplied or when important input fields are omitted 31.4% were indifferent (x) 51.4% of the participants agreed that *Malavefes* software disallows every form of attempts to misuse it (xi) 34.3% disagreed that *Malavefes* software does not have enough controls to disallow misuse, while 34.3% were indifferent (xii) 71.5% agreed that *Malavefes* software was sufficiently robust, while 25.7% were indifferent (xiii) 88.6% agreed that *Malavefes* software possess adequate security access control while 5.7% were indifferent (xiv) 82.8% agreed that they would use *Malavefes* software for supplementary healthcare support (xv) 91.4% agreed that *Malavefes* software was very easy to use, while 8.6% were indifferent (xvi) 100% agreed that *Malavefes* software is generally simple to explore without any difficulty (navigation & exploration) (xvii) 65.7% agreed that they were satisfied with the services and operations provided by *Malavefes* software (xviii) 88.6% agreed that *Malavefes* software will be particularly useful and supportive to developing countries with high rates of

Table 1
Malavefes's Questionnaire Performance Evaluation Result and Analysis.

Question Number	Strongly Disagree (SD)	Disagree (D)	Neutral (N)	Agree (A)	Strongly Agree (SA)	Total
1	1	1	1	16	16	35
2	0	0	7	12	16	35
3	0	0	4	15	16	35
4	0	0	2	20	13	35
5	0	0	8	15	12	35
6	0	1	1	17	16	35
7	0	0	2	25	8	35
8	0	1	8	14	12	35
9	0	1	11	15	8	35
10	0	0	17	12	6	35
11	3	9	12	9	2	35
12	0	1	9	17	8	35
13	0	2	2	21	10	35
14	0	3	3	18	11	35
15	0	0	3	14	18	35
16	0	0	0	22	13	35
17	0	1	11	11	12	35
18	0	0	4	16	15	35
19	0	0	1	17	17	35

A higher percentage of the participants in this experiment agreed (as shown in Table 1 are in the Strongly Agree and Agree column) that *Malavefes* software is a viable, effective and complementary tool for correct dosage prescription of anti-malarial drugs.

Table 2
Percentage Analysis of the Performance Evaluation of *Malavefes.*

Question Number	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total (100%)
1	2.9%	2.9%	2.9%	45.7%	45.7%	100%
2	0%	0%	20.0%	34.3%	45.7%	100%
3	0%	0%	11.4%	42.9%	45.7%	100%
4	0%	0%	5.7%	57.1%	37.1%	100%
5	0%	0%	22.9%	42.9%	34.3%	100%
6	0%	2.9%	2.9%	48.6%	45.7%	100%
7	0%	0%	5.7%	71.4%	22.9%	100%
8	0%	2.9%	22.9%	40%	34.3%	100%
9	0%	2.9%	31.4%	42.9%	22.9%	100%
10	0%	0%	48.6%	34.3%	14.3%	100%
11	8.6%	25.7%	34.3%	25.7%	5.7%	100%
12	0%	2.9%	25.7%	48.6%	22.9%	100%
13	0%	5.7%	5.7%	60%	28.6%	100%
14	0%	8.6%	8.6%	51.4%	31.4%	100%
15	0%	0%	8.6%	40%	51.4%	100%
16	0%	0%	0%	62.9%	37.1%	100%
17	0%	2.9%	31.4%	31.4%	34.3%	100%
18	0%	0%	11.4%	45.7%	42.9%	100%
19	0%	0%	2.9%	48.6%	48.6%	100%

Table 2: The percentage analysis of the performance evaluation of *Malavefes* software showing the percentage ranking of each category of user response to the 19 evaluation criteria (See Table 3) performance evaluation questionnaire administered.

malaria infection (xix) 97.2% agreed that *Malavefes* software would be useful as a desktop healthcare platform.

Here, Fig. 8 consists of the graphical results for the performance evaluation of *Malavefes* software after evaluation. The vertical axis represents the total number of respondents after evaluating the software. The horizontal axis represent the specific question that each respondent provided answers to. SD implies "Strongly Disagree"; D implies "Disagree"; N implies "Neutral"; A implies "Agreed"; and SA implies " Strongly Agree". It will be observed carefully that the SAs and As have higher bars than other categories of assessment (See Fig. 8). Fig. 9 shows a comprehensive fuzzy logic predictive results from *Malavefes* software.This figure adequately depicts the rules applied, severity of symptoms entered, and the fuzzy rule-based evaluations (See Fig. 9).

4. Discussion

From the results highlighted in the results section, *Malavefes* is a good and effective software that has a high potential as a complementary tool for prescribing correct dosage of anti-malaria drugs to infected patients resident in developing countries.

However, high levels of incidences of wrong usage of anti-malarial drugs limit the efficacy of such drugs. In extreme cases, this has led to many adverse effects on the health of ignorant patients. The adverse reactions of patients, as a result of wrong usage of anti-malarial drugs, are a strong warning sign. Thus, precautions should be taken in the empirical use of these drugs.

In order to control and reverse the negative trends and impacts of wrong usage of anti-malarial drugs on a local, regional and national level, *Malavefes* (an informatics software), was developed and should be helpful to assist in the development of efficient intervention strategies.

From surveys conducted in a previous study, it was discovered that at community level, close to 85% of malaria incidences were not well managed by home-based care providers. It was also observed that 96% of caregivers took conscientious efforts within 24 h to address the situation, but about 20% of their efforts yielded positive results as a result of wrong dosages (Simon, 2002). The risk of under-dosage, over-dosage and incorrect dosage can increase as a result of informal administration of anti-malarial drugs (WHO, 2003). According to a recently concluded survey, in which about four hundred (400) respondents participated in, most of the

Table 3
Questionnaire for evaluating *Malavefes* Software's performance. Please fill in the number from 1–5 in front of each raw in the table which you feel most fit. "5" stands for strongly agree while "1" stands for strongly disagree.

Criteria for Evaluation	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. The *Malavefes* software has the ability to prescribe malaria drugs to patients via a voice module. *(voice-based feature)*	1	2	3	4	5
2. The quality of the voice module in the *Malavefes* software was clear and audible enough for the purpose of understanding *(voice-module quality)*	1	2	3	4	5
3. The *Malavefes* software has the ability to diagnose patients of malaria (*Diagnosis feature*)	1	2	3	4	5
4. The *Malavefes* software has the ability to graphically analyze and present theintensity of malaria infection for a malaria patient based on the input dat. *(graphical depiction of malaria intensity)*	1	2	3	4	5
5. The developers of *Malavefes* software have adequately modelled the software according to the operations of typical healthcare providers and pharmacists *(Modelling)*	1	2	3	4	5
6. The *Malavefes* software also has the capability of generating email alert notifications for correct dosage prescription of anti-malarial drugs. *(Notifications)*	1	2	3	4	5
7. The *Malavefes* software accepts appropriate data type for each field. *(data validation)*	1	2	3	4	5
8. The *Malavefes* software was able to prescribe the correct dosage of anti-malarial drugs to be administered to infected patients based on the intensity of malaria. *(Prescription feature).*	1	2	3	4	5
9. *Malavefes* software prompts error message whenever wrong data is supplied or when important input fields are omitted. *(data validation)*	1	2	3	4	5
10. *Malavefes* software disallows every form of attempts to misuse it	1	2	3	4	5
11. *Malavefes* software does not have enough controls to disallow misuse	1	2	3	4	5
12. I consider *Malavefes* software to be sufficiently robust. *(Sufficiency)*	1	2	3	4	5
13. *Malavefes* software posses adequate access control. *(Security)*	1	2	3	4	5
14. I would use *Malavefes* software for supplementary healthcare support *(Intension to use)*	1	2	3	4	5
15. *Malavefes* software is and very easy to use *(Ease of use)*	1	2	3	4	5
16. *Malavefes* software is generally simple to explore without any difficulty *(Ease of use)*	1	2	3	4	5
17. I am satisfied with the services and operations provided by *Malavefes* software *(Satisfaction)*	1	2	3	4	5
18. *Malavefes software* will be particularly useful and supportive to developing countries with high rates of malaria infection	1	2	3	4	5
19. Generally, *Malavefes* software would be useful as a desktop healthcare platform *(Usefulness)*	1	2	3	4	5

Table 4
Some variables and factors associated with non-adherence to dosage prescription of anti-malaria drug for malaria treatment.

S/N	Variables and factors	Brief Description	References
1	Poverty and lack of food	Non availability of food to accompany drug administration;	Gerstl et al., 2010; Anyanwu et al., 2016
2	Fear of future recurrence of malaria and Insufficient funds	Keeping drugs for future recurrence of malaria and due to lack of funds to procure such drug in the future in case of future recurrence	Watsierah et al., 2011
3	Anti-malaria drug sharing	As a result of insufficient drugs, some patients share anti-malaria drugs with others thus leading to non-adherence to medication prescription	Cohen et al., 2010
4	Educational level	Ability to read and write, job type, level of income, settlement type a patient might live in; These abilities can influence the adherence or non-adherence of patients to correct dosage prescription and administration of antimalarial drugs.	CBN (2012); Ezenduka et al., 2014; Onyango et al., 2012; Ohen et al., 2012
5	Knowledge among drug dispensers	Lack of knowledge and proper information about dosage prescription of anti-malarial drugs among drug dispensers	Kamuhabwa and Silumbe (2013)
6	Insufficient details from anti-malaria drug dispensers	Failure to provide sufficient explanation on the correct dosage prescription of the anti-malaria drugs by dispensers has resulted to non-adherence by patients to correct dosage prescription.	Depoortere et al., 2004

Table 5
Table showing linguistic variables and corresponding fuzzy values.

S/N	Linguistic Variables	Fuzzy Values
1	Mild	$0.1 \leqslant z < 0.3$
2	Moderate	$0.3 \leqslant z < 0.6$
3	Severe	$0.6 \leqslant z < 0.8$
4	Very Severe	$0.8 \leqslant z \leqslant 1.0$

patients (precisely 118 (33.71%)), claimed to have administered anti-malarial drugs based on self prescription and recommendation (Ekanem et al., 1990). About One hundred and forty (140) of them weren't cured and had to undergo treatment repeatedly with other anti-malarial medication. Further results showed that one hundred and twenty-five (125 (35.7%)) patients administered anti-malarial whenever they were feverish. However, ninety-eight (98 (28.0%)) patients used anti-malarial as prescribed and recommended in hospitals. Forty-seven (47 (13.43%)) patients purchased their anti-malarial drugs from friends (Ekanem et al., 1990). These results are indications that patients can be prone to and subjected to the negative consequences of self-prescribed anti-malarial medications. Other dangers associated with point-of-sales where patients purchase their anti-malarial drugs from, include; the risk of purchasing expired anti-malarial drugs, counterfeit or substandard anti-malarial drugs and receiving prescriptions from unqualified or fake pharmacists. In fact, some factors constitute hindrance to efficient malaria management. In a study in South Eastern Nigeria between March to October 2010, it was revealed that ignorance constituted 13.0%; fake drug usage constituted 50% and incorrect diagnosis constituted 19.1% (Omole and Onademuren, 2010). There are strong indications that these factors pose major threat to the health of patients. Another study in South Western Nigeria indicated that 58.15% of children were treated for malaria at home. The community however, had a wrong perception of the possible adverse effects of malaria. It was a community that never perceived malaria as a serious disease but tagged malaria as "Iba lasan" which translates to mean "ordinary fever", and had their beliefs that too much sun or too much work was the main cause of malaria (Chukwuocha, 2011). In Kenya, another study was conducted on the knowledge and behaviour of

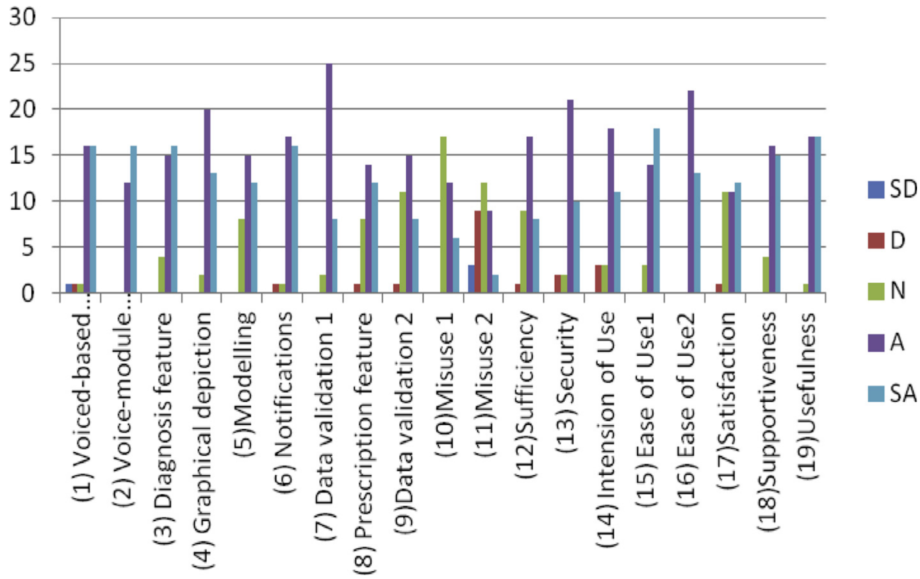


Fig. 8. Graphical result for the performance evaluation of *Malavefes* software.

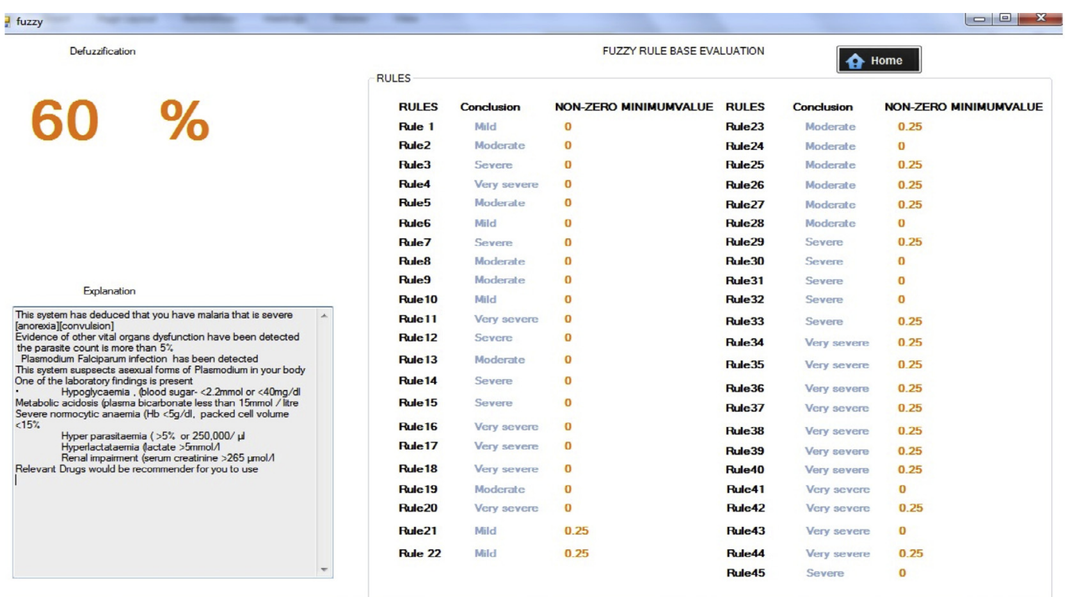


Fig. 9. Sample Result from the Fuzzy logic prediction of malaria intensity for a patient based on symptoms entered and the rules applied.

patients in determining their patterns of anti-malarial drug usage (Falade et al., 2006). Results from the study showed that with respect to knowledge level and the pattern of anti-malarial drug usage among households of Manyatta-B, ninety (90 (70.6%)) took incorrect dosage of Artemether combined therapy (ACT), while thirty-seven (37 (29.4%)) took correct dosage of ACT. One hundred and twenty-five (125 (85%)) took correct dosage of Sulphadoxine-pyrimethamine (SP), while (12 (15%)) took incorrect dosage of Sulphadoxine-pyrimethamine (SP). Fifteen (15 (51.7%)) took correct dosage of Chloroquine, while fourteen (14 (48.3%)) took incorrect dosage of Chloroquine (Falade et al., 2006). Counterfeit and sub-standard anti-malarial drugs are also being sold in markets (Pincock, 2003; ten Ham, 2003) and ignorant people fall prey of such products.

When anti-malarial drugs are prescribed by informed health experts, there is the likelihood that there will be reductions in the harm posed by patients' irrational intake of anti-malarial drugs (Kelesidis et al., 2007). The role pharmacists and medical professionals play in drug prescription cannot be underestimated. Their roles promote the overall health of patients. Similarly, a complementary but alternative method to promoting public health among patients is to adapt and incorporate anti-malarial drug prescription and recommendation knowledge, into voice-enabled user-friendly software. This software can be used by medical professionals, pharmacists and patients in homes and institutions; thus, promoting public health and safety.

In the present study, we have developed *Malavefes*, (a malaria voice-enabled computational fuzzy expert system for correct dosage prescription of malaria drugs). The significance of *Malavefes* cannot be overemphasized. Notable features of *Malavefes* which makes it different from any other existing expert systems include; (i) an programmed voice-enabled feature (ii) a programmed graphical statistical facility to adequately depict the disparity between complicated and uncomplicated cases of malaria based on the severity level (iii) a comprehensive database that accommodates more disease-symptom data, and malaria drug-correct dosage data (iv) supporting materials such as video description of this system (v) a flexible feature that allows both administrator (a health practitioner such as a medical Doctor or Nurse, edits and updates the system. It also allows patients to view their data and updates (vi) an email notification feature that enables communication between administrators and patients (vii) a provision for pregnant women diagnosis and drug recommendation (viii) a notepad that contains all the password for the *Malavefes* software (ix) provision for more disease symptoms (i.e. 23 disease symptoms) and more rule-based system evaluation (it contains 45 fuzzy-related rules), (x) a module for determining whether an anti-malaria drug has expired or not (See Algorithm in 3.1.5 and Figs. 10 and 11.

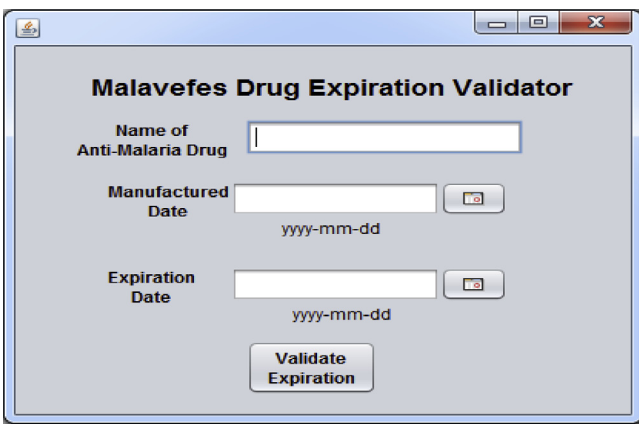


Fig. 10. Graphical User Interface (GUI) of the *Malavefes* Anti-malaria Drug Expiration Validator.

4.1. Significance of this study to researchers in bioinformatics, computational health and pharmacy disciplines

The significance of *Malavefes* to researchers in bioinformatics, biomedicine, computational health and pharmacy disciplines cannot be underestimated. Many malaria researchers have engaged in bioinformatics approaches towards permanently solving the problem of malaria over many years. Some of the researchers have succeeded in identifying drug targets which has ultimately led to the production of anti-malaria drugs such as Artemisin Combination Therapy (ACT). However, a misuse of these anti-malaria drugs can result in the death of the victims who exhibit such ignorance. Thus, the significance of *Malavefes* software is that it is a drug-informatics complementary tool that will help in reducing the mortality rate caused by malaria. This tool will help to complement the effort of pharmacists and drug discovery researchers.

5. Conclusion

Malavefes will help guarantee a drastic reduction in the complications that result from wrong self -administration and usage of anti-malarial drugs. This will ultimately reduce mortality rate especially among pregnant women and children. This computational system will be particularly useful among English-speaking malaria endemic and developing countries of the world. There is need to sensitize and educate people on the proper ethics and caution associated with self-medication or personal administration of anti-malarial drugs. People can also be educated through the use of this informatics-related software. *Malavefes* is now able to identify expired anti-malaria drugs. We were able to include a module in the extended version of *Malavefes* in the revised implementation of *Malavefes* software. An extra feature has been implemented and incorporated into *Malavefes*. This extra feature is a module that helps to identify expired anti-malaria drugs. The algorithm was

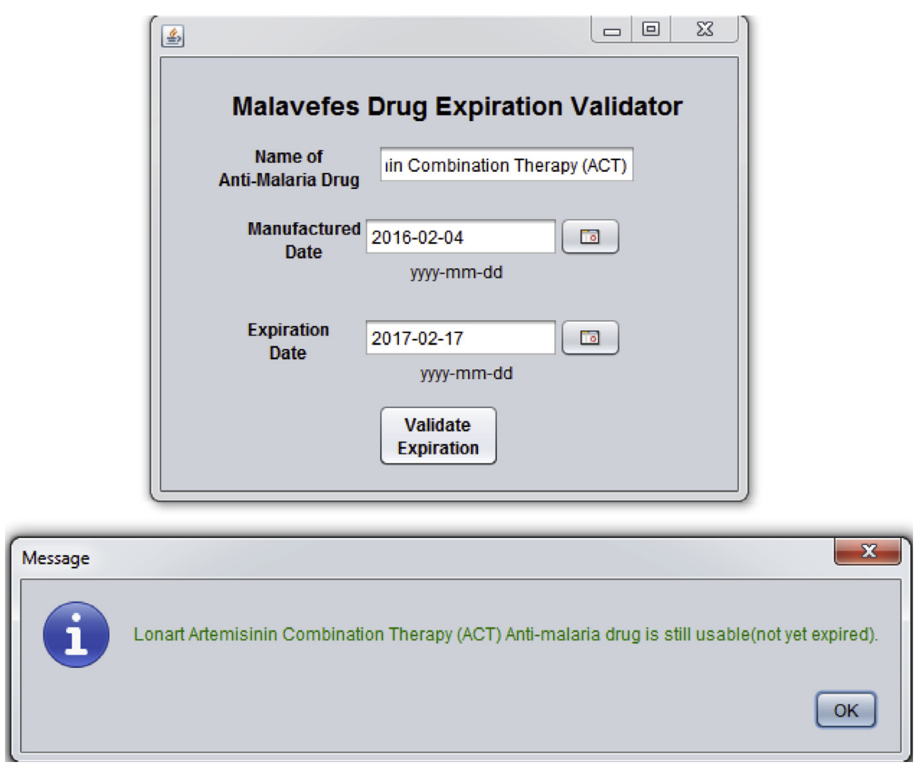


Fig. 11. Results of the *Malavefes* Anti-malaria Drug Expiration Validator.

developed and the implementation was done using Java programming language.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

OOO conceived the study, designed the algorithm and coordinated the project. OOO directed the implementation. OOO and OF carried out the implementations. OOO designed the data request materials and conducted the interviews, data collation. OOO and FEO designed the overall architecture of the software (*Malavefes*) architecture. OOO and FEO wrote the final manuscript. All authors read and approved the final manuscript.

Acknowledgements

We sincerely thank Dr. Ajani Olayinka who was involved in revising this article critically for important intellectual content. We wish to thank Jatto Ahmed for his contributions to this research. We also thank the medical director of Livingword Mission Hospital Ltd., Abia State, Nigeria, for granting us personal formal interviews with some of their medical personnel with respect to the *Malavefes* software and also granting us ethical authorization and clearance/consent. We also want to thank some of the staff of the Covenant University Health Centre, Ogun State, Nigeria, for their time in granting some personal informal chats about different anti-malaria medications. This research was partly supported in kind (through the provision of computers, software and internet support) by The Oluwagbemi Research, Development and Philanthropic Foundation (TORDPF).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jksuci.2017.04.003.

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