Journal of King Saud University – Computer and Information Sciences xxx (2017) xxx–xxx

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 xxxx

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/

Please cite this article in press as: Oluwagbemi, O.O., et al. *Malavefes*: A computational voice-enabled malaria fuzzy informatics software for correct dosage prescription of anti-malarial drugs. Journal of King Saud University – Computer and Information Sciences (2017), http://dx.doi.org/10.1016/j.jksuci.2017.04.003

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.,

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