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REVIEW ARTICLE

A Review of Predictive Models on Diagnosis and Treatment of Malaria Fever

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Abstract—Malaria fever has been identified as a threat to human existence, killing millions of people annually, and also contributing to economic backwardness due to huge amount of money and time being spent by many countries of the world in managing the menace, mostly Africa and Asia countries. Shortages of medical experts, hospitals and necessary equipment have been adjudged some of the prominent factors for the very high number of deaths associated with malaria fever annually. These challenges have made Information Technology (IT) experts to work with medical experts in using modern IT initiatives to address the situation in the form of providing Predictive Models that can carry out diagnosis and in some cases provide therapy. This study looks at some of these Computer Based Systems (Predictive Models) developed to manage malaria with a view to providing meaningful contribution on improving on them. The work looks into present methods and future needs in order to provide computer based viable classifiers in diagnosis and treatment of malaria fever cases. It is hopeful that researchers in the area of providing diagnosis and therapy systems can make use of our valuable improvement suggestions.

Keywords— Malaria Fever, Diagnosis, Therapy, Data Mining, Predictive Models

I. INTRODUCTION

Medical knowledge is today expanding rapidly making computer aided diagnostic system desirable. Such system can give a clinician a second opinion. Recent advances in Artificial intelligence (AI) offer methods and techniques with potential of solving tasks previously difficult to solve with computer-based systems in medical domains. Research worldwide is focusing on the new applications in the medical field and particularly in diagnosis [20]. Today's world is one with increasing access to intelligent systems. In recent time, Artificial intelligence methods have significantly been used in medical applications and research efforts have been concentrated on medical expert systems as complementary solution to conventional technique for finding solutions to medical problems [7]. Health care personnel make predictions routinely every day. They group patients according to disorders, render prognoses of the health status of a given patient at future point in time, or classify laboratory specimens. With the emergence of integrated hospital information systems, the potential of using computerized predictive models to tasks like these is significant [24]. The emergence of information technology (IT) has opened unprecedented opportunities in health care delivery system as the demand for intelligent and knowledge-based systems has increased as modern medical practices become more knowledge-intensive [20].

Information and communication technology (ICT) is an agent of a revolution, which has changed all aspects of society, the way we learn, talk, communicate, buy and sell. The use of telecommunication technologies to deliver health care service has been dated back to the birth of television and telephone in 19th century. The telephoned countries as leading countries in technological advancement have exploited these ICT potentials in bringing hospital to homes [4].

Diagnosis is the identification of abnormal condition that afflicts a specific patient, based on manifested clinical data or lesions. If the final diagnosis agrees with a disease that afflicts a patient, the diagnostic process is correct; otherwise, a misdiagnosis occurred [25]. Medical diagnosis is a categorization task that allows physicians to make prediction about features of clinical situations and to determine appropriate course of action [5]. It involves a complex decision process that involves a lot of vagueness and uncertainty management, especially when the disease has multiple symptoms [26]. Medical diagnosis has undergone different phases of research from statistical methods, which saw the application of bayesian inference, Utility theory, boolean logic and discriminant analysis. When it was evident that statistical tools could not deal with most complex medical problems, Artificial Intelligence (AI) principles were applied [14]. Computer tools help to organise, store and retrieve appropriate medical knowledge needed by the practitioner in dealing with each difficult case and suggesting appropriate diagnosis, prognosis, therapeutic decisions and decision-making technique [15].

Therapy is the attempted remediation of a health problem, usually following a diagnosis. In the medical field, it is synonymous with the word "treatment". Preventive therapy or prophylactic therapy is a treatment that is intended to prevent a medical condition from occurring. For example, many vaccines prevent infectious diseases. An abortive therapy is a treatment that is intended to stop a medical condition from progressing any further. A medication taken at the earliest signs of a disease, such as at the very symptoms of a migraine headache, is an abortive therapy. A supportive therapy is one that does not treat or improve the underlying condition, but instead increases the patient's comfort. Supportive treatment may be palliative care. One of the primary goal of data mining is to predict an "unknown" value of a new sample from observed samples, such a prediction is achieved by two sequential phases (a) training phase- producing a predictive model from training samples using one of the available supervised learning algorithms; and (b) testing phase- evaluating the generated predictive model using testing samples that are not used in the training phase. Numerous applications of data mining process showed validity of the so-called "No Free- Lunch Theorem". It states that there is no a single learning algorithm that is the best and most accurate in all applications. Each algorithm determines a certain model that comes with a set of assumptions. Sometimes these assumptions hold, sometimes not; therefore, no single algorithm "wins" all the time [11].

Malaria is a mosquito borne infectious diseases caused by a eukaryotic protist of the genus plasmodium. It is wide spread in tropical and subtropical regions, including parts of the American, Asia and African. Five species of the plasmodium parasite can infect humans, the most serious form of the disease are caused by plasmodium falciparum. Malaria caused by plasmodium vivax, plasmodium ovale and plasmodium malariae causes milder disease in humans that is not generally fatal. A fifth species, plasmodium Knowlesi, is a zoonosis that causes malaria in macaques but can also affect humans [3]. Amongst the tasks considered in Artificial Intelligence (control, monitoring, scheduling…), the diagnosis is considered one of the most complex and great efforts have been done in AI to resolve this problem in different scenarios [9]. A computer-aided clinical decision support system (CDSS) for diagnosis and treatment often plays a vital role and brings essential benefits for clinicians. Such CDSS could function as an experienced clinician to their decision making task. Nevertheless, it has been a real challenge to design and develop such functional system where *accuracy* of the performance is an important issue [12].

Due to the adverse effect of malaria on people and economy, researchers had undergone series of researches to develop computer based systems that could diagnose or diagnose as well provide therapy for malaria cases. Some of these earlier works are presented below.

II. REVIEW OF RELATED LITERATURES

Web-Based Medical Assistant System for Malaria Diagnosis and Therapy was developed in [3]. The motivations for this work are: most of the existing systems on malaria diagnosis fail to provide therapy while some provide therapy without diagnosis, half of the world's population is at risk of malaria, deaths associated with malaria are at increasing rate and the need of a web-based system that could diagnose malaria and provide therapy. Research Methods: A machine learning technique Rough Set was used on training set to generate a classification model for malaria diagnosis for different malaria cases and therapy was provided accordingly. A Fuzzy Expert System for the management of malaria was developed by Djam et al in [7]. The motivations for this study are: As a prominent environmental health problem in Africa, malaria constitutes a great threat to the existence of many communities and the complexities in medical practice make traditional quantitative approaches of analysis inappropriate. Research Methods: Fuzzy techniques were incorporated on data collected and fuzzy expert system was developed for the management of malaria.

In [25] - The Application of Machine Learning Techniques for malaria diagnosis, motivations for this study are: insufficiency of medical specialist, which has increased the mortality of patients who suffer from malaria and the need to use computer technology to reduce the number of mortality and reduce the waiting time to see the specialist on malaria. Research Methods: The research methodology adopted is the Structured System and Design Methodology (SSADM).Feasibility study of the manual method for performing a medical diagnosis was carried out. The potential of decision tree was used for the design of the system to overcome the weaknesses of the manual method. Kamukama in [10] developed A Clinical Protocol-Based Decision Support System for Malaria Treatment. The motivations for this research are: The medical field has become overwhelmed by large volume of data to manage, resulting into variations in treatment processes, which sometimes lowers quality of service, malaria has continued to be a global scourge, killing several millions of people annually, the vast majority of deaths occur among young children and pregnant women in Africa, especially in remote rural arrears with poor access to health services, Protocol non-compliance, inadequate knowledge and expertise are all responsible for these millions of death. Research methods: Research and Review of the existing literature on concepts underlying Protocol Based Decision Support System including the critical elements needed in their development and the technology .Knowledge acquisition for the knowledge base of the Protocol-Based Decision Support System, Analysis and Representation ,Data manipulation and Inference, System Development, Testing and Validation, Documentation. Fuzzy-rule based framework for the management of tropical diseases, using malaria as a case study was developed by Obot and Uzoka in [14]. The motivations for this study are: The application of the conventional symbolic rules found in knowledge base technology to the management of a disease suffers from its inability to evaluate the degree of severity of a symptom and by extension, the degree of the illness. Research Methods: The fuzzy logic for the diagnosis of malaria disease involves fuzzification, inference and defuzzification. There were qualitative and quantitative variables, which were fuzzified, inferred and defuziffied. Fuzzification begins with the transformation of raw data. During the process, linguistic labels are attached to the symptoms and the diagnostic steps are accompanied by associated degrees of intensity rated on a likert scale of 1 – 5. The linguistic labels are later assigned some degrees of membership for mild, moderate, severe and very severe labels and fuzzy rules are then developed. The fuzzy inference employed is root sum square (RSS) and the deffuzification inference is a mapping from a space of fuzzy actions defined over an output universe of disclosure into a space of non-fuzzy actions.

Uzoka and Barker [26] in Medical Decision Support System using Analytical Hierarchy Process: A case study of malaria diagnosis. The motivation for the research include: Malaria attack is so prevalent, especially in the tropics, malaria is a major source of morbidity and mortality in most African countries, high incidence among children less than 5 years old, roll back malaria has not succeeded in eradicating malaria, research has been intensified in the past decade to facilitate finding more appropriate means of malaria diagnosis, treatment and control. The method used involved interaction with medical doctors on symptoms of malaria, the possible grouping of the symptoms and the pairwise comparison of the symptoms. Design of a computer oriented model using the analytical hierarchy process (AHP) powered inference mechanism. The major components of the model are Knowledge base, Decision Support base (Powered by AHP) and User interface.

Decision Support Systems to identify different species of malaria parasites was developed by Prabhu et al in [19]. The research was motivated due to the fact that timely and accurate diagnosis of different species of malaria is essential to prevent mortality and morbidity. In the method used, two expert systems were developed to aid in the diagnosis of malaria. A rule based decision support tool (CLIPS) was used to create the medical expert system. A limited Bayesian prototype was also developed in Netica, to compare and assess the usefulness of probabilistic systems. Certain assumptions were made to formalise the knowledge in both the rule based and Bayesian systems. Olabiyi et al in [16] presented A Decision Support System for Diagnosing Tropical Diseases Using Fuzzy Logic. The motivation for this research include- Tropical diseases are associated with a high level of mortality rate, and also they are very common in tropical countries, the tropical diseases have some similar symptoms which makes it difficult sometimes for doctors to diagnose, patients sometimes have difficulty explaining how they feel to the doctors, some doctors are not familiar with some of the new changes in medicine and human health. Research Method: Data were gathered by interacting with various medical doctors who are experts in diagnosing tropical diseases to gain heuristic knowledge on the diseases. The system was developed to diagnose ten tropical diseases including malaria. Diagnosis was carried out by weighing each symptom with respect to the disease in question using generalized fuzzy soft set (GFSS).

A Knowledge-Based Data Mining System for Diagnosing Malaria Related Cases in Healthcare Management was developed by Olugbenga et al [17]. Research Motivations: In some hospitals in Nigeria, it is difficult to select or extract very important information from the database, the increasing volume of data in modern business and science, most especially the health sector calls for computer based approaches. Methods used-Data collection was obtained by survey from four hospitals in Lagos metropolis of Nigeria. Visualization and knowledge representation techniques were used to present the mined knowledge to the user. The

components of the knowledge based data mining system are: knowledge base, inference engine, rules and decisions. The implementation of the system was carried out using C#.NET programming language and Microsoft SQL Server 2005. Computer Automation for Malaria Parasite Detection Using Linear Programming by Vipul et al [27]. Motivations: Malaria causes more than 1 million deaths arising from approximately 300-500 million infections every year. Manual microscopy is not a reliable screening method when performed by non-experts. Need of an automated system aims at performing this task without human intervention and to provide an objective, reliable and efficient tool to do so. Methods: Formulation of a linear programming model based on the given data. Solving and displaying the result using graphical method approach for detecting parasite.

Online System for Diagnosis and Treatment of Malaria was developed in [8]. Motivations for the work: It is estimated that a child is killed every 30 seconds, and there is an annual report of 500 million cases of malaria in Africa. Malaria prompt diagnosis is hindered by the fact that current diagnostic tools are affected by the harsh tropical weather, the lack of qualified medical laboratory technicians to read test results, the lack of regular or no supply of electricity to preserve available diagnostic tools. Additional four million health workers are needed throughout the world. Research Method: Medical experts from Ahmadu Bello University Teaching Hospital, Nigeria were interviewed and data describing the evolution cycle of malaria and the method of treatment were collected. The obtained data were used to build the knowledge based of the rule based system. PhP was used as scripting language; MySQL was used as the database, while Apache serves as the server that housed the inference engine.

Decision Support System for Malaria and Dengue Disease Diagnosis (DSSMD) By Priynka et al [18]. Research Motivations: Malaria and dengue remain to be the most vital cause of morbidity and mortality in India and in many other tropical countries with complete 2 to 3 million new cases arising every year, Malaria is a major health problem in the world, oldest chronic and most widespread fatal disease, unavailability of pathological and imaging based medical diagnosis tool in remote areas. Methods: The system was developed using the MATLAB. The overall classification was done using fuzzy logic toolbox. The system has three modules; GUI interface showing the symptoms, Knowledge Base where fuzzification takes place, and Inference Engine where the fuzzified value is defuzzified in the decision support system model. More than 200 fuzzy rules were generated by the system for diagnosis. An Intelligent Decision Support System for the Prompt Diagnosis and Treatment of Malaria and Typhoid Fever in the Malaria Belt of Africa by Adehor and Burell in [2] Research Motivation- A child is killed every 30 seconds and there is annual report of 500 million cases in Africa, Malaria's prompt diagnosis is hindered by the fact that current diagnostic tools are affected by the harsh tropical weather, lack of qualified medical laboratory technicians, lack of regular supply of electricity to preserve available diagnostic tools and lack of adequate transport means to transport patients from rural areas to the urban areas. Method- A study was carried out in the Niger-Delta region of Nigeria, in the West African sub regional network where malaria and typhoid are known to be prevalent. The initial findings showed that malaria can be diagnosed based on signs and symptoms. A simple model was used to capture signs and symptoms that are similar to known febrile diseases in the region from the consultants interviewed. The knowledge based analysis of the system was carried out using the Mockler Situation Analysis Methodology. The system was designed and developed using rapid prototyping with a simple expert system shell because of its simplicity and the fast learning curve. The knowledge base of the shell holds details of the heuristics. The system has a total of 53 rules in its knowledge base.

A Knowledge Based Expert System for Symptomatic Automated Healthcare was developed in [23]. Research Motivations: Healthcare distribution is being transformed by developments in e-health, the revolution of medical science to computer technology has made life easy and patients or end users are not bound to the doctors or other resources of medical science. Methods- The system is an artificial Expert or Expert System, having three client modules – user interface, inference engine and knowledge base. Patients or users remotely interact with the system and find out the disease by giving some symptoms to the computer. In this way, the system makes feasible diagnosis for patients and also suggests particular treatment regarding the disease. Forty-eight diseases, including malaria, were diagnosed by the system. The Integrated Management of Health Care Strategies and Differential Diagnosis by Expert System Technology: A Single- Dimensional Approach [1]. Research Motivations: Malaria and typhoid kill more people than the most dreaded Acquired Immune Deficiency Syndrome (AIDS). Though diagnosing malaria based on signs and symptoms is justifiable, its management by healthcare personnel in the rural areas has become ever more complicated because of its overlapping symptoms and signs with those of other febrile diseases in the region. Methods: The knowledge acquisition and elicitation stages of the system were achieved using questionnaires and interview techniques. The knowledge gathered from these processes were analyzed and represented in the form of Mockler Situation Analysis Methodology. Rapid Prototyping, using a simple expert system shell was used to develop the system due to its simplicity and fast learning curve.

Malaria Disease Identification and Analysis Using Image Processing was developed in [22]. Motivations: Malaria is a serious infectious disease which responsible for nearly one million deaths each year. Manual Microscopy as a method of diagnosing Malaria is time consuming and prone to human error even in experienced

hands. Methods: Support Vector Machine (SVM) is used in this work for classification of affected or not affected images by malaria. The statistical learning theory provided a framework for studying the problem of gaining knowledge, making predictions, making decisions from a set of data. Motivation: Malaria causes more than 1 million deaths arising from approximately 300-500 million infections every year, manual microscopy is not a reliable screening method when performed by non-experts need of an automated system aims at performing this task without human intervention and to provide an objective, reliable and efficient tool to do so. Method: Formulation of a linear programming model based on the given data. Solving and displaying the result using graphical method approach for detecting parasite. Shruti and Shirgan in [21] developed Automatic Diagnosis of Malaria Parasite Using Neural Network and Support Vector Machine. The research was carried out because malaria affects at least 200 to 300 million people every year and causes an estimated 300 million deaths per annum.

III. SUMMARY OF COMPUTER BASED SYSTEMS USED IN DIAGNOSIS AND TREATMENT OF MALARIA

From the reviewed works, researchers working on Computer Based Systems for Malaria diagnosis and treatment had approached it in two different ways- Image Processing (imaging) which involves the identification and prediction using the images of the parasites obtained from infected blood and Symptomatic Approach which carries out diagnosis based on available symptoms of the patient. The researchers working on the two approaches have made use of different data mining techniques described in the Table1 below.

TABLE 1

SOME OF THE AVAILABLE PREDICTIVE SYSTEMS ON MALARIA DIAGNOSIS AND TREATMENT

Researcher(s)	**Method Used**	**Imaging/ Symptomatic Approach**	**Motivation(s)**
Adetunmbi et al [3]	Rough Set	Symptomatic	Increased deaths due to malaria Most systems on malaria lack therapy
Djam et al [7]	Fuzzy Logic	Symptomatic	Malaria constitute great threat to existence of many communities etc
Ugwu et al [25]	Decision Tree	Symptomatic	Insufficiency of medical experts which has increased the mortality rate
Kamukama 10]	Clinical Protocol Based Decision Support	Treatment based on laboratory results	Malaria has become a global scourge killing several millions of people annually.
Obot and Uzoka [14]	Fuzzy Logic	Symptomatic	The need to evaluate severity of symptoms and degree of illness
Uzoka and Barker [26]	Analytical Hierarchy Process (AHP)	Symptomatic	Malaria is a major source of morbidity and mortality in most African countries
Prabhu et al [19]	Rule Based and Bayesian Approach	Imaging	Timely and accurate diagnosis of different species of malaria to prevent mortality and morbidity.
Olabiyi et al [16]	Fuzzy Logic	Symptomatic	Malaria and Dengue Fever remain the most vital cause of morbidity and mortality in India and Tropical Countries
Olugbenga et al [17]	Visualization and knowledge representation techniques involving knowledge base, inference engine, rules and decisions	Symptomatic	Difficulty in extracting information from the patients databases in Nigeria hospitals
Vipul et al [27]	Linear Programming	Imaging	Malaria Caused 1 million deaths from 300-500 million infections every year
Donfact et al [8]	Rule Based Expert System	Symptomatic	The world needed additional 4 million health workers. A child is killed every 30 seconds and annual report of 500 million cases of malaria yearly in Africa

Priynka et al [18]	Fuzzy Logic	Symptomatic	Malaria and dengue remain to be the most vital causes of morbidity and mortality in India and in many other tropical countries. Imaging based medical tools are not available in remote areas.
Adebor and Burell [1]	Knowledge Based using Mockler Situation Analysis	Symptomatic	A child is killed every 30 seconds, annual report of 500milion cases of malaria yearly. Diagnostic tools are affected by harsh tropical weather and lack of qualified medical lab technicians
Soomro et al [23]	Expert System with three Client Modules	Symptomatic	Healthcare System is being transformed by development in e-health.
Shruti and Shirgen [21]	Neural Network and Support Vector Machine	Imaging	Malaria affect 200 to 300 million people every year causes an estimated 300 million deaths yearly.

IV. CONCLUSION

It is evident from the reviewed work that malaria is a deadly disease, killing millions of people annually with largest proportion in Africa. This study shows the large number of deaths occur annually as a result of many factors which include shortages of medical personnel, laboratory equipment, hospitals and wrong interpretation of laboratory results. It also established the fact that remote areas are majorly affected. The fusion of Medical Science and Computer Science (Information Technology) in managing deadly diseases as a result of the earlier mentioned challenges was also established. This collaboration has led to development of computer based predictive models in medical diagnosis and treatment. These models are either based on available symptoms or images of the malaria parasites. The models are expected to be of immense assistance in both urban and rural areas of the affected regions. However, adequate care must be taken while developing these computer based systems. Accuracy and reliability of such systems must be thoroughly evaluated. It is observed from the reviewed works that most of these Computer Based Systems for malaria diagnosis are based on a single predictive models, most provide diagnosis without therapy and vice versa. In addition, most researchers failed to evaluate the detection rate (accuracy) of the systems. Accessibly and simplicity of these systems must also be put into consideration by future researchers.

Researchers can endeavour to make these systems mobile application based, especially those working in symptomatic environment so that many people can have access to it.

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