Design of Expert System for Diagnosis of Malaria Using VB 6.0

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Abstract
It’s been found that missing medical data leads to mis-diagnosis, which in turn leads to inappropriate treatment and this usually triggers a chain reaction of repeat diagnosis, re-treatment, missed disease outbreak recognition and eventually high cost of medical care. This is worse when the mis-diagnosis is on endemic, infectious and preventable diseases that are leading causes of death in the developing countries, such as malaria. The aim of this study is to design an expert system for diagnosis of malaria using the Microsoft Visual Basic 6.0. When malaria is effectively diagnoses it leads to proper treatment and thus prevents the deaths resulting from its disease complex. This type of automation of medical diagnosis to improve the diagnosis of malaria and thus the overall outcome following appropriate treatment is mostly beneficial to the remote areas of developing countries, where the population is deprived of the facilities of having several medical experts to diagnose diseases. This expert system designed to diagnose malaria, called ***MALARES,*** uses the rule-based, forward-chaining and employed Visual Basic 6.0 programming language. Knowledge base is built by accumulating factual knowledge from literature, internet and medical experts of malaria. Different production rules were used for diagnosis based on Sign / Symptom / Investigating reports. The system provides a simple, interactive, graphical user interface with menu.

***Keywords**: Design, Expert systems, Medical Diagnosis, Malaria, Knowledgebase, MALARES, VB 6.0*

1. Introduction

Patients will normally seek the help of physicians, who are medical experts, for diagnosis (or determination) and treatment of various health problems [1]. This usually follows a clinical diagnostic process involving a combination of the patient’s history and a clinical examination by the physician with laboratory investigations and/or diagnostic imaging procedures. All these are required to make diagnoses and decide whether medical treatment is needed, and what treatment should be given [2].

Sometimes, the decision making process (diagnosis) is difficult and more clinical information may be needed to confirm a clinically suspected diagnosis [2]. This is made worse when its remembered that any wrong diagnosis by whatever reason or guise translates to a wrong treatment leading to the vicious circle of repeat diagnosis and repeat treatment until the right diagnosis is arrived at and then the appropriate treatment. This surely increases the cost of healthcare for such individual.

When such decision making becomes complex and a herculean process, especially from the need to select from many possible diagnoses (differential diagnosis), a diagnostic support system

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can be made available in form of intelligent healthcare informatics to ease the process of diagnosis and in turn improve treatment and medical or healthcare. Thus intelligent healthcare informatics can be brought to bear on the dual problems of improving medical diagnosis to improve quality and then of reducing healthcare costs occasioned by repeat diagnosis from failed or inappropriate diagnosis and subsequent wrong treatment [3].

1.1 Medical Diagnosis and Expert Systems

Intelligent healthcare informatics is used to mean an expert system, which is a computer program used for

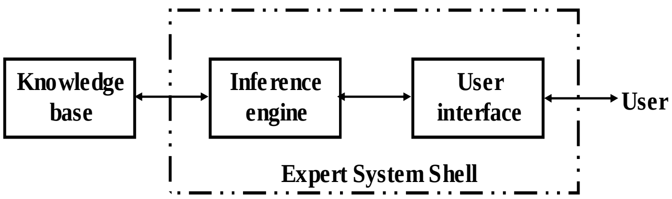

Figure 1: The Simplest form of an Expert System

medical diagnosis. It performs complex data processing similar to evaluation made by a human expert like the medical doctor [4]. The program is able to draw conclusions and make decisions, based on knowledge, represented in its database. Therefore, an intelligent healthcare informatics or expert system can also be a decision support system.

Now, when conclusions are drawn (inferences) by computer-based systems, they are contained in the *inference engine*. These inferences are derived from information (knowledge) supplied by experts in the field to or stored in the computer system as *knowledge-base.* Therefore expert systems usually consist of two core parts in its kernel: a knowledge base and an inference engine [5,6]. A user interface is included to enable a user interact with the computer system (Figure 1).

Expert system is an application area of Artificial Intelligence that extensively employs specialized knowledge to solve problems at the level of a human expert. And a human expert can be defined as a person who has expertise, knowledge or special skills that are not known to most people outside of his field.

Expert system emulates the decision-making ability of a human expert [7]. As a result, it’s designed to solve complex problems by reasoning about knowledge, like a human expert, and not by following the procedure of a developer as is the case in conventional programming [8]. In fact, it is expected that modern expert systems should solve very difficult problems as well as or better than human experts [9].

Expert systems currently play important roles in medicine, medical practice and medical or healthcare [10]. About nine areas of the medical practice have been identified to employ the use of computer expert systems. These are: Prediction of Disease, Prevention of Disease, Diagnosis of Disease, Staging of Disease, Therapy of Patient, Rehabilitation of Patient, Health Status of the Patient, Counselling of the Patient, Advocacy for the Patient [11].

Categorically, expert systems can be applied in the following tasks in the medical practice [12]: Generating alerts and reminders, Diagnostic assistance, Therapy critiquing and planning, Agents for information retrieval. In the task of *diagnostic assistance*, an expert system can help suggest likely diagnoses based on patient data, when a patient's case is complex, rare or the clinician making the diagnosis is quite inexperienced in the given specialty.

Therefore, medical diagnosis can effectively be performed via expert systems. This is based on given patient’s case or data, which enables the physician to properly diagnose diseases and describe methods of treatment to be carried out. The diagnostic result of the computer expert system (with the knowledge-base of many human experts) is expected to be more accurate and therefore more reliable than that of a single human expert. This in turn is meant to prevent mis-diagnosis with the attendant mis-treatment and so reduce the overall cost of medical care.

1.2 The Diagnostic Process

Medical diagnosis as a process is a cognitive process. It is a part of an entire clinical care process, where a physician uses several sources of data and puts the pieces of the puzzle together to make a diagnostic impression [13]. The initial diagnostic impression can be a broad term describing a category of diseases instead of a specific disease or condition. After the initial diagnostic impression, working diagnosis, the physician obtains follow up tests and procedures to get more data to support or reject the original diagnosis and attempts to narrow it down to a more specific level using the diagnostic procedures. A typical diagnostic process is shown in Figure 2.

vomiting, cough, diarrhoea and abdominal pain [18]. The malaria parasite is transmitted by the female Anopheles mosquito, as its vector of transmission.

The human malaria infection begins when an infected female anopheles mosquito bites a person. The cycle of the parasite causing malaria can for simplicity be divided into two: the cycle in mosquito and the cycle in human. Before a human infection,

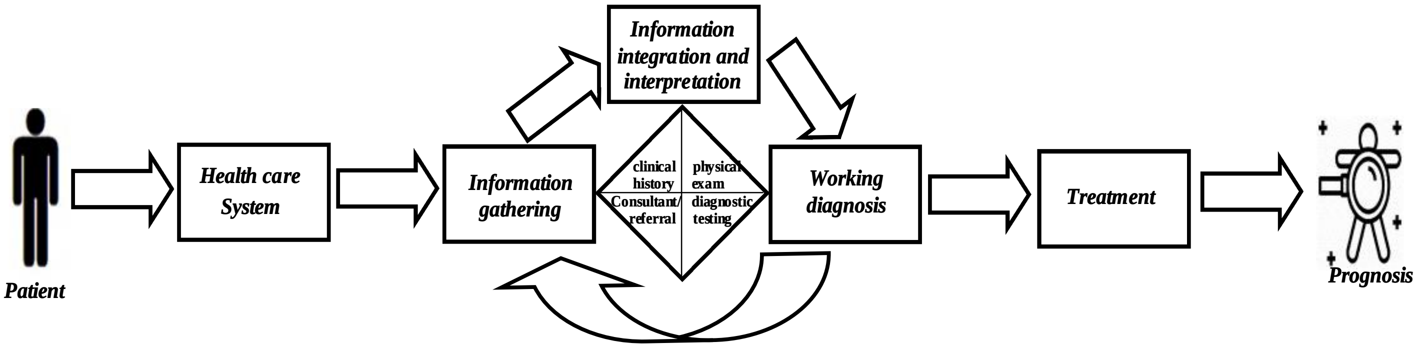

Figure 2: The Diagnostic Process

In a typical Diagnostic Process, a *Patient*: experiences a health problem or need and engages or consults with a human expert (medical doctor) in a *Health care system.* Here, *Information gathering* (through *consultation* by the physician leads to data collection including *clinical history, physical exam* and *diagnostic testing*) and *Information integration and interpretation* take place to formulate a *working diagnosis.* Based on the diagnosis, the planned path of care is instituted in form of *Treatment*. Following these, a prognosis from both patient and system in form of outcomes, which are itemized to learn from diagnostic errors, near misses, and accurate and timely diagnosis.

1.3 Malaria as a Public Health Disease

Malaria is an infectious disease caused by the protozoan parasite called *Plasmodium*. In the human, malaria is caused by four of Plasmodium species: *P. falciparum, P. malariae, P. ovale* and *P. vivax*. Malaria has fever as a main symptom, is endemic in many developing countries and a life-threatening systemic infection [14,15,16,17]. The most severe form of malaria is caused by P. falciparum and when uncomplicated has variable clinical features as fever, chills, headache, muscular aching and weakness,

the plasmodium will first undergo a cycle in the mosquito to produce sporozoites. So when an infected female anopheles mosquito bites a person it injects its saliva infected with the plasmodium sporozoites into the blood circulation. This triggers the parasitic life cycle in human to produce gametocyte. When again a female anopheles mosquito bites an infected person it will this time ingest gametocytes from the human's blood. The simplified life cycle of malaria parasite is shown in Figure 3 [19].

Malaria has estimated global 300 million new cases yearly and 2-3 million deaths resulting from contractions [20]. It is one disease that is commonly associated with the 'factor of developing' called poverty and so known to have a major negative effect on economic development especially in the developing countries [21]. This socioeconomic implication of malaria makes it an important issue in its diagnosis. Malaria alone has estimated losses of up to US$12 billion a year in developing countries, especially Africa, due to increased healthcare costs, loss of ability to work, and negative effects on tourism [22].

The World Health Report of 2017 indicates that Africa accounts for 90% of malaria cases and deaths worldwide. Fifteen countries – all but one in

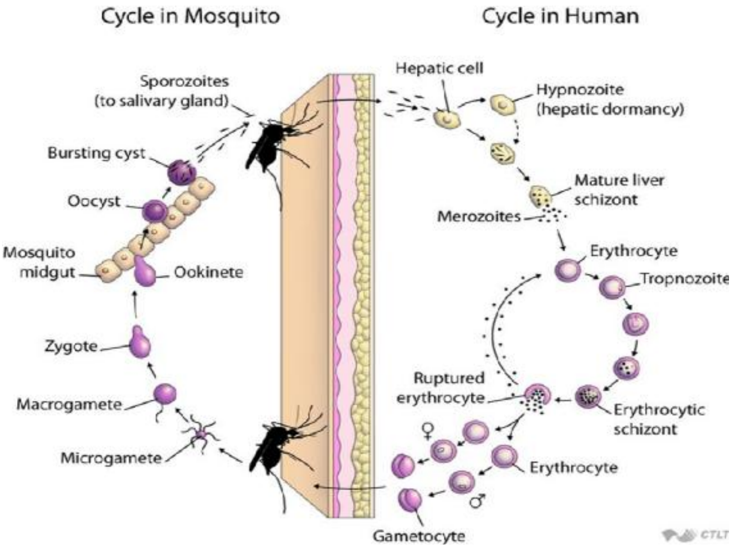

Figure 3:: Simplified Life Cycle of Plasmodium spp
(*Source: http://www.malwestgr/en-us/nsrf.aspx*)

sub-Saharan Africa – carry 80% of the global malaria burden [23]. This burden is not restricted to health but encompasses many other facet of national life: education, economy and national development. For instance, Countries with intensive malaria as in sub-Saharan Africa exhibit a 1.3 per cent loss in economic growth; at least 20 per cent of all childhood deaths in Sub-Saharan Africa can be attributed to malaria; two countries (Democratic Republic of the Congo and Nigeria) account for about 40% of estimated mortality due to malaria worldwide; in Africa malaria transmission coincides with planting and harvesting seasons, thus seriously hampering agricultural production [24]. Generally speaking, malaria is estimated to result in economic losses of up to US$12 billion a year in developing countries, especially Africa, due to increased healthcare costs, loss of ability to work, and negative effects on tourism [25].

1.4 Medical Diagnosis of Malaria

As itemized above, malaria is commonly associated with poverty and poor sanitation. This is true for Nigeria, because with a population of nearly 200 million people, a large percentage of its population lives in rural areas, without access to portable water and adequate healthcare [26]. These have a major negative effect on economic development [21].

Malaria has the highest mortality rate in Nigeria: 20% [27,28]. This is because the Plasmodium falciparum protozoa causing malaria caries a poor prognosis with high mortality if untreated. Yet, this disease has an excellent prognosis if diagnosed early and treated appropriately [25].

This is why proper diagnosis and treatment of malaria, a preventable cause of death, is important for the developing countries like Nigeria and more so for the rural and remote areas where the population are deprived of the facilities of having several medical experts to diagnose this disease. The dearth of several medical experts in the remote areas can be compensated by the employment of computer expert systems. So in expert systems, the expertise of specialists is stored in computers through the use of expert system technology and few rural medical doctors can achieve the same result compared to when there are several medical experts [3].

Now for malaria to be diagnosed, a suspicion is likely by the presence of fever and by excluding other causes of fever on history and physical examination, a firm diagnosis of malaria is made on microscopic examination of a blood slide. This process is called medical diagnosis. The intricate processes of arriving through this diagnostic procedure involving the collection of clinical data and their processing to a definitive diagnosis of malaria can be automated using the computer expert system.

1.5 Expert Systems in Medical Diagnosis

A classical medical diagnosis expert system is the *MYCIN*. It was developed to capture the knowledge of medical experts in infectious blood diseases [29]. Aside from MYCIN, another expert system, *Diagnosis Pro* provides differential diagnosis in the field of general internal medicine, family practice, paediatrics, geriatrics and gynaecology [30]. Another expert system used in medical diagnosis is the **G**lobal **I**nfectious **D**iseases & **E**pidemi**O**logy **N**etwork**,** GIDEON. In addition to diagnosis, GIDEON is used for simulation and informatics in the fields of geographic medicine and infectious diseases, and Clinical Microbiology [31]. Though, GIDEON is country specific. Then, **P**ost-**O**perative **E**xpert **M**edical **S**ystem, POEMS provides decision support system for post-operative care. POEMS was developed to give advisory and decision support to less experienced staff [32].

A number of works have been done on use of expert systems for diagnosis of malaria and other febrile illnesses especially for malaria and typhoid fever. In his work, Anigbogu adopted the Structured System Analysis and Design Method (SSADM) and the Expert System Methodology to develop the system [33]. Adehor also developed a Clinical Protocol-based Decision Support System (PBDSS) for the treatment of malaria [34]. This system was able to provide a treatment based on the level of severity of the disease. Uzoka et al did a work on fuzzy expert system for the management of malaria (FESM) [35]. Their system was described as capable of providing decision support platform to malaria researchers, medical doctors and other healthcare practitioners in malaria endemic regions.

1.6 Use of the Computer Systems to Diagnose Malaria

This work is a computer expert system designed specifically to diagnose malaria. Therefore it is called ***Malaria Expert System*** (MALARES). Malaria is chosen for its public health as well as socioeconomic importance in a developing country like Nigeria, which is the scope of the study. The intention is to contribute to the improvement in the diagnosis of malaria in order to prevent mis-diagnosis and mis-treatment that follow improper diagnosis of malaria leading to high mortality rate in a disease that is considerably a preventable cause of death.

The expert system is developed using the Microsoft Visual Basic 6.0 (VB 6.0) in Windows platform. Visual Basic is a third-generation event-driven programming language and integrated development environment (IDE) from Microsoft Incorporated [36]. VB 6.0 is a very good tool for expert systems. It has a user friendly interface: the Graphical User Interface (GUI). It may be executed in three ways: interactively using the GUI interface; interactively using a window/menu/mouse interface on windows, or as embedded expert system in which the user provides a main program and control execution of the expert system. The present design employed execution interactively using the GUI interface.

Besides, a number of expert systems were considered for implementation of the expert system with respect to appropriateness and affordability having in mind the target environment, Nigeria as a developing country. Finally, the VB 6.0 was selected over the other equally good expert system tools like Java and CLIPS. The features that endeared Visual Basic 6.0 to this work included: object orientation, platform independence, simplicity, security, modularization, GUI interface, robustness, high performance, dynamism, low cost, styles, customized gradient colours and advance owner draw modern interface.

2. Methodology

In this study, the Rule-based systems methodology is used, which stipulates the step by step procedure undertaken to arrive at the diagnosis and treatment of malaria with their possible prognoses. These steps include the following: analysis of the present (conventional) system; identification of problems of the current system; analysis of the proposed system; and system design of present system and its feasibility.

2.1 Analysis of the Present System

The conventional system of diagnosing malaria is a manual type, in which one human expert, the medical doctor, solely evolves the decision-making process based on his prior training and knowledge on malaria to come up with a diagnostic decision. This dependence on a single human expert has a lot of limitations and disadvantages, including the fact that humans: can get tired, be forgetful, be inconsistent, have limited knowledge and memory, are unable to comprehend large amounts of data quickly [37].

Figure 4 shows a typical data flow diagram of the traditional diagnostic process. In the diagram, the rate-limiting steps include: initial *creation of patient folder*, *data collection* of patient (from signs, symptoms and clinical investigation), *information integrating & interpretation* of collected data to form a diagnosis, *cognition* of the working diagnosis and *consultation* with the patient for treatment and lastly the final *outcome* of the treatment.

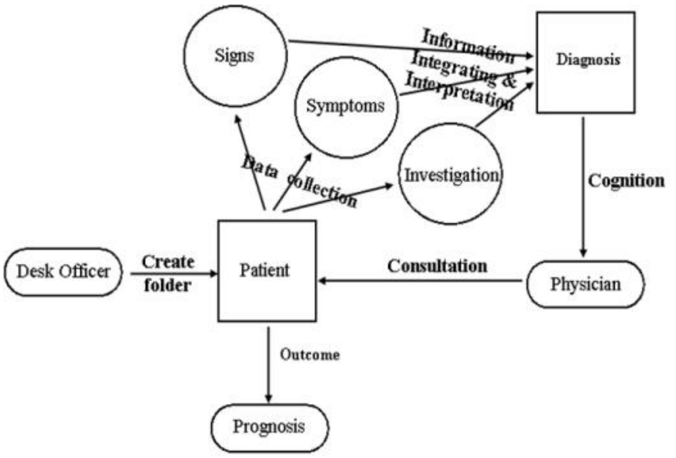

Figure 4: A Typical Data Flow Diagram of the Traditional Diagnostic Process

From the information flow above, it is clear that the levels of diagnosis and treatment depend solely on those of data collection and information integration and interpretation. This means that any process or event that causes these two later levels of the information flow-data collection and information integration and interpretation - to malfunction, will lead to poor prognosis. The opposite is also true: any process, event or even intervention that causes the two later levels of the information flow to function well will lead to a good prognosis.

2.2 Proposed Solution to the Present System: MALARES

The proposed solution to the present system is a rule based medical expert system for the diagnosis of malaria using Visual Basic 6.0 as the programming language called ***Malaria Expert System*** (MALARES). The system employs a forward chaining inference mechanism and has a good graphical user interface interactive system where systems communicate with user in response to a click of a mouse.

The system consists of multiple options to Point Diagnosis, Differential Diagnosis, Treatment and Prognosis of Malaria. As the system uses plain English language to interact with user no special knowledge is required for individual to use it. In the Diagnosis option, based on the patient's response to questions from the user, a clinician, who inputs data into the system through the user interface, the system concludes the point diagnosis of malaria in the person.

The expert system shell, MALARES Shell, developed in this work consists of the user interface, the explanation system**,** the inference engine and the knowledge base editor. The complete architecture of the proposed expert system is as shown in Figure 5. The inference engine uses problem solving methods that interacts with the user and processes the result from the collection of rules and data in the knowledge base. The system has the capacity to acquire, store, retrieve, communicate, process and use knowledge for the purpose of solving problem.

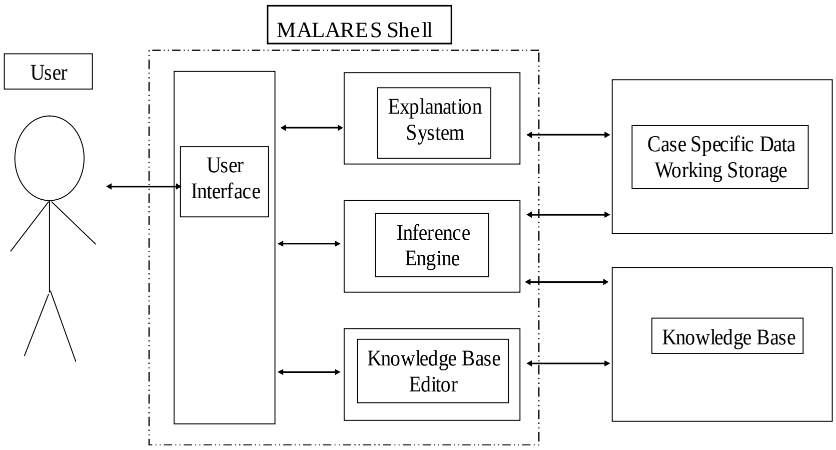

Figure 5: Architecture of the Proposed MALARES

2.3 Analysis of the Proposed MALARES

In building the Expert System, factual knowledge was accumulated for the expert system knowledge-base. Knowledge was acquired from three sources: literature, internet and human experts (medical doctors) in the relevant medical specialties. A six-page questionnaire was used to acquire knowledge on malaria from human experts. Twenty medical doctors (experts) in the medical domain of malaria were used for this purpose selected randomly from Abia State University Teaching Hospital, Aba, Abia State, South Eastern Nigeria.

For purposes of analysis, data from the seven section questionnaire, the possible symptoms, signs

and investigation reports of these diseases were initially coded and then categorized in groups. Each disease coding is provided with three groups of symptoms/signs/investigation results used as determining factors in the diagnosis as follows:
1) Sr = Sign/Symptom/Investigating report is Strongly Required for Diagnosis;
2) Rn = Sign/Symptom/Investigating report is Relevant but Not necessary for diagnosis;
3) Nr = Sign/Symptom/Investigating report is Not Related/Relevant for diagnosis.

The knowledge from the questionnaire were analyzed in conjunction with those from literature and internet and used as a base for analysis, diagnosis and recommendations. Knowledge in the design was represented via a production rule. Table 1 displays the symptoms of malaria, Table 2 displays the signs of malaria and Table 3 displays the possible clinical investigations for malaria as accumulated in questionnaire and confirmed by knowledge from literature and internet. Different rules exist for diagnosis based on the three groups of determining factors of Sr, Rn and Nr for signs/symptoms/ investigation reports of malaria.

Table 1: Table of Symptoms of Malaria

Symptoms	Determining Factor
*fever, paroxysmal	(Sr)
* headache	(Rn)
* malaise	(Sr)
* retro-orbital pain	(Nr)
* cough	(Rn)
* painless skin chancre	(Nr)
* anorexia	(Nr)
* fatigue	(Sr)
* arthralgia	(Rn)
* constipation	(Nr)
* abdominal pain	(Nr)
* weakness	(Rn)
* erythematous skin lesions	(Nr)
* myalgia	(Rn)
* weight loss	(Nr)
* shaking chills	(Sr)
* nausea and vomiting	(Nr)
* haemoptysis	(Nr)
* facial oedema	(Nr)
* sweating	(Rn)
* rash	(Nr)
* sore throat	(Nr)
* transient urticarial	(Nr)
* lymphadenopathy	(Nr)
* chest pain	(Nr)
* back pain	(Nr)

Table 2: Table of Signs of Malaria

Signs	Determining Factor
*fever, paroxysmal	(Sr)
* peritonitis	(Rn)
* malaise	(Sr)
* jaundice	(Rn)
* cough	(Rn)
* Intestinal perforation	(Nr)
* unconsciousness	(Rn)
* Haemorrhage	(Nr)
* fever	(Sr)
* epistasis	(Nr)
* high fever	(Nr)
* weakness	(Rn)
* erythematous skin lesions	(Nr)
* cyanosis	(Rn)
* weight loss	(Nr)
* shaking chills	(Sr)
* nausea and vomiting	(Nr)
* mild fever	(Sr)
* finger clubbing	(Rn)
* sweating	(Rn)
* skin rash	(Nr)
* lymphadenopathy	(Nr)

The computer expert system, MALARES, on which the knowledgebase is run provides a simple, interactive, graphical user interface with menu. It stores all the rules as a batch file. So the series of rules can automatically read or run directly from a batch file as a result of clicking on an icon. That is, whenever the user clicks the batch file icon, the VB 6.0 file with rules will start automatically.

Table 4 shows an example of a Production Rule for malaria using the signs/symptoms/clinical investigation results of malaria in Tables 1, 2 and 3. In the production rule, the If, then condition is applied. For instance, to diagnose malaria, if sign/ symptom of paroxysmal fever is present and Strongly Required (Sr) for diagnosis, and if shaking chills is also Strongly Required (Sr) for diagnosis, both will be connected by AND. So also will fatigue and

Table 3: Table of Investigations of Malaria

Clinical Investigations	Determining Factor
* Packed Cell Volume / Haemoglobin concentration	(Rn)
* wbc count	(Nr)
* Sputum culture	(Nr)
* Fluorescent dyes/ultraviolet indicator tests	(Rn)
* PCR may detect dengue virus in serum early in the illness.	(Nr)
* Blood Culture	(Rn)
* Stool Culture	(Nr)
* Urine Culture	(Nr)
* Tissue Culture	(Nr)
* Blood / Serum Assay	(Nr)
* Erythrocyte Sedimentation Rate (ESR)	(Nr)
* Acid Fast Bacilli staining	(Nr)
* Blood smears (thin/thick or unstained/Giemsa-stained)	(Sr) (plasmodium)
* Chest X-ray	(Nr)
* Widal test	(Nr)
* Rapid diagnostic tests	(Sr)
* Platelet count	(Rn)
* Aspiration (chancre, lymph node or bone marrow)	(Nr)
* Lumbar puncture	(Nr)

positive rapid diagnostics test (and all Strongly Required (Sr) signs/symptoms) for diagnosis will be connected by AND. On the other hand, signs/symptoms like myalgia, arthralgia and headache, which are all Relevant but Not necessary (Rn) for diagnosis will be connected by OR. Finally, signs/symptoms like positive stool culture, which is Not Related/Relevant (Nr) for diagnosis is connected by NOT. Then the diagnosis is confirmed to be malaria. Therefore, diagnosis is performed via the designed

Table 4: Production Rule of Malaria

If there is fever, paroxysmal (Sr)
AND shaking chills (Sr)
AND fatigue (Sr)
AND malaise (Sr)
AND positive rapid diagnostic test (Sr)
OR positive Blood smear—thick/thin film (Rn)
OR myalgia (Rn)
OR arthralgia (Rn)
OR headache (Rn)
NOT positive stool culture (Nr)
Then the Disease is Malaria

expert system, based on patient data put into the system.

2.4 High Level Model of the MALARES

The main advantage of generation of a high level model in system design is that it makes it easy for the designer(s) to be able to test the product against what was originally specified. Such high-level models usually deal with areas such as performance, reliability, availability, maintainability, and system safety [38]. The High-level model (HLM) function to explain the architecture that would be used for developing a software product. The architecture diagram provides an overview of an entire system, identifying the main components that would be developed for the product and their interfaces. Therefore, the high level model of the MALARES is as shown in Figure 6.

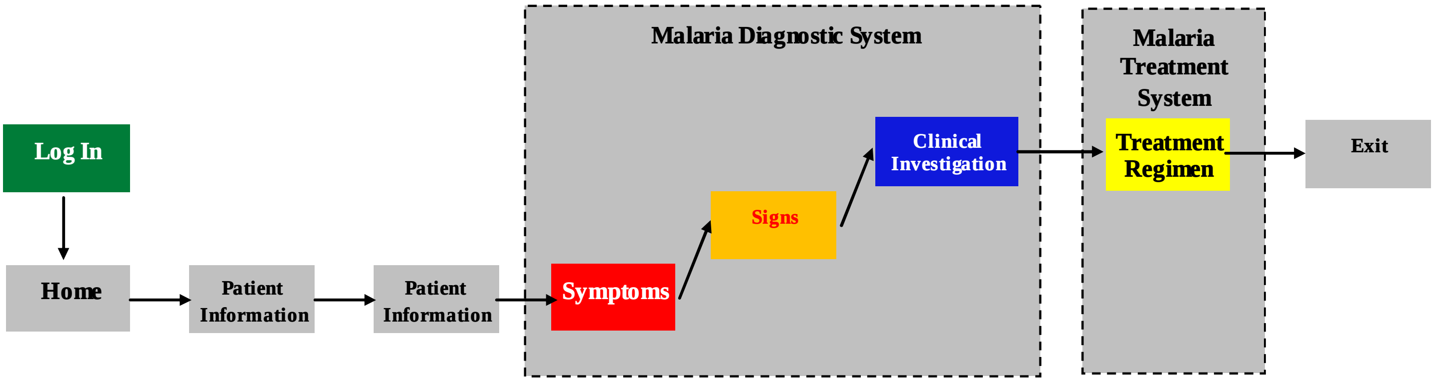

Figure 6: High Level Model of the Proposed MALARES

3. Results and Discussions

MALARES is switched on by double-clicking the system's program icon 'expert_medical_sys' from the system''s folder. A title display first announces the system. This is followed by a log in window, where the user is expected to click proceed to continue. A booting slash panel is used to open into the login window which requires the user to insert his username and password (Figure 7). If these are correctly inserted, the system opens into the main screen, which contains the main menu.

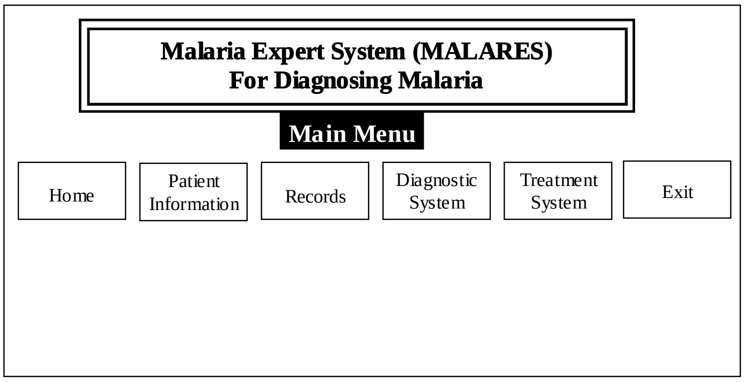

Figure 8: Home Panel (Main Menu) of the MALARES

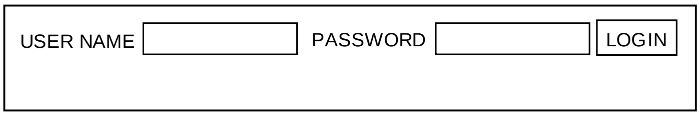

Figure 7: Login window of the Expert System MALARES

When the system is accessed, the main menu window containing the sub-system options - Home, Patient information, Records, Diagnostic System, Treatment System and Exit – pops out. The Home Panel option is default and forms the Main Menu. Figure 8 shows the Home Panel screen of the MALARES.

The Patient Information enables the user to key in new patients' biodata or to retrieve old patients' information by supplying their card no and clicking the FIND button. Figure 9 represents the Patient Information screen of the MALARES. The MALARES also uses the user interface to display desired result to users. Visual Basic scripts alerts will display result output to the user. Some of the outputs from the system include information on malaria, email addresses, diagnosis results, and treatment recommendation. Figure 10 represents the result for Patient Information. The Records option enables the user to access previously registered patients' data. Figure 11 represents the result of clicking the Patient's Record of the MALARES.

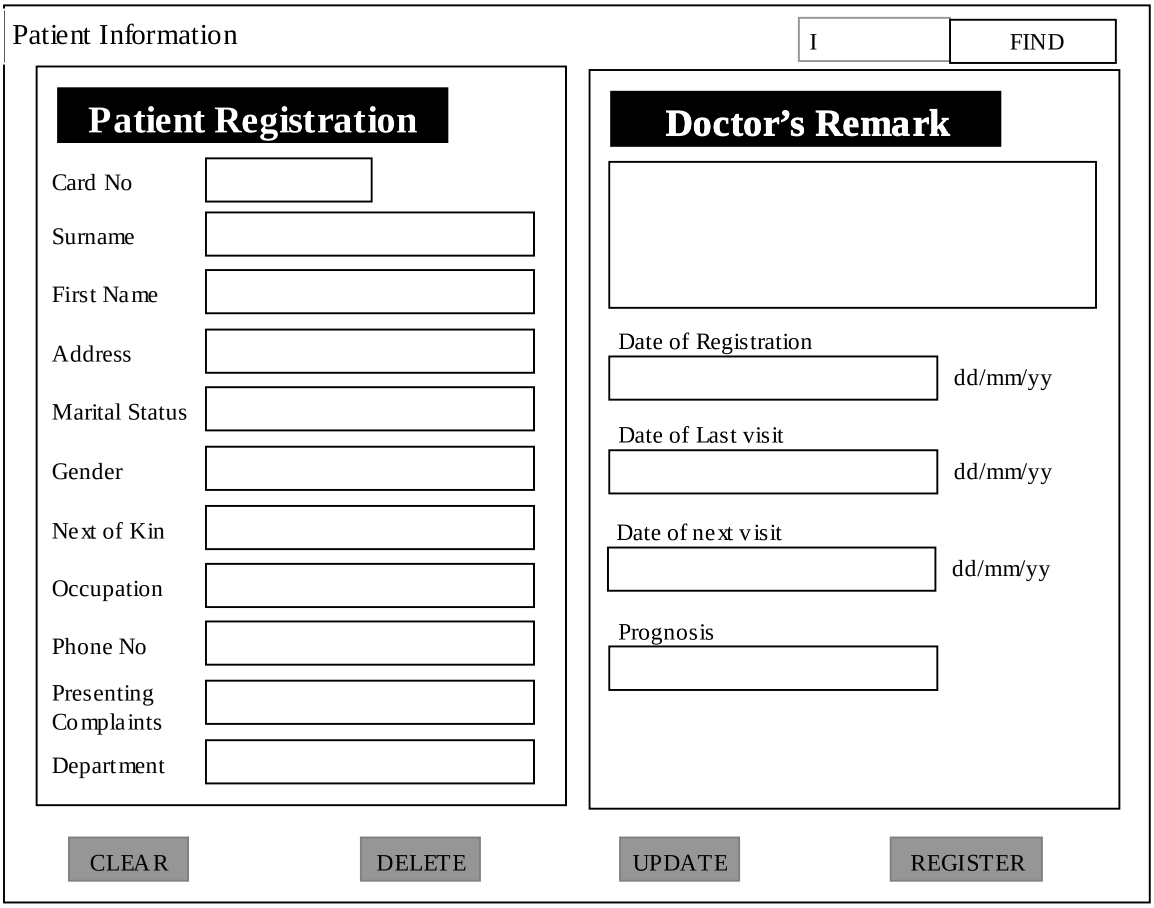

Figure 9: Patient Information Panel of the MALARES

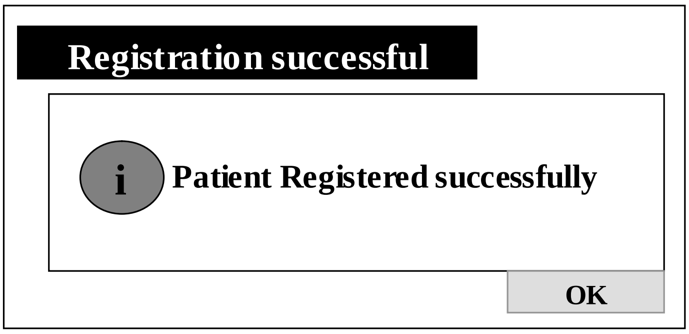

Figure 10: Output for Patient Information of the MALARES

The Diagnosis system option enables the user to decide on whether the patient has malaria or not. In the Diagnostic System panel, the user has the option of checking the symptoms, signs and/or clinical investigation results of patient under consultation. As each of the three options is clicked, the system pops up many options of symptoms, signs or investigation results from which user selects by checking boxes. This enables the system to make a diagnostic decision with respect to the data put into the system. The system diagnoses malaria or not based on the data of the patient - signs, symptoms and investigation reports – entered appropriately.

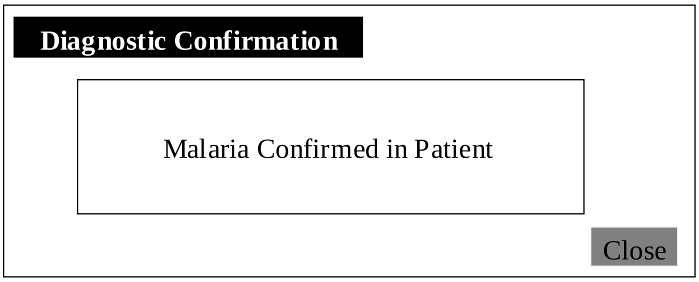

Figure 13: Output for Diagnosis of malaria of the MALARES

Patient's Record

ID	Card No	Surname	OtherName	Address	Marital Status	Sex
20	01	Kalu	David	5 Okigwe Rd Aba	Single	Male
21	02	Goodness Lot	Ihechiluru	54 Dikenafai St Aba	Single	Female
23	03	Love	Mercy	5 Abam St Aba	Married	Female

Close

Figure 11: Patient Record Output of the MALARES

Figure 12 represents the Diagnostic System screen of the MALARES, while Figure 13 represents the output for Diagnosis System for malaria.

When the diagnosis is confirmed from the Diagnosis system, the Treatment System is used to recommend therapeutic regimens based on the diagnosis. The user, who is a human expert (medical doctor), now uses his/her initiative to choose the best treatment option he/she thinks best fit. Figures 14 and 15 represent the Treatment System input and output respectively.

At the end of any patient's session, the user logs out. When this is done, the Log out pops out of the MALARES (Figure 16).

For the system to function as specified, the various data as knowledgebase are stored in facts list. Different rules exist for different symptoms. The system consists of about 41 rules. It provides a simple, interactive,

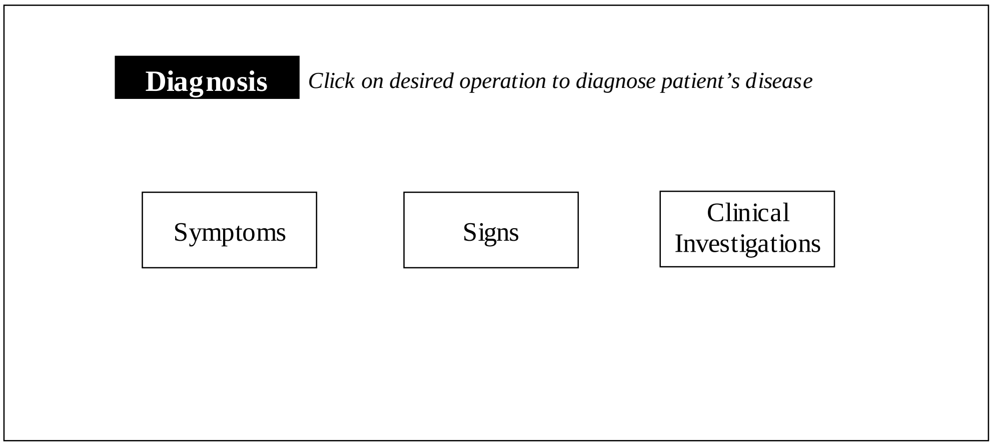

Figure 12: Diagnostic System Panel of the MALARES

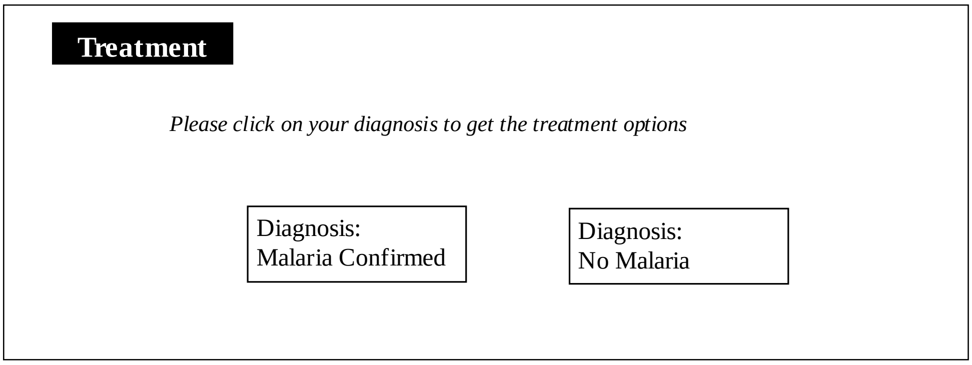

Figure 14: Treatment System of the MALARES

graphical user and menu based interface and stores all the rules as a batch file. So the series of rules can automatically run directly from a batch file as a result of clicking an icon.

Finally, the MALARES system was testes for its workability. The test activities were carried out in stages. Each module was tested with some test data. For instance, the Patient information module was tested by keying in a volunteer's biodata. The results of the system are shown in Figures 7, 10, 11, 13, 15 and 16. So the MALARES was evaluated and ascertained for its workability according to specification.

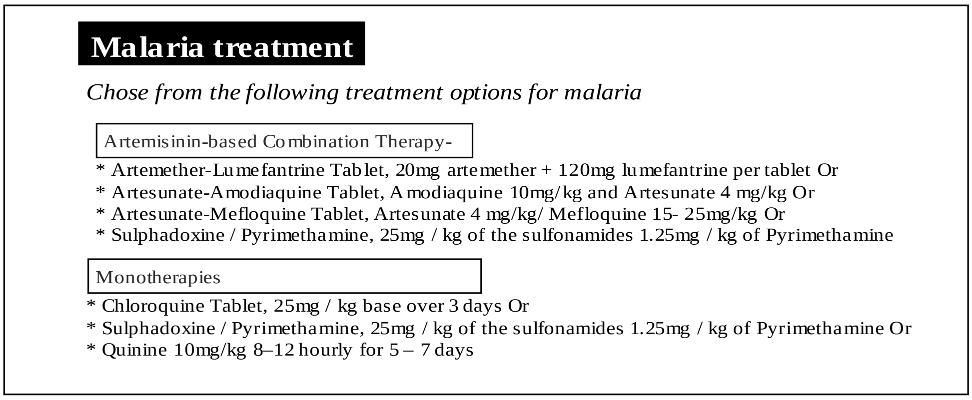

Figure 15: Output for Treatment of Malaria of the MALARES

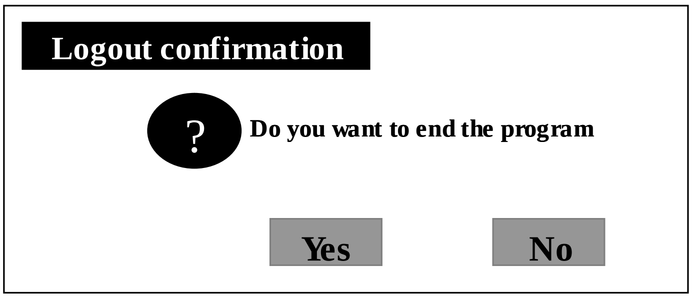

Figure 16: Log Out pop out of the MALARES

3.1 Discussion

A handful of works, though, has been done in the field of application of expert systems in diagnosis of malaria. However, its rare to get one that employed such an affordable tool as the Microsoft Visual Basic 6.0. First, Kamukama et al did a work: *Clinical protocol-based decision support system for malaria treatment.* In Clinical protocol-based decision support system for malaria treatment, Kamukama described a medical decision support system that was capable of diagnosing malaria using analytic hierarchy process was developed [39].

Also in *Web-Based Medical Assistant System for Malaria Diagnosis and Therapy,* Adetunmbi et al developed, a web based diagnosis and therapy system that used a machine learning technique was developed [40]. According to the study, a machine learning technique rough set was used on labeled sets of malaria fever symptoms collected to generate explainable rules for each level of severity. In their project, *A Rule Based Expert System for Diagnosis of Fever,* Tunmibi et al considered the development of a rule based expert system for diagnosing fever [41]. In their work, Developing a Knowledge-Based System for Diagnosis and Treatment of Malaria, Diriba et al used the SWI prolog programming language to develop the prototype KBS. [42]. The system had a major limitation of excluding laboratory reports in the consideration for diagnosis. This is a major flaw, though.

4. Conclusion and Recommendation

The developed system, MALARES is a medical expert system for diagnosing malaria. It is a generic tool for malaria and can be used by all levels of medical doctors because the signs, symptoms and investigation reports of malaria, enteric and dengue fever are similar and universal respectively for each disease. It is a rule based system that supports forward chaining inference. Using this system, the user can enter patients' signs, symptoms and investigation reports. The system will evaluate it and diagnose whether the patient has malaria or not. If the patient has malaria, for instance, system will give suggestions for treatment.

The MDES is not meant to replace medical doctors but to assist them in the quality service they render to humanity. It is also invaluable where younger inexperienced doctors are practicing, especially in remote rural areas of Nigeria, Africa or the other developing countries, where it is difficult to refer out patients. So Medical diagnosis will have greater part of the advantages of expert system, knowing that only a few medical experts (or specialists) exists in the medical field. The knowledge of such specialists can be replicated and made use of in times when they are extremely of necessity.

The development of the MALARES for malaria should be seen as a contribution towards reducing deaths due to the endemic disease of malaria causing preventable death. This is because the MALARES is designed to enhance the diagnosis of malaria so that no missed data or misdiagnosis will cause any preventable death. So by allowing for more efficient diagnosis of malaria, the MALARES would aid in reducing the workload of scarce medical practitioners.

The MALARES presents both diagnostic and treatment recommendations for malaria. A major bottleneck of this research is seen when there are a lot of symptoms and signs requiring diverse and non-correlated diagnosis of malaria other than those in the malaria knowledgebase of the system. My recommendation is for the study to be expanded by including more malaria treatment with their drug resistance and management.

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