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Developing a Knowledge-Based System for Diagnosis and Treatment of Malaria

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Abstract. Malaria is a serious and fatal disease caused by a parasite that can infect a certain type of mosquito which feeds on human blood. It is a public health problem in Ethiopia and a major cause of illness and death. More than 75% of the total land of Ethiopia is malarious affecting more than 68% of the population, making malaria the leading public health problem in Ethiopia. In an effort to address such problems, it is important to develop knowledge-based system (KBS) that can provide advice for health professionals and patients to facilitate diagnosis and treatment of malaria patients. Experimental research design was used to developed prototype system. Purposive sampling technique was used to select domain experts for knowledge acquisition. The domain experts are selected from Jimma special hospital, Adama hospital and Agaro health centre. The knowledge was acquired using both structured and unstructured interviews from domain experts and represented by production rule, (if- then method). The user's acceptance of the prototype system by visual interaction method that by showing the prototype system to the domain experts was conducted result is 83.21%. In addition, performance of the prototype system was evaluated using case testing method and produce result of 82.3%. It is promising to save the life of people in rural area where there is scarcity of health professionals and apparatus. In addition, it is possible to reduce time and cost of diagnosis and treatment in health centre by implementing intelligent systems. Developing in local languages, good interface programming language and in other techniques are the future works of the study.

Keywords: Knowledge-based system; diagnosis and treatment; knowledge acquisition; rule based system; knowledge representation.

1. Introduction

1.1. *Background of the study*

Malaria is a serious and fatal disease caused by a parasite that can infect a certain type of mosquito which feeds on human blood. It is one of the most dangerous

parasitic diseases in the world. Of the world population, 40% are concerned, especially those of tropical regions (Tchapet and Nana, 2013). Malaria remains one of the major public health problems in the African continent (Lisa, 2012). As world malaria day 2013 report show, there were 219 million malaria cases leading to approximately 660,000 malaria deaths, mostly among African children under the age of five years, which is estimated to be 90%.

There are five types of malaria parasites. They are falciparum, vivax, ovale, malariae and knowlesi. Plasmodium falciparum and vivax are the dominant malaria parasites distributed all over Ethiopia and account for about 60% and 40% of malaria cases, respectively (ACIPH, 2009).

It is obvious that in developing countries like Ethiopia the major difficulties in relation to malaria include lack of medical experts and trained manpower, scarcity of funds and improper budgetary allocation for rural health at regional and federal government level. As a result diagnosis and treatment of malaria is challenge.

Besides, once the diagnosis of malaria has been made, appropriate antimalarial treatments must be initiated immediately. However, malaria treatment is challenging due to the need of different treatment modalities. Moreover, the treatment is provided depending on such factors as the age group of the patients, the stages of the diagnosed malaria after infecting the person and the specific species of the malaria.

Integrating computer technology and artificial intelligence is a promising approach in the provision of quality health delivery services in medicine. Therefore, the emergence of information technology (IT) has opened unprecedented opportunities in health care delivery system as the demand for intelligent and KBSs have increased as modern medical practices become more knowledge intensive (Djam *et al.*, 2011).

KBS is a branch of Artificial Intelligence that help to represent experts knowledge in artificial way. It is computer program that replicate the problem solving abilities of human beings and developed to overcome difficulties in solving complex problems. Currently, KBS are receiving attention in many fields. With availability of advanced computing facilities and other resources, attention is now turning to more and more demanding tasks, which might require intelligence (Eds and Akerkar, 2010).

Health sector is one of the areas in which KBSs received much attention mainly because of the potential benefits that can be gained from using these technologies.

Hence, employing computerized technologies are needed for quickly assisting access to medical diagnosis and treatment related information.

According to Pandey and Mishra (2009) KBSs use reasoning techniques like Fuzzy logic, Case based reasoning and Rule based reasoning to provide significant performance in the area of diagnosis. A rule-based system is handling problems from a well-defined knowledge base that contains facts and rules. It is evident that rule based technique of AI is appropriate methodology for all medical domains and tasks (Tomar and Saxena, 2011).

1.2. *Statement of the problem*

Malaria is one of the tropical diseases that kill a number of people every second all over the world, because of the environmental problems, economy, nature of the malaria disease, lack of professionals in rural area and lack of permanent control of the disease. In Ethiopia, more than 75% of the total land area was malarious, it was about 68% of the population; this indicates malaria the leading public health problem (Dawit *et al.*, 2012).

In Ethiopia more than 90% of child deaths are caused by malaria, pneumonia, diarrhea, neonatal problems, malnutrition and HIV/AIDS, as stated on health sector development program IV in 2010, which was written by Federal Democratic Republic of Ethiopia Ministry of Health.

Concerning the nature of the disease, malaria has signs and symptoms that are similar to those of typhoid, yellow fever, dengue and typhus (Tchapet and Nana, 2013). So, it is complex to provide diagnosis and treatment at the absence of professionals or experts in the area. As a result, some mis-conclusions are being made resulting to death, for instance, as a result of taking medicine of typhoid, yellow fever, dengue and typhus instead of malaria medicine. For diagnosis and treatment of such diseases where there are many controversial and ambiguous factors being involved, intelligent system can helps in support decision making.

In Ethiopia and other developing countries where there is scarcity of facilities, like lab equipment and professionals, it is difficult to make diagnosis and provide relevant treatments to save life. Even though, there are apparatus like microscopy and RDT to detect malaria parasite in the blood of patients, the quality of microscopy can vary significantly, and thus resulting to the unreliability of the microscopy. Beside this problem, if the amount of parasites in red blood cell is low it is very difficult to diagnosis by laboratory. This demand supporting the laboratory result with the option of diagnosing by using the patient symptoms. The other common problem observed is the lack of keeping tracking of the expiry date of RDT. Expired RDT often show negative result which leads to an incorrect treatment. In addition, RDTs can determine that the patient is infected with malaria, but it cannot confirm the species or the parasitemia.

Furthermore, there is also lack of qualified medical laboratory technicians to read test results correctly are other headeck to diagnosis and treatment of malaria.

Therefore, this study attempts to explore the possibility of developing a KBS that provides the necessary advice for experts so as to enable them make the necessary diagnosis and treatment of malaria.

To the end, this study explores and answers the following research questions.

- What is the suitable conceptual model for organizing and structuring of the acquired knowledge?
- It is possible to develop a KBS for diagnosis and treatment of malaria?
- To what extent the proposed system is acceptable by professionals?

1.3. *Objective of the study*

The study has the following general and specific objectives.

1.3.1. *General objective*

The general objective of the study is to develop a KBS that provides expert advice for diagnosis and treatment of malaria.

1.3.2. *Specific objectives*

In attempt to achieve the general objective of the study, the following specific objectives are formulated.

- To acquire explicit and tacit knowledge from the knowledge experts on how they provide diagnosis and treatment for malarious people.
- To model and represent the acquired knowledge from knowledge experts and other documents.
- To develop a KBS for diagnosis and treatment of malaria.
- To evaluate the performance of the prototype KBS and its level of user acceptance.

1.4. *Scope and limitations of the study*

The scope of this research is to develop a prototype KBS that provides expert advice for diagnosis and treatment of malaria. Rule based reasoning approach is followed in this research. There are five types of malaria parasites such as falciparum, vivax, malariae, ovale and knowlesi. Falciparum, vivax, malariae and ovale were the focus of the study. An experimental research design was used. The researcher had acquired domain knowledge from domain experts in Adama hospital, Jimma specialized hospital and Agaro health centre.

This study was intended to design KBS which includes the tasks of knowledge acquisition, modelling, knowledge representation and develop KBS that provide the necessary expert advice malaria diagnosis and treatment.

In addition laboratory testing result is not included in this prototype KBS. Moreover, the issue of self-learning KBS for diagnosis and treatment of malaria was not solved yet in this study.

1.5. *Significance of the study*

The proposed KBS assist medical personnel in the tedious and complication task of diagnosing especially in rural areas, where there are shortages of doctors, thereby, offering primary health care for the people.

The prototype system has much significance for the patients and researchers. The system will assist medical personnel in rural areas, where there are shortage of doctors. The prototype system contain explanation about how to diagnosis and treatment of malaria, especially in rural area where there is no material to read, so it can be used as information source for health professionals.

In addition, the developed prototype KBS can provide the efficient and effective way to take care of the patient's health, promote the human's quality of life, provide disease monitoring and control and improve the medical facilities by reducing the time, cost and medical error to diagnosis and treatment of malaria.

Furthermore, the prototype system can be implemented by using low cost popular computer. It is also easy and flexible to distribute and implement to any health centres.

It is very useful to make immediate decision for references where the patients get appropriate treatments. For example if the developed prototype KBS result indicates the disease is complex malaria, the professional can refer the patients to the right hospital ward where he/she gets appropriate treatments. Especially, severe malaria which is difficult to treat in rural areas health centres.

In general, the proposed KBS acts as a decision support tool for inexperienced professionals, senior nurses in rural health centres with limited or no physicians; provide an alternative way to reach a reasonable diagnosis and treatment, and hence early commencement of clinical management of patients in the absence of laboratory facilities in many rural and semi-urban health centres.

1.6. *Methodology of the study*

There are different approaches and tools that can be used to develop KBSs in diagnosis and treatment of diseases. In order to achieve the objectives of this research, the following methods and techniques were employed.

1.6.1. *Research design*

Dipanwita *et al.* (2011) were used experimental research design to develop intelligent medical system for diagnosis of common disease by acquiring tacit and explicit knowledge from domain knowledge expert. The domain knowledge was acquired and then represented. The acquired and represented knowledge was inserted into the knowledge base. Based on the result of evaluation of inserted knowledge it changed again and again. In addition, during prototype development stages the sequence of the facts and rules were changes again and again until it fitted the best sequence. Moreover, the way to test and evaluate the performance of the prototype system by feeding the cases and records the result to compare it against with the decision made by domain experts in similar settings.

1.6.2. *Study area, population and sampling technique*

The study focus on the urban and rural health centres which covered only governmental hospitals and health centres in Oromia region. By consideration of the size of the hospitals (in number of professionals), easy to get domain experts, prevalence of the disease, proximity, time and finance in to account the researcher selected Jimma specialized hospital and Adama hospital from urbans and Agaro health centre from rural areas. Jimma specialized hospital is found in Oromia regional state, Jimma

town in Jimma University main campus. From the rural health centres Agaro health centre was selected for the study which is 50 km far from Jimma town. The weather is conducive for breeding of mosquitoes as compared to other woredas in Jimma zone. So, the area is highly affected by malaria resulting with sufficient availability of malaria cases.

The populations of this study were the technical staffs of Jimma university referral hospital, Adama hospital and Agaro health centre.

Purposive sampling is one of the most common sampling techniques in qualitative research in which participants were decided to preselected criteria relevant to a particular research question. In this study purposive sampling technique was used to select domain experts for knowledge acquisition from number of hospitals and health centre. The criteria used in selecting the domain experts for the study considered their professions, educational qualification level, years of experience on malaria or related diseases.

The researcher selected 3 doctors and 3 health officers for interviews. One doctor and one heath officer were selected from each study area (Jimma referral hospital, Adama hospital and Agaro health centre).

In addition, purposive sampling technique was used for collecting cases for evaluation of the prototype system. Fifteen (15) cases were purposely collected.

In order to check the acceptance of prototype system by professionals, a questionnaire was developed and distributed to 8 professionals. Sufficient visual interaction was given for the respondent on how the system helps to diagnosis and treatment malaria. Following the demonstration, the questionnaires were distributed for the respondents to fill. Lastly the data was collected and analysed.

1.6.3. *Methods of data collection*

For this study non-documented source of knowledge is necessary which was acquired from medical doctors and health officers. Even if it is difficult to acquire tacit knowledge, interview and observation are appropriate methods in gathering such knowledge (Santosh *et al.*, 2010). Besides according to Turban (1992) interviews are important for effective knowledge acquisition. Structured and unstructured types of interview were used for acquire domain knowledge from domain experts.

The purpose of this interview is to gather domain knowledge from experienced doctors who are well knowledgeable in diagnose and treatment of malaria.

Observation was used to acquire domain knowledge which is often very difficult for an experts to explain what he/she does and indeed the interpretation of what he/she actually does may not be totally accurate. It is very useful for the knowledge engineer to observe the domain knowledge experts in action. The way the expert actually solves the problem can have nuances that will not come across when the expert is interviewed. For this reason the researcher was selected and used interview and observation.

Moreover, codified sources of knowledge were acquired by using document analysis technique from different sources.

Production rules were used to represent the collected domain knowledge and a decision tree was used for conceptual modelling of the acquired knowledge.

Visual interaction method was used to collect data for user's acceptance of the prototype KBS.

1.6.4. *Implementation tools*

SWI prolog (PROgramming in LOGic) programming language was used as a tool to develop prototype KBS. It is the most popular logic programming language rose within the realm of Artificial Intelligence (AI). Prolog is a logic programming general purpose fifth generation (AI) language. It has a purely logical subset, called pure Prolog, as well as a numbers of extra logical features. Prolog is a programming language developed especially to enable the implementation of logic-based systems. It is often used to develop automated proof systems and automated problem solvers. Prolog, by the nature of being logical, can be very powerful. It is flexible, especially compared to shells, and because it includes a control strategy there is no need to write an inference mechanism.

1.6.5. *Testing and evaluation*

System can be evaluated with respect to different aspects, for example, functionality, reliability, usability, efficiency, maintainability, portability. Any evaluation has pragmatically chosen goals. In the domain of system evaluation, the goal can be characterized by one or more of three questions (ISO/IEC, 1991): which one is better?, how good is it? and why is it bad? How good is it? This goal aims at the determination of the degree of desired qualities of a finished system, which is related to this study.

In addition it is possible to categorize system evaluation in to two types (Gunther and Christoph, 2007); Summative and Informative. Summative evaluation is concerned with the global aspects of system development, and does not offer constructive information for changing the design of the system in a direct manner. It is performed when the development of the system is almost or entirely accomplished. While formative evaluation focuses on usability problems that need to be solved during the prototype design stage before a final design can be accepted for release. Concerning this aspect the researchers were used both of the methods.

After a prototype KBS was developed, evaluation procedures were conducted to check the performance of the prototype system and acceptability by the users. Accordingly 15 cases were collected from Jimma specialized hospital and Agaro health centre. Precision, recall and F-measure were used. Questionnaires can be used to test the user acceptance of a prototype KBS (Solomon, 2013). Similarly, user's acceptance was conducted by questionnaire after users were exposed to interact with the system.

2. Literature Review

2.1. *Overview of knowledge-based system*

There have been many definition of artificial intelligence (AI) offered over the years. The definitions have also changed in the course of time due to the rapid developments of AI applications. But most of them can be classified into the following four categories. They are systems that think like humans, systems that act like humans, systems that think rationally and systems that act rationally.

AI is a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behaviour, and with the creation of artefacts that exhibit such behaviour (John, 1992). From the different definitions written by different scholars, AI is the part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics associated with intelligence in human behaviour such as understanding language, learning, reasoning and solving problems (Vasant, 2006). As mentioned in the above definition one of the human intelligence behaviour is problem solving behaviour and this is the focus of this study.

KBS, natural language processing, robotics, speech understanding, speech (voice) recognition, computer vision and scene recognition, intelligent computer-aided instruction, neural computing, intelligent agents, automatic programming, translation of languages, and summarizing news can all be considered AI technologies. The major technologies and algorithms are neural networks, intelligent agents, fuzzy logic, and genetic algorithms.

The emphasis of AI paradigm is moved from a general to specific problem solving approach. KBS is one of the major family members of the AI group (Eds and Akerkar, 2010). It was introduced below.

There are various KBSs developed by different researchers all over the world. But there are limited numbers of KBSs developed especially in Ethiopia. The following are some of the KBSs that are developed all over the world including in Ethiopia.

Intelligent medical system for diagnosis of common disease that can be detected by patient data was developed by Dipanwita *et al.* (2011). To develop this prototype they used different literatures and human experts for acquiring tacit and explicit knowledge. Knowledge representation they used is production rule facilitated by MATLAB and a neural network. The developed system is experimented on various scenarios in order to evaluate its performance. In all the cases, the developed system exhibits satisfactory results.

Santosh *et al.* (2010) developed an expert system for diagnosis of human diseases. The system is rule-based system and makes inferences with symbols for knowledge representation. Interview and observation were used for acquiring tacit knowledge from expert domains and document analysis was used to get explicit knowledge from articles, journals, books and websites. They are recommended automated diagnosis system should give explanation for the conclusion, a factor that is important for user

acceptance. A trained expert would evaluate the quality of the diagnosis performed by the system.

KBS for pre-medical triage treatment (Tagel, 2013). The objective of the study was to investigate the applicability of rule-based reasoning approach in the development of KBS for hospital triage service so as to improve the quality of decision made by general practitioners. To achieve this objective, domain knowledge is acquired using semi-structured interview technique is implemented. Domain experts are selected using purposive sampling instrument. The prototype is developed with LPA WIN prolog by using "if – then" rules method that means production rules. According to the system evaluators 85% of the users are satisfied with the prototype. In addition, the performance of the system is evaluated by using predictive validation techniques with twenty test cases. The results of the validation test case indicate that the prototype is about 80% accurate. Integration of rule based reasoning and case based reasoning and developing in local languages are some of the recommendations in this work.

Integrated KBS architecture for histopathological diagnosis of breast diseases is other study related the researcher work (Kayode *et al.*, 2013). The paper presents a KBS that uses a combination of rule-based and case-based techniques to achieve the diagnosis. In this thesis how to acquire domain knowledge, how to model and represent acquired knowledge is not mentioned. Performance and users acceptance is also not presented.

Malaria is a public health problem in Ethiopia and a major cause of illness and death. Yet up to the researcher knowledge there is no KBS that provides assist for diagnosis and treatment of malaria by using rule based techniques and prolog language.

3. Implementation and Experimentation

In the following sections, the implementation includes the real construction of the prototype system for diagnosis and treatment of malaria. After the necessary knowledge was represented using a rule-based knowledge representation technique, the next step is coding the represented knowledge using Prolog programming language into a suitable format that is understandable by the inference engine. The system performance testing and user acceptance result were included in this chapter.

3.1. *Architecture of the prototype system*

Architecture defines how the system is constructed, describes what the critical components were and how they fit together. A KBS tool is a software development environment containing the basic components of KBSs. The core components of developed KBS are shown in Fig. 1.

Given users query through the user interface the system reasons for diagnosis and treatment of malaria using reference engine. Back ward chaining is used in study. During reasoning knowledge base is constructed. In this prototype there are two main categories of knowledge bases, signs and symptoms knowledge base and

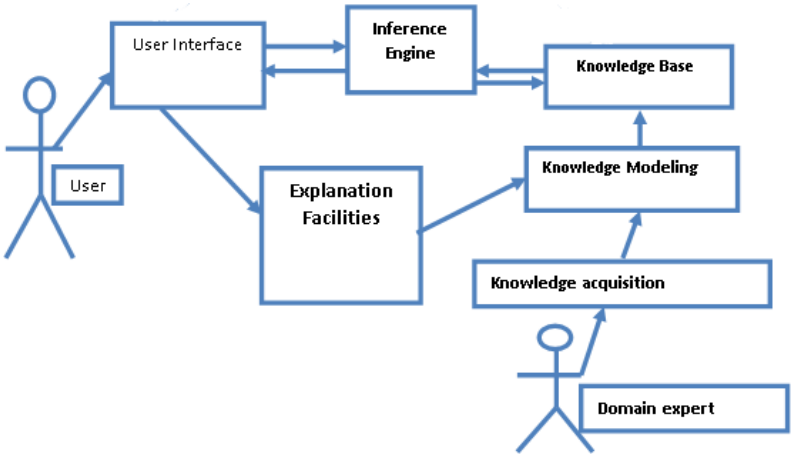

Fig. 1. Architecture of the developed prototype system.

treatment knowledge base. In addition, the system is capable of proving explanation for sign and symptoms of malaria.

3.2. *Patient history*

The developed prototype system has capability of storing patient history with its diagnosis result. The storage of patient history is important to giving the patient information when he/she returns back for treatment. Figure 2 shows how the prototype system registers patient history.

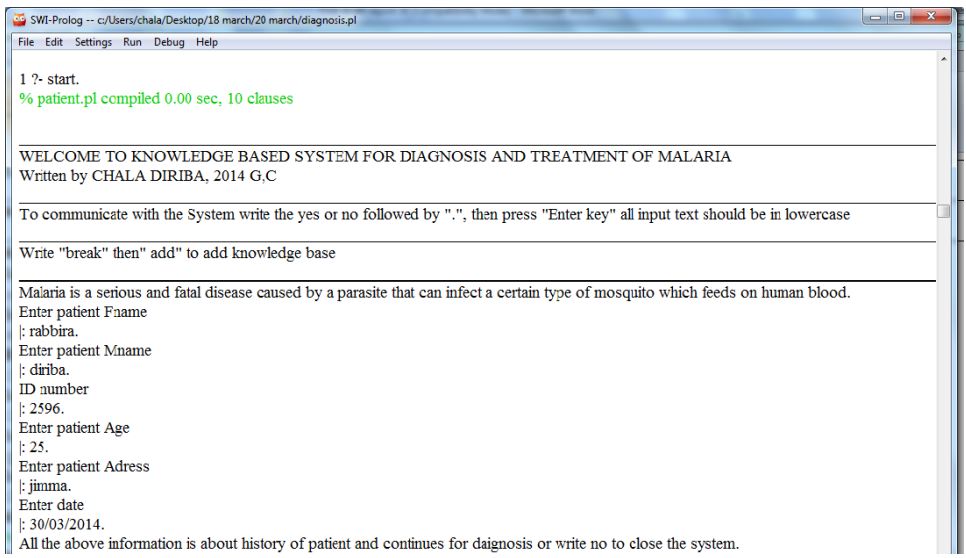

Fig. 2. How prototype system registers patient history.

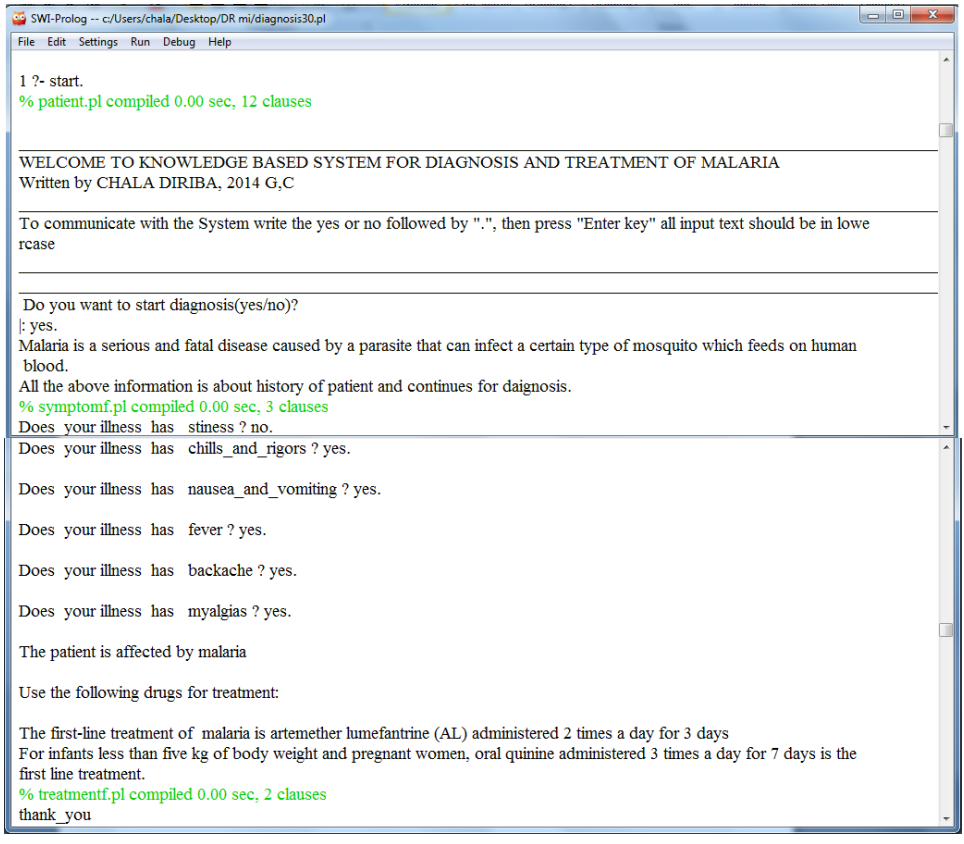

Fig. 3. How prototype system diagnosis and treatment the patient.

3.3. *Diagnosis and treatment*

The developed system has the capability of providing diagnosing and treatments of falciparum, vivax, ovale and malariae. Even though malaria species and stages have some similar signs and symptoms, also they have difference sign and symptoms. It is possible to diagnosis malaria by combining different signs and symptoms. The prototype system integrates tacit and explicit knowledge acquired from domain knowledge experts concerning the sign and symptoms of malaria species and its stage. Figure 3 shows sample of how the prototype system accepts user response and provide the final advice as a solution for diagnosis and treatment.

3.4. *Explanation facility by prototype system*

A prototype system can provide facility of what signs and symptoms mean which is used during diagnosis and why it is selected as the signs and symptoms of malaria for diagnosis and treatments. Figure 4 show how a prototype system provides explanation facility for the signs and symptoms.

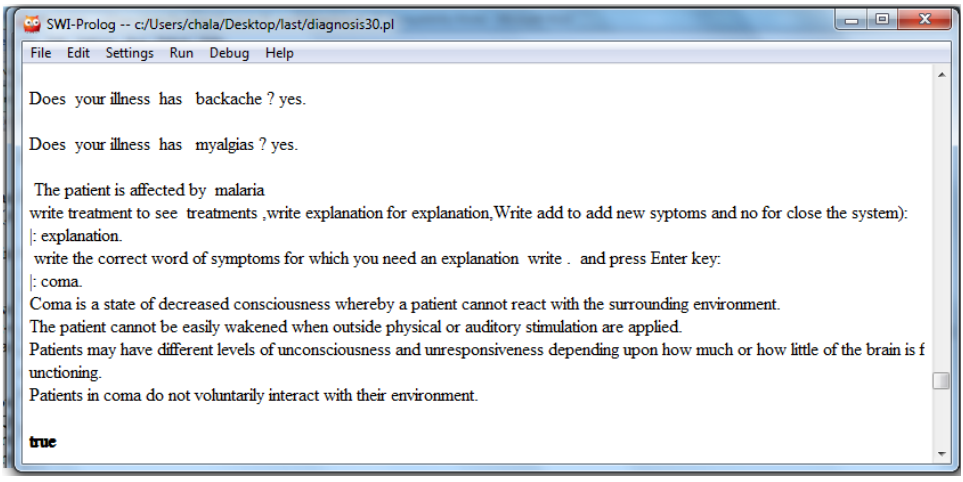

Fig. 4. How prototype system gives explanation facility.

In general the study was about developing a KBS for diagnosis and treatment of malaria. This developed prototype has a capability of diagnosis and treatment of malaria species falciparum, vivax, ovale and malariae. In addition the system can register patient history during diagnosis and treatment. Moreover, the system can provide explanation facility when the user need explanation about malaria sign and symptoms.

3.5. *Testing and evaluation of the prototype system*

3.5.1. *System performance evaluation*

In the process of testing the performance of the prototype system, the domain experts classify correctly and incorrectly diagnosed patients cases by comparing the judgments reached by the prototype system with that of the experts' judgments reached on the same patient's test cases. The result was presented by confusion matrix in Table 1.

From Table 1, the correct diagnosis by prototype system is 12 and incorrect diagnosis is 3. This indicated the system performance is 80%. The recall, precision and F measure were calculated depending on the above data in the confusion matrix.

KBS evaluation plays an important role in judging the efficiency and effectiveness of it. Recall and precision are the common performance measures of the system.

Table 1. Confusion matrix of the prototype system.

	Actual correctly diagnosis cases	Actual incorrectly diagnosis cases
Predicted correct by the prototype system	8	1
Predicted incorrect by the prototype system	2	4
Total	10	5

Table 2. Accuracy of the prototype system.

	TP Rate	FP Rate	Precision	Recall	F-Measure
Results	0.777	0.166	0.875	0.777	0.823

As it showed in Table 2 the value of recall is 0.875 and precision is 0.777. F measure is a derived effectiveness measurement. The resultant value was interpreted as a weighted average of the precision and recall. The best value is 1 and the worst is 0. As it showed in Table 2 the F measure of the prototype system is 0.823 which indicate that the prototype has a very good performance.

The challenges behind evaluation performance of prototype system are some of the cases have no contain enough information of signs and symptoms of malaria at least the commons ones. The knowledge variation among the profession on malaria diagnosis and treatment is the other challenge.

3.5.2. *User acceptance testing*

User acceptance testing is a form of testing to verify if the system can support day-to-day business and user scenarios to validate rules, various workflows, data correctness, and overall fit for use and ensure the system is sufficient and correct for business usage (Vince, 2010). It is a process of evaluating a new or revised system undertaken by domain experts, knowledge engineer and end-users of the system to make sure it meets the objectives of its development (John, 2001). User acceptance testing is independent of the system development process and performed by end-users and stakeholders before formally produced. Performing system acceptance testing depends on different user acceptance criteria like functionality, correctness, validation, verification, ease of use and user interface. Solomon (2013) selected visual interaction techniques to check acceptance of their system.

Eight (8) domain experts were selected from Jimma specialized hospital. Since, the procedure requires visual interaction with all selected domain experts, it difficult to take a lot of respondents. The prototype system was showed to the domain experts what is the prototype system can do including its user interface. Then the researchers distributed the questionnaire for those domain experts and data was collected.

Lastly the user acceptance of the prototype system was analysed. As data collected indicate, 50% of the users evaluated the prototype as excellent, 25% as very good, 25% as good. This shows that the system is easy to use and interacts. The second evaluation criteria are attractiveness of the prototype system which showed a greater rate of attractiveness by the evaluators. The majority 50% was scored as excellent, 25% as very good, and 25% as good. In the efficiency of the prototype system with respect to time criteria of evaluation, 62.5% of the evaluators scored as excellent, 25% as very good, and the rest 12.5% as good. Moreover, 50% of the evaluators gave the prototype system an excellent score with regard to the accuracy

of the prototype system in diagnosis of malaria, 25% as very good, 12.5 as good and 12.5% as fair. And when asked if the prototype system included adequate knowledge about diagnosis and treatment of malaria, 37.5% of the evaluators rated the prototype system as very good and as good, and 25.5 as excellent. The ability of the prototype system in making right conclusions and recommendations criteria was scored 50% of the evaluators as excellent while 37.5% and 12.5% of the evaluators scored it with very good and good, respectively.

To this end, the significance of the system in the domain area criteria indicate, 50% of the evaluators gave the prototype system very good, 25.5% rated the prototype system as excellent and 25% as good. Finally, the average performance of the prototype system according to the evaluation results filled by the domain experts is 4.16 out of 5 or 83.21% which is very good.

The user acceptance of the prototype system is not registered 100% because of unawareness of domain experts about KBS importance in their domain area. In addition, misunderstanding some of them considered if the prototype system is implemented it can be reduce number of workers.

4. Conclusion and Recommendation

4.1. *Conclusion*

KBS have been found to be very useful in our today's world driven by technology. Technology and research can put appropriate attention on diagnosis and treatment of diseases. Malaria is problematic disease all over the world. It causes the death of many people in many countries especially who live in tropical area and developed countries where there is scarcity of doctor and apparatus for diagnosis and treatments. The developed prototype can be used to assist and give verification to medical personnel for diagnosis and treatment of malaria.

Rule based reasoning was used for the development of a prototype KBS is to assist diagnosis and treatment of malaria.

The user acceptance testing of the system indicated 83.21% which show that the prototype system is acceptable by the professionals and necessity to implement in health centres. In addition, as the performance results indicate the system registers 82.3% accuracy. This shows that in the study promising result was registered.

The prototype system has strength of diagnosis and treatment of malaria species falciparum, vivax, ovale and malariae. In addition the system can register patient history during diagnosis and treatment. Moreover, the system can provide explanation facility when the user need explanation about malaria sign and symptoms. The prototype has constrained feature concerning self-learning by itself is not possible; however, improving learning of the new facts and rules by the help expert' is possible.

In addition, laboratory testing result is not included in this prototype KBS. Depending on the above limitations of the prototype system, the following recommendations were stated.

4.2. *Recommendation*

The following recommendations were given based on the observed opportunities and uncover areas by this research.

- The doctors should have write detail information on the cases during diagnosis and treatment. Because the cases very important for development such like KBS and also for its performance testing. As it is stated in different KBS articles, one of the challenge of developing KBS is getting accurate knowledge whether from cases or from experts'. In this study both of the approach was used. As it is very difficult to extracts tacit knowledge from knowledgeable personnel, it is very hard to get accurate cases if the doctors not fill the cases in very appropriate ways. So, the researchers were challenged in this case.
- The record managers should have to classify and store the patient cases properly.
- It is a difficult task to extract the necessary knowledge due to the nature of tacit knowledge. Therefore, it is important to apply data mining techniques to extract the hidden knowledge about malaria and more research work must be done to integrate the application of data mining techniques with KBSs.
- To develop in local language (Afaan Oromo and Ahmaric).
- In today's world people are so busy that they hardly have enough time to visit a doctor. So they want to use service online system that cans diagnosis and treatment of disease.
- It is very important and can be increase the quality of diagnosis and treatment if it can be developed in others reasoning techniques.
- To develop these KBSs, SWI-prolog editor environment was used, but to make this system more interactive and make life easy for potential users, other visual user interface tools should be used, such as Java and C#.
- The developed system was learning KBS which mean it can learn new rules and facts by the help of experts', but self-learning KBS was yet not fixed which mean the KBS learn new rules and facts by itself without the inference of human being. Therefore, it suggested as for warded as the future work.
- The other limitation of this prototype was not included laboratory testing results of Malaria diagnosis and treatment.

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