

Building a Computer-Based Expert System for Malaria Environmental Diagnosis: An Alternative Malaria Control Strategy

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Abstract

As a predominant environmental health problem in Africa, malaria constitutes a great threat to the existence of many communities. The harmful effects of malaria parasites to the human body cannot be underestimated. In this paper, an expert system for malaria environmental diagnosis was presented for providing decision support to malaria researchers, institutes and other healthcare practitioners in malaria endemic regions of the world. The motivation behind this work was due to the insufficient malaria control measures in existence and the need to provide novel approaches towards malaria control. A malaria expert system prototype was developed that involved a knowledge component, the application component (AC), the database system component (DC), the Graphical User Interface (GUI) component and the User component (UC). The User interface component was implemented using the Java Programming language. The application component was implemented using the Java Expert System Shell (JESS) and the Java IDE of Netbeans while the database component was implemented using SQL Server.

Keywords: *Database system; Expert system; Environmental Diagnosis; Knowledge based system, Malaria; Malaria Control.*

1. Introduction

Malaria, a potentially fatal blood disease, is caused by a parasite that is transmitted to human and animal hosts through the Anopheles mosquitoes. This mosquito-borne disease has resulted in the death of many people annually. Environmental effects on health, however, have always been multi-faceted [1], especially as regards the transmission of malaria. However, the knowledge of Artificial Intelligence, especially Machine learning in Computer Science, can be deployed into malaria research to provide meaningful control measures to curtail the spread of malaria in endemic regions.

Machine learning refers to a system capable of the autonomous acquisition and integration of knowledge. It has the capacity to learn from experience, analytically make critical observations, and, results in a system that can continuously self-improve. The aim of this work is to build an expert system for malaria environmental diagnostics, which will ultimately help in proffering quality control measures to malaria in Africa, Asia and other regions of the world. Thus, this project work aims to elucidate the level of malaria parasite transmissions through variously specified environmental and climatic factors in any affected country for appropriate control measures.

2. Related work

Several related work have shown that malaria remains a major public health problem in Africa [2]. However, concerted efforts are continually been made to control malaria spread and transmissions within and between communities. In the work carried out by (Utzing J. et al.,2001), it was reported that monthly malaria incidence rates and vector densities were used for surveillance and adaptive tuning of the environmental management strategies; which resulted in a high level of performance. Within 3-5 years, malaria-related mortality, morbidity and incidence rates were reduced by 70-95% [3]. In a recent study, it was concluded that malaria control programmes that emphasized environmental management were highly effective in reducing morbidity and mortality [4]. Another study also showed that Environmental management of mosquito resources is a promising approach with which to control malaria, but it has seen little application in Africa for more than half a century [5]. In a recent study carried out by (Utzing et al., 2002) the economic payoffs of malaria control strategies was highlighted [6]. Copper production and revenues, was increased dramatically during malaria control interventions.

The great failure of malaria control in Africa, from a district perspective in Burkina Faso was highlighted in the work carried out by (Kouyaté et al., 2007) [7].An integrated approach to malaria control was presented by (Clive Shiff, 2002). [8]

In the scientific commentary delivered by (Jeffrey D. Sachs, 2001), he stressed the need for a new global commitment to disease control in Africa. In the commentary, malaria was among the diseases highlighted [9]. However, in the work carried out by (Vincent P.A. and Thomas G. E., 2003), it was observed that malarial control strategies consisted majorly of chemotherapy directed against the malaria parasite and prevention of mosquito vector/human contact using insecticide-impregnated bednets. This control strategy achieved minimum results [10].

Another research was carried out on the island of Bioko (Equatorial Guinea). The purpose of this study was to access the impact of the two control strategies (insecticide-treated nets (ITNs) indoor residual spraying (IRS) on the island of Bioko (Equatorial Guinea), with regards to Plasmodium infection and anaemia in the children under five years of age. The results obtained showed that IRS and ITNs have proven to be effective control strategies [11].

Recently, a research was conducted to determine the cost effectiveness of selected malaria control interventions. It was concluded that on cost effectiveness grounds, in most areas in sub-Saharan Africa, greater coverage with highly effective combination treatments should be the cornerstone of malaria control [12].

Thus, there is a pressing need to research into the best methods of deploying and using existing approaches, such as rapid methods of diagnosis, to have effective control over malaria transmissions [13].

3. Expert System for malaria environmental diagnostics

An expert system for malaria environmental diagnostics is a system that helps to determine the extent of malaria parasites presence within different environments based on environmental factors supplied.

The framework is made up of four components, namely;

- (i) The User component
- (ii) The GUI component

- (iii) The Application component
- (iv) The Database System component

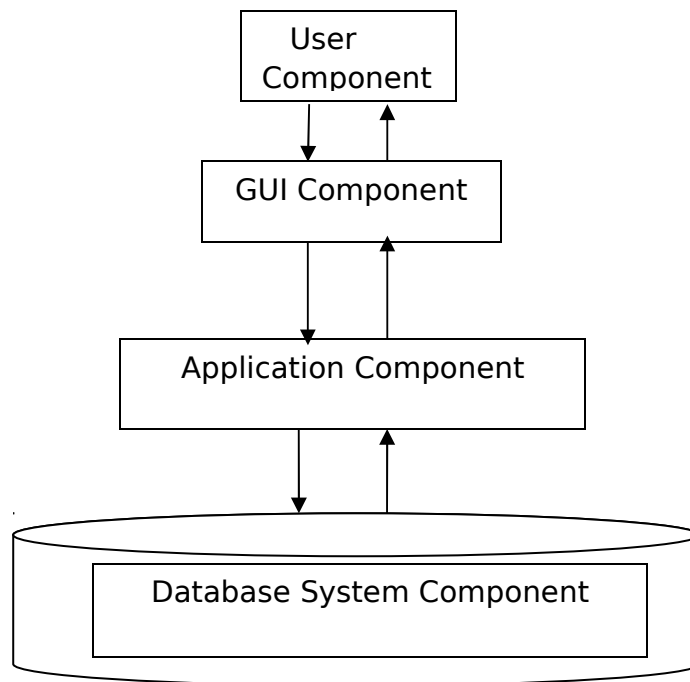


Fig. 1 Framework for the Malaria Expert System

4. Knowledge Base, Uncertainty and Searching Technique in Expert Systems

Expert systems are computer applications which embody some non-algorithmic expertise for solving certain types of problems. They are used in many areas including diagnostic applications. Expert systems have a number of major system components and interface performing various roles. Their major components are briefly explained below.

1. Knowledge base - declarative representation of the expertise, often in IF THEN rules;
2. Working storage - the data which is specific to a problem being solved;
3. Inference engine - the code at the core of the system which derives recommendations from the knowledge base and problem-specific data in working storage;
4. User interface - the code that controls the dialog between the user and the system.

The major bottleneck in expert system development is the building of the knowledge base. Many expert systems are built with products called expert system shells. The shell is a piece of software which contains the user interface, a format for declarative knowledge in the knowledge base, and an inference engine. The knowledge engineer uses the shell to build a system for a particular problem domain. The data in the shell constitutes the knowledge base of the system. With a customized system, the system engineer can implement a knowledge base whose structures are as close as possible to those used by the expert. For all rule based systems, the rules refer to data. The data representation can be simple or complex, depending on the problem.

5. JESS (Java Expert System Shell) as a Knowledge Base

A JESS document is usually created in text editor, including the windows platform editor, Notepad. As the name implies, it's usually incorporated into a Java program for

functionality, although it can work alone and could be run on the windows command prompt. The jess file is usually saved with a “.clp” extension as against the normal “.txt” extension. It contains a JAR file which links the JESS to the java IDE environment and as soon as the jess is referenced in the code, it would run predefined instructions subject to user’s input from the Java Interface. The JESS is usually run and manipulated on the Java interface. In Java environment, program codes are usually written for specific functions.

5.1. Expert System Features

There are a number of features commonly used in expert systems and they are:

1. Coping with uncertainty - the ability of the system to reason with rules and data which are not precisely known;
2. Data driven reasoning - an inference technique which uses IF THEN rules to deduce a problem solution from initial data; a diagnostic system fits this model, since the aim of the system is to pick the correct diagnosis. The knowledge is structured in rules which describe how each of the possibilities might be selected. The rule breaks the problem into sub-problems. The system would try all the rules till it finds a perfect match which is then returned to the user through a user interface;
3. Data representation - the way the problem specific data is stored and accessed in the system;
4. User interface - that portion of the code which creates an easy to use system;
5. Explanations - the ability of the system to explain the reasoning process that it used to reach a recommendation.

5.2 Uncertainty in the Expert System

This is the ability of the system to reason with rules and data which are not precisely known. For expert systems to work in the real world they must also be able to deal with uncertainty because the expert’s rules might be vague or the user might be unsure of answers. This can be easily seen in medical diagnostic systems where the expert is not definite about the relationship between symptoms and diseases or the system users cannot explain the problem in definite terms. In fact, the doctor might offer multiple possible diagnoses. In our system, the knowledge base contains data that are based on certain and proven facts and it has the capability to handle a user’s uncertainty.

Searching the knowledge base through the user interface

The acceptability of an expert system depends to a great extent on the quality of the user interface. The easiest to implement interfaces communicate with the user through a dialog box, drop-down menu and so on. The system responds to commands, and asks questions during the inference process. Then, the user can respond to questions, pick choice answers and also enter commands. The Drop-Down searching technique is used in our system, as shown in Fig 1.

6. Methods

Technical aspects of our methodology involved the design and implementation of a 4-agent architectural model namely, The User interface component, the application component and the database component.

The expert system for malaria environmental diagnostics was developed using Net Beans 5.5; JESS (Java Expert System Shell) for the rule/knowledge base and Microsoft SQL Server 2000 is used as the Database engine for this project. The JESS file is called in the Net Beans environment and the Database also. All inputs are has equal slots in the JESS file where necessary action is carried out to generate accurate results.

There are necessary factors in determining the probability of mosquito as a vector in an area, the knowledge of this would help in devising the appropriate control measures and also help to reduce the risk of contact with the malaria parasites.

The Main Form in Fig.2 contains various input factors like Period of Day; Zone information; Weather Status; Natural Disasters; Rain and Water Content; Population; Nature of Country and Vegetation Cover. All these factors have their contributions to the spread of the malaria parasites

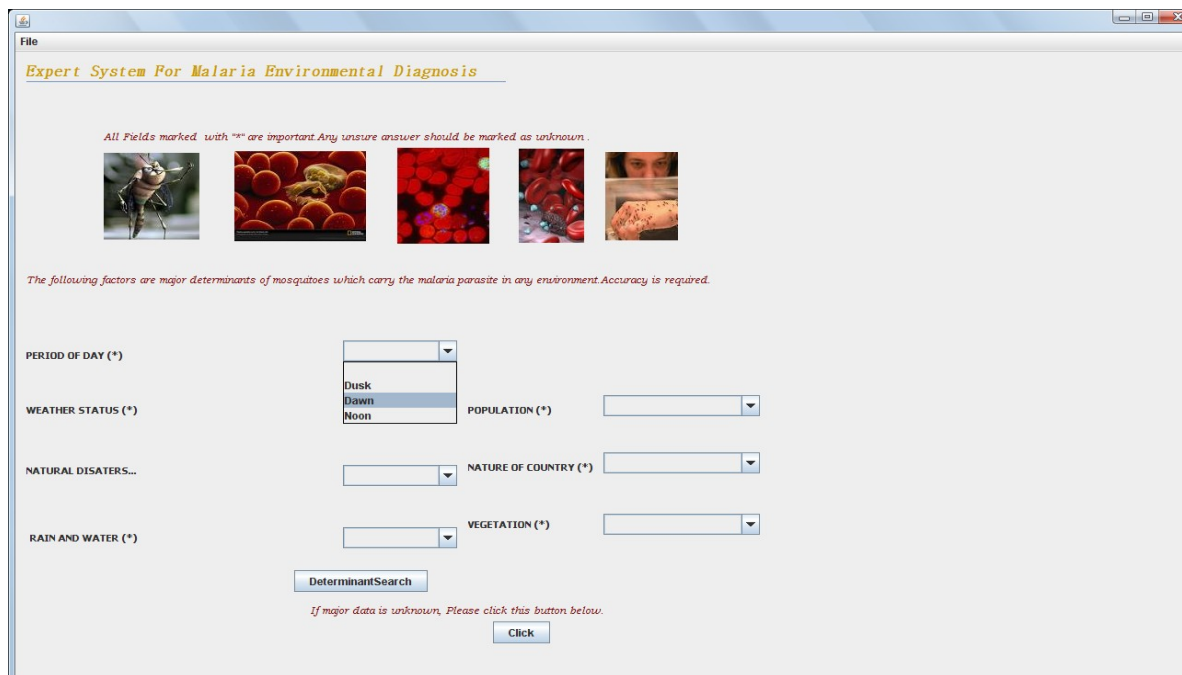


Fig.2 Developed Application showing various contributory environmental factors to malaria spread through the Graphical user interface component

7. System Design

A formal model of the proposed system was built using Unified Modeling Language (UML).

(i) Use Case diagram of the Proposed System

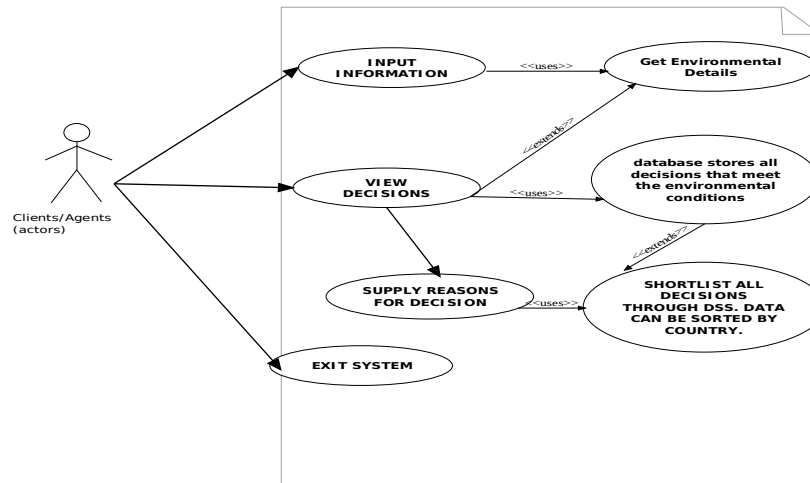


Fig.3 Use Case Diagram of the Expert System

A **Use Case diagram** graphically depicts the interactions between the system, the external system (if any) and the user. Use case diagrams play a major role in system design because it acts as a roadmap in constructing the structure of the system; it also defines who will use the system and in what way the user expects to interact with the system.

The purpose of the use case diagram is to portray:

- The actor.
- A set of use cases for a system.
- The relations between the actor and the use cases.

Here, we introduce three main Use cases which extend, include or use other Use cases.

- Input Information;
- View Decisions;
- Exit System.

The User (actor): This is one of the clients that make use of the application.

Input Information: this represents the interface where the users are going to feed data into the system based on questions about their environment. The system then responds based on the correlation between user data and its foreknown intelligence. This uses another Use Case called Get Environmental Details and that is the set of questions representing the environment.

View Decisions: this is an avenue that enables the user of the system to view the system response. It's usually through an interface. All system possible decisions have been stored in a database external to the system and this is for code efficiency. It has a Use Case that is used by the decision taking Use Case.

Exit System: the user of the system can decide when to leave the application in the event of getting enough information or otherwise.

ii. Sequence diagram for the Proposed System

A Sequence diagram is a graphical visualization of sequences of messages between objects i.e. sequence of method invocation of objects which results in accomplishing some tasks. The emphasis in a sequence diagram is on the sequence of messages. A Sequence diagram is a structured representation of behavior as a series of sequential steps over time. It is used to depict work flow, message passing and how elements in general cooperate over time to achieve a result. The sequence diagram for this system is shown in the next section.

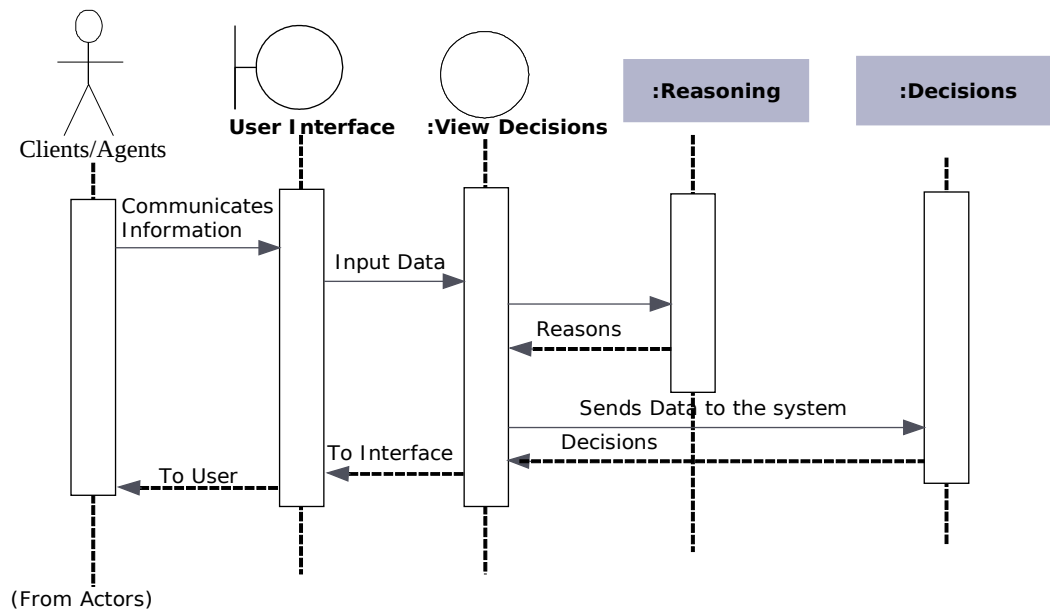


Fig.4 Sequence diagram of the Expert System

iii. Activity diagram for the Proposed System

Activity diagrams graphically show represent the performance of actions or sub activities and the transaction that are triggered by the completion of the actions or sub actions. It is a means of describing the workflow of activities.

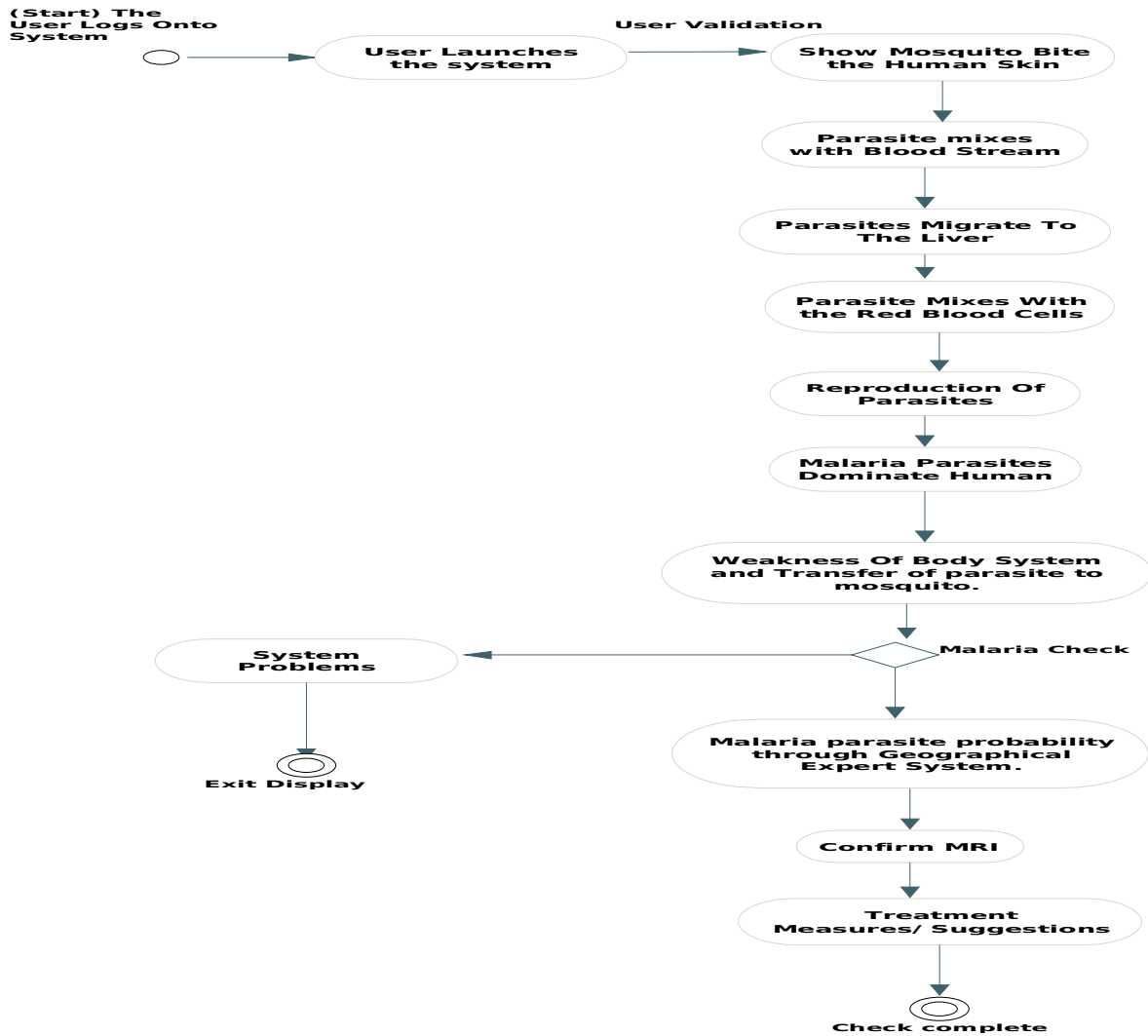


Fig.5 (a) Activity diagram of the Expert System

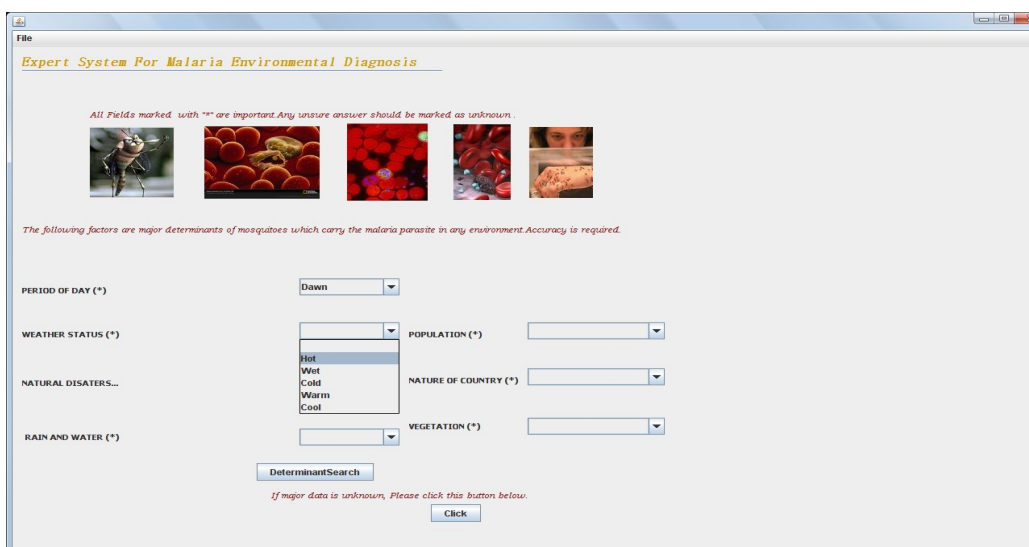


Fig.5 (b) Application showing a user in the selection process.

This form shows a user in the selection process. The Period of the Day has two main determinants, Dusk or Dawn. This is because the mosquito is generally more active at these periods. The user selection would determine the result the system would generate.

The second user agent action performed is the selection of the Zone.

The zone (height above sea level) is also a determinant for vector in that environmental area. At 10 feet above sea level, there are more possibilities of malaria parasite and so was considered as a criteria.

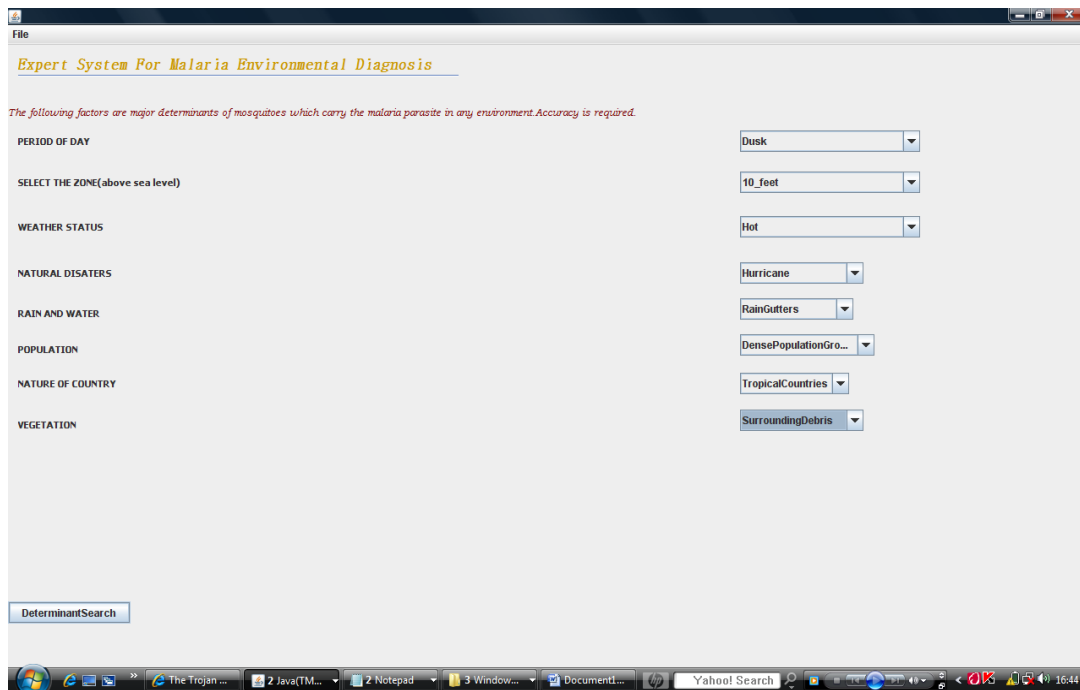


Fig. 6 Application showing the period of the day, selected zones , weather status, natural disasters, population, nature of a country and vegetation as a determinant for malaria parasite spread

8. Results

At this point all necessary data (as stated above) would have been inputted. The JESS platform performs the necessary knowledge evaluation to determine what result is given out at what point as shown below:

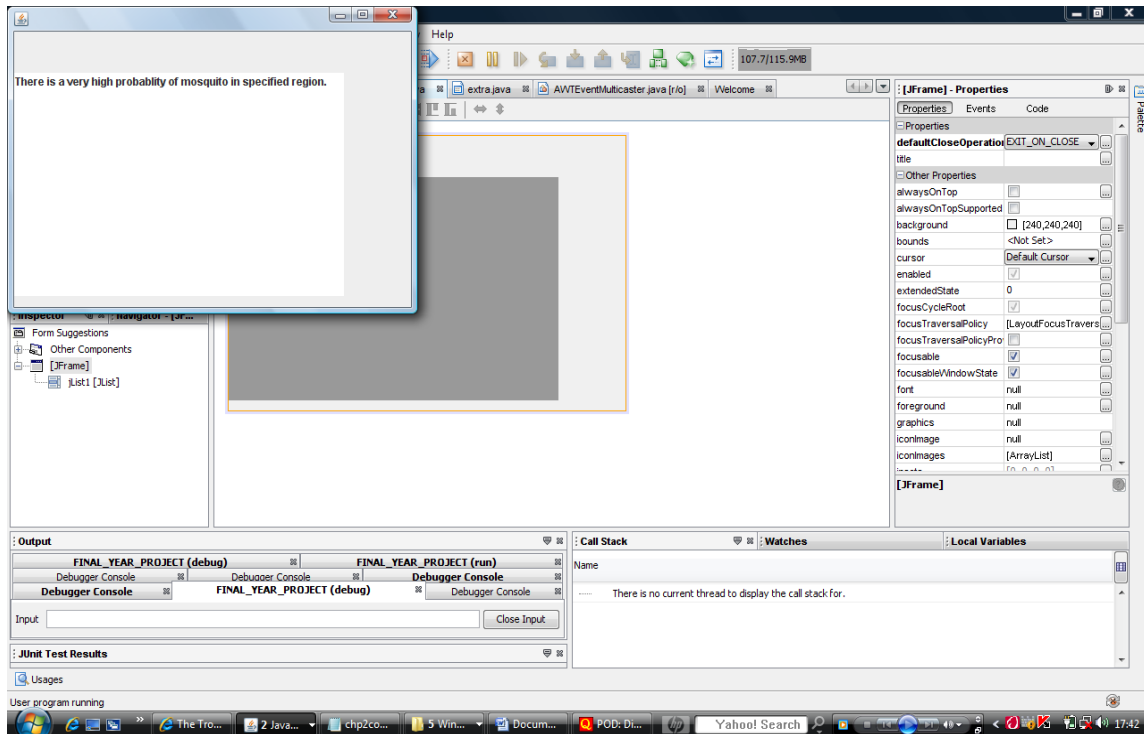


Fig.7 Results produced by the malaria expert system

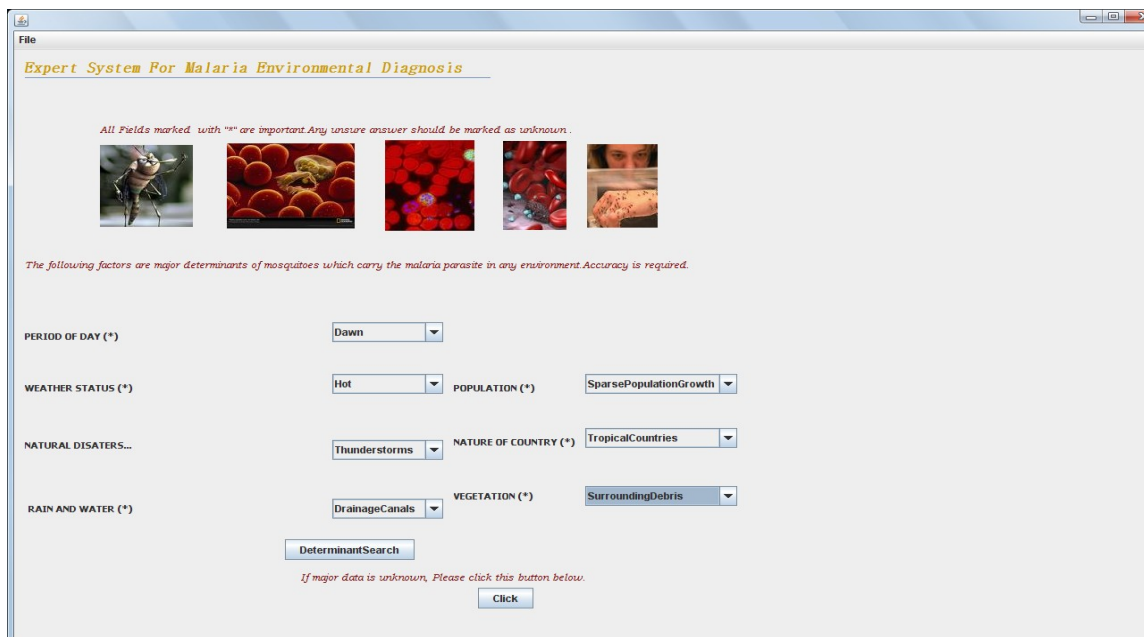


Fig.8 Results produced :The weather status is a major determinant of the vector in a geographical area. There are more possibilities of malaria parasite during high temperatures and vice-versa.

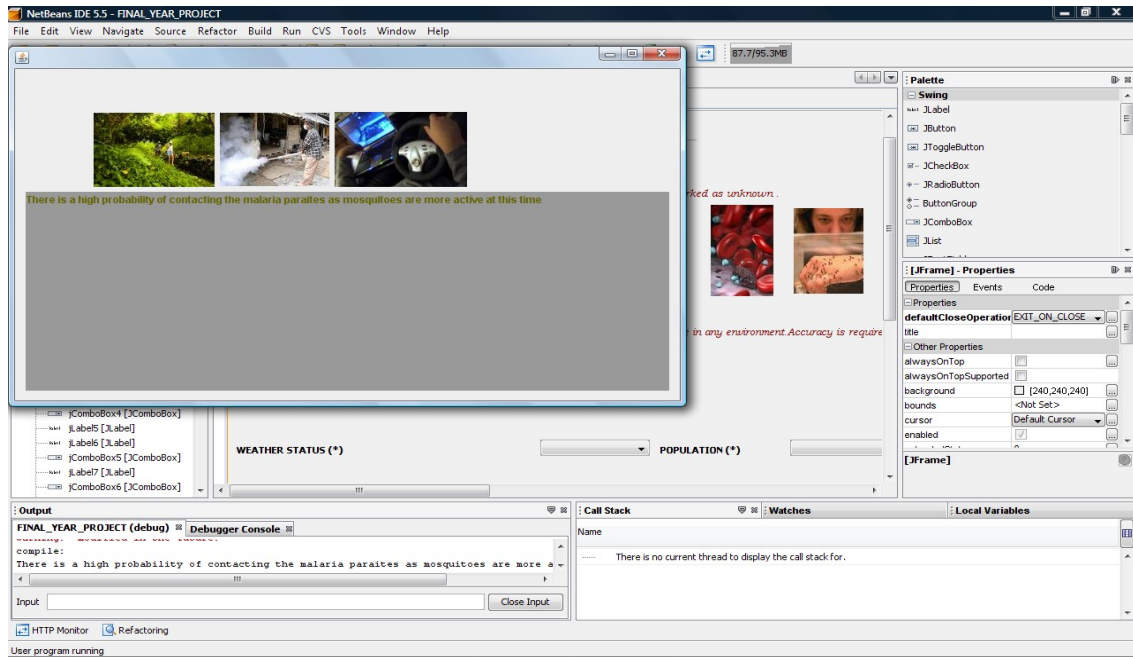


Fig.9 The result here shows mosquito would be very high in the specified region and then the system would go on to proffer solutions and medications.

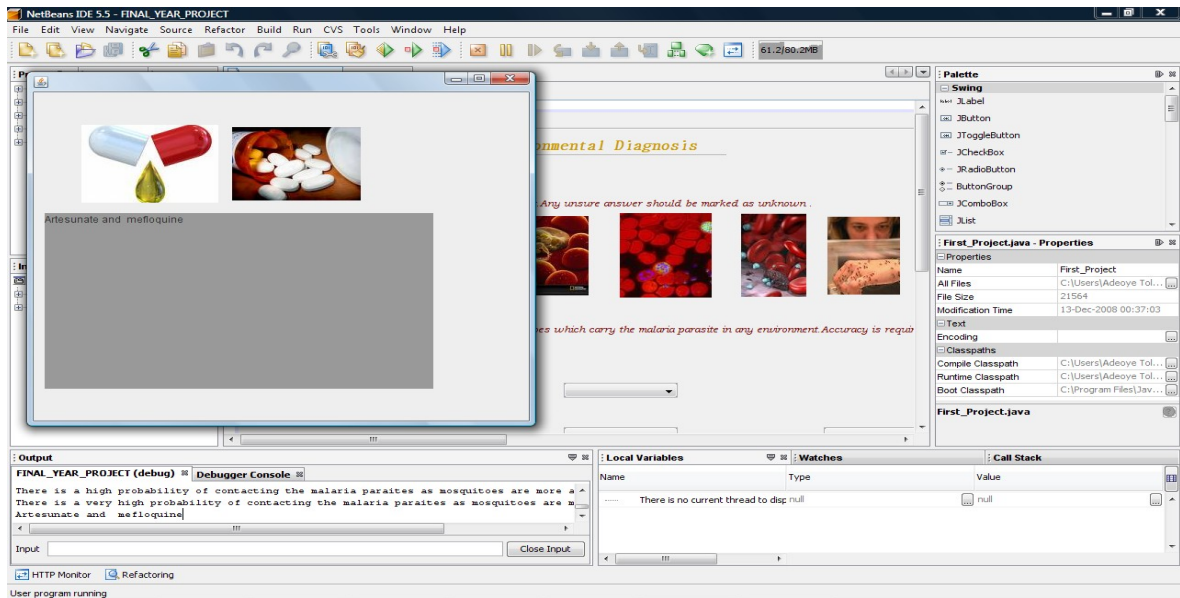


Fig.10 The result here shows the results obtained by clicking on the suggestion to view the solution or the recommendation of the expert system.

Here, mosquito population would be very high in the specified region, as a result lead to increase in the spread of malaria parasites transmission; and then the system would go on to proffer necessary solutions and medications.

In the course of the software development, all unknowns lead to another form where the user should select the country where he is in- everyone is expected to have that information. Then, the system gives the user a load of information based on the country specified.

Another addition to the current program is the ability of the system to proffer medication (as a doctor would) based on the country or data specified. This is the point the Database engine would be required.

9. Discussion

The malaria expert system acts as a diagnosis tool which can assist malaria researchers determine the intensity or concentration of malaria parasites in designated geographical locations, which in turn can help in developing effective control measures to the spread of malaria in such regions.

In Fig.2, the expert system for malaria environmental diagnosis showed the various climatic and environmental factors which could determine the intensity of malaria parasite occurrences within a geographical region or country. With this, the user agent could specify and choose any of the sub-factors within these major factors.

In Fig.6-Fig.7, shows the selected sub-factors; at this point, all necessary data (as stated above) would have been inputted. The JESS platform performs the necessary knowledge evaluation to determine what result is generated.

Fig.8 showed the output of the results generated by the malaria expert system. This result showed a high probability of malaria parasites within this geographical region and hence, a high risk of malaria transmissions. Extended work on the development of this expert system also showed the ability of the system to proffer medication (as a doctor would) based on the country or data specified.

Fig.9 showed the results produced: The weather status is a major determinant of the vector in a geographical area. There are more possibilities of malaria parasite during high temperatures and vice-versa.

The result in Fig.10 showed that mosquito would be very high in the specified region and then the system would go on to proffer solutions and medications.

Fig.11 shows the results obtained by clicking on the suggestion to view the solution or the recommendation of the expert system.

Another addition to current program is the ability of the system to proffer medication (as a doctor would) based on the country specified. The Database engine would also be required here. This can be done from the main form.

From the main form, the user is expected to explore geographical information by country of current location. Clicking the Click Button on the main form takes the user to another form as shown below:

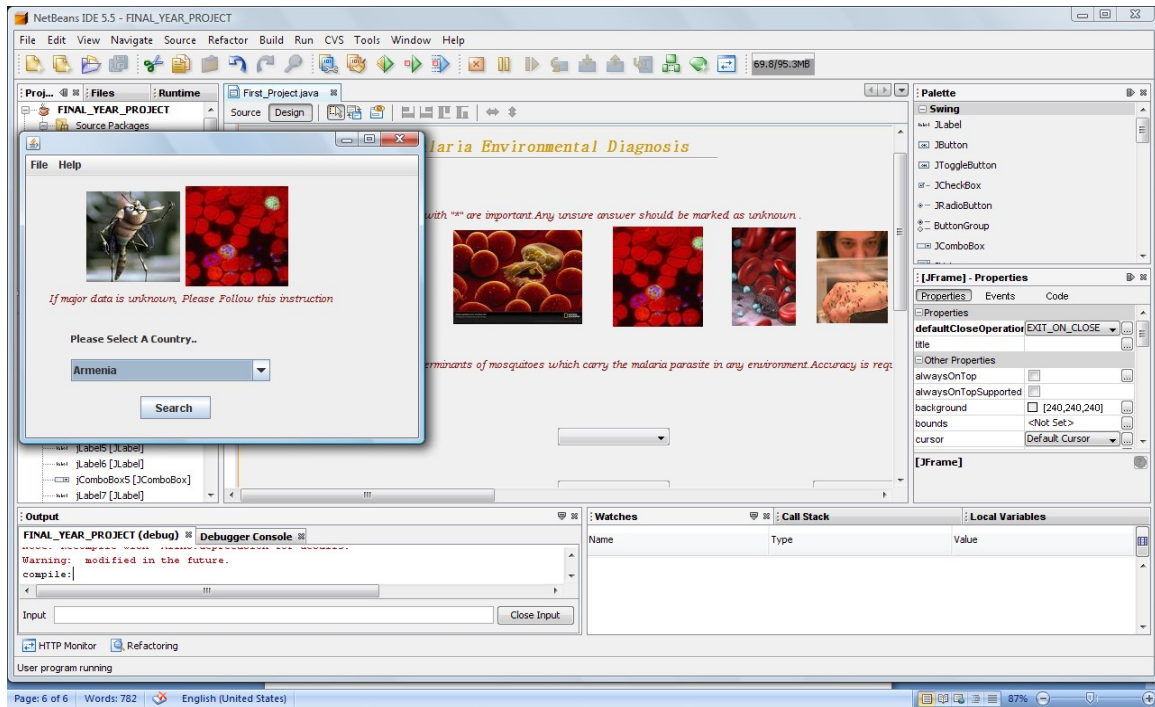


Fig.11 Here, the country Armenia was selected

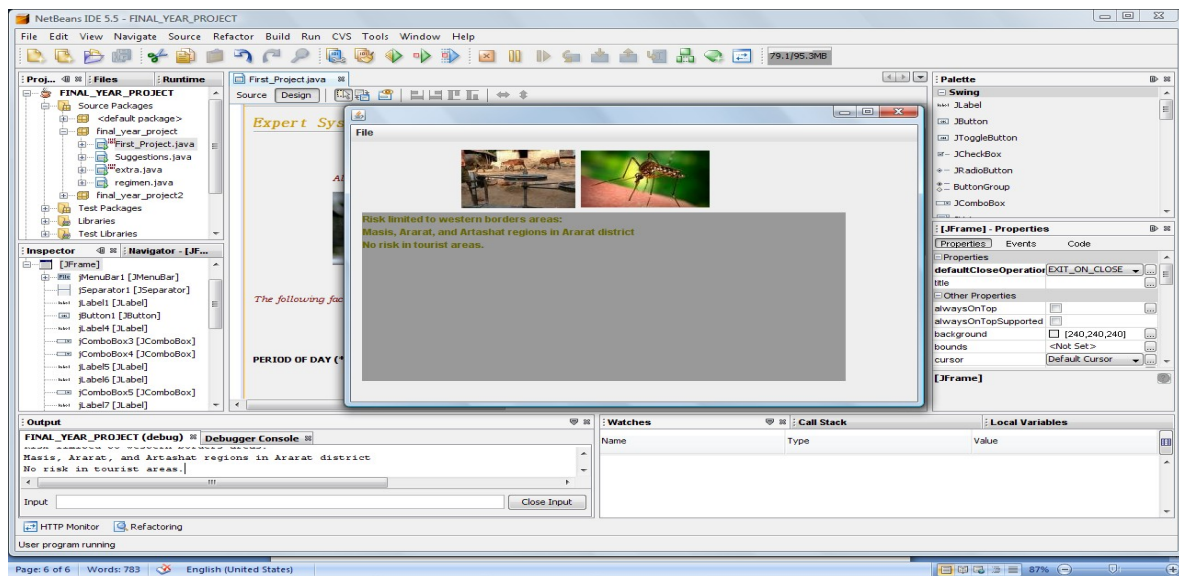


Fig.12 and then on-click of search brings out all malaria information about the Armenia according to current research.

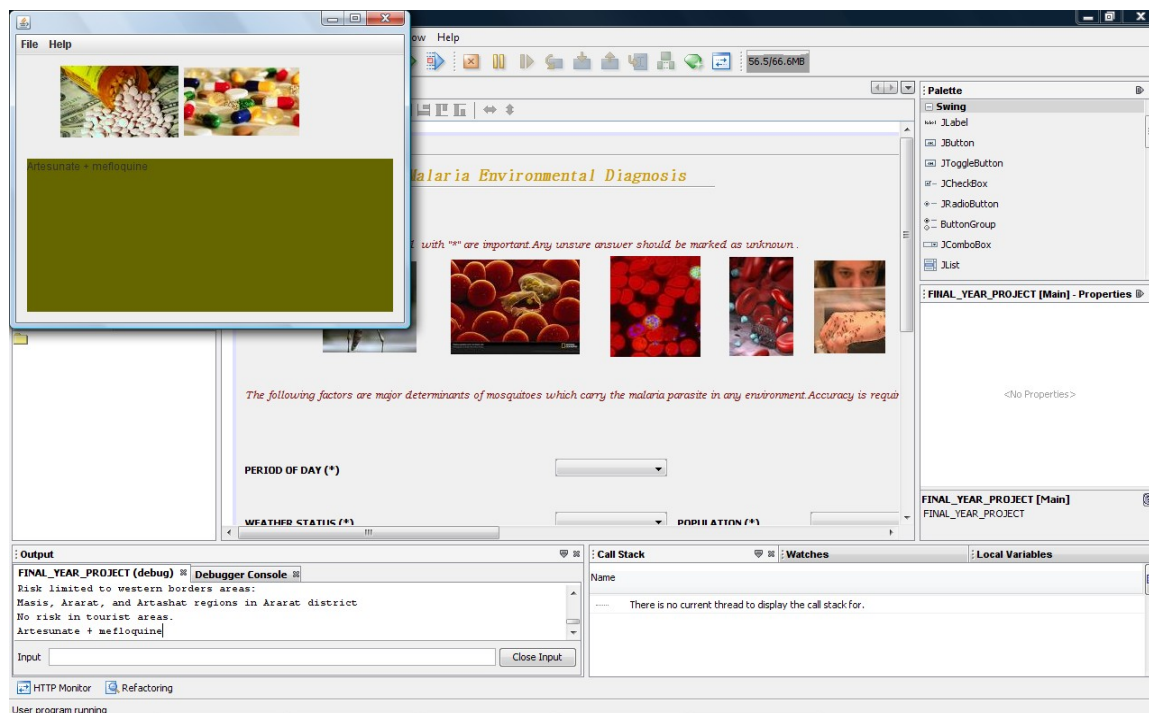


Fig.13 Results of the recommendations of the expert system for the selected country

10. Conclusion

The malaria expert system agent built in this research work, was a rule-based system and contained in its knowledge base, some important rules on malaria causative agents, environmental and climatic factors which can favor the multiplicity of malaria transmissions. It also proffers solution to how malaria transmission can be handled by a reasoning approach based on its knowledge base. The results obtained from this expert system does not only show the possibility of controlling and reducing malaria spread through an environmental diagnostic approach, but also shows the future prospects of the application of different sub-fields of artificial intelligence to various infectious disease research.

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