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Full Length Research Article

An intelligent system with the model-view-controller pattern querying visual objects: Application in the malaria control domain

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Malaria affects hundreds of millions of people in the world, particularly in the tropics. This results in particularly high death rates among children and pregnant women, especially the poor living in squalid conditions. This situation is not only due to the increasing drug resistance of malaria and the resistance of the main vector to pesticide control, but also the lack of awareness on the part of communities to fight the disease. In this view, vector control is a cornerstone of the strategy that needs to be implemented and monitored. In this regard, the problem of estimating malarial transmission rate is still very important. It is the aim of this paper.

Key words: Model-view-controller (MVC) pattern, visual object, web programming, malaria transmission, malaria vector.

INTRODUCTION

Many studies have been performed to estimate malaria transmission rates in some villages in Africa. A comparison of three sampling methods has been presented (Le Goff et al., 1997). To get a good view of the vector-borne disease transmission, the entomologist must select a catching method that meets a main requirement: Get the best evaluation of host/infective vectors relationship in a given situation. In Antonio-Nkondjo et al. (2006), the contribution of the so-called secondary malaria vectors to the overall parasite transmission intensity is highlighted. High malaria transmission intensity is studied in Antonio-Nkondjo et al. (2002) and in Cohuet et al. (2004). In the current paper, a system is described that significantly results in increasing malaria transmission rate understanding. The measure of malaria transmission depends on qualitative statistics. The final result is not to quantify the rate of malaria transmission but to qualify it into four levels: Weak, average, fairly strong and strong.

Model-view-controller (MVC) is a classic design pattern often used by applications that need the ability to maintain multiple views of the same data (Crane et al., 2006). The MVC pattern hinges on a clean separation of objects into one of three categories: Models for maintaining data, views for displaying all or a portion of the data, and controllers for handling events that affect the model or view(s). A developer needs to take care in linking between all views and appropriate controllers. Because of this separation, multiple views and controllers can interface with the same model. Even new types of views and controllers that never existed before can interface with a model without forcing a change in the model design.

On another plan, one of the most fundamental approaches in software engineering is the layered architecture. It implies dividing a system into several interacting layers with certain limitations imposed on how layers may interact.

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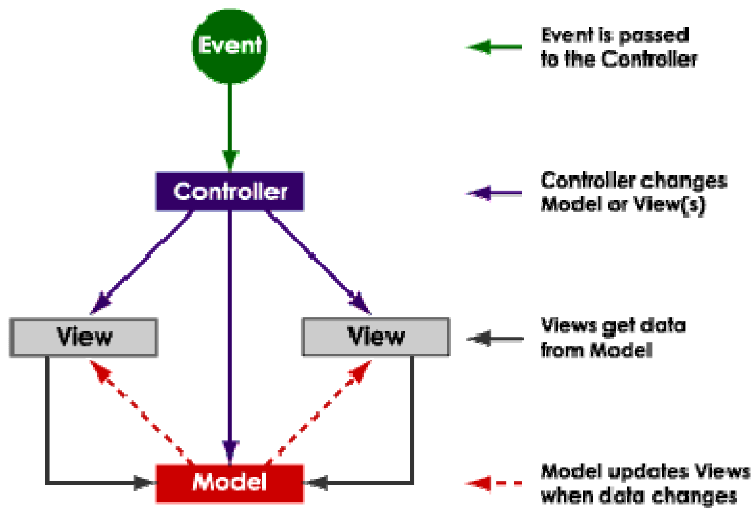

Figure 1. MVC pattern.

Layered architecture finds its application in various systems for example: Internet protocols (TCP/IP layers), operating systems (three layers: Core, drivers, applications), information systems (database management systems, geographic information systems, etc) and others.

A particular case of layered architecture is the 3-tier architecture with its variation (Cloux et al., 2002): Model-view-controller. All this can be implemented in a heterogeneous environment containing a geographic information system (GIS), a database management system (DBMS) and an expert system (ES). Views are performed to present visual objects. Visual objects may be textual, graphical, and geographic. Derived data are expressed through particular graphical objects that are points. Usually, graphical objects are points, lines, ellipses, rectangles and other polygons.

An intelligent system is implemented generally when an expert system is involved. In GIS-based surveillance applications, successful expert systems have a well defined focus and are confined to a specific domain like malaria transmission.

An application of MVC pattern in the field of malaria transmission dynamics is the base of this prototype; four levels of malaria transmission rate are defined as: Weak, average, fairly strong, and strong.

MATERIALS AND METHODS

In model-view-controller (MVC) based applications, maintaining an application logic layer may require considerable efforts and may not be easy to implement. When this problem is taking place in a heterogeneous environment comprising a variety of systems, every view and controller may be attached to a particular system so that a better understanding of the whole system can be obtained. This simplifies and speeds up the development of such applications. This paper aims at implementing a model-view-controller pattern in an intelligent system constituted of a geographic information system (GIS), a database management system (DBMS), and an expert system (ES). This is applied in malaria control to measure the rate of malaria transmission. A qualitative approach is used, estimating the levels of disease transmission in localities of Cameroon. Views display objects which can be textual, geographic or derived and are called visual objects.

MVC patterns

According to MVC objects, the presentation layer consists of view objects and application logic consists of controller objects. For each view object, a corresponding controller exists and vice versa. Views process presentation needs and controllers handle application logic. The MVC pattern has two major characteristics:

1. MVC controllers receive and process user input.
2. MVC controllers affect their views by changing the intermediate presentation model, which the views are subscribed to (by observer patterns). This makes views pure observations without any direct access to the controllers.

The MVC abstraction can be graphically represented as shown in Figure 1.

Events typically cause a controller to change a model, or view, or both. Whenever a controller changes a model's data or properties, all dependent views are automatically updated. Similarly, whenever a controller changes a view, for example, by revealing areas that were previously hidden, the view gets data from the underlying model to refresh itself. There can be as many controllers and views. An event is directly related to a particular controller. For this purpose, we consider the task concept. A task unites several views with their controllers in fulfilling a particular job.

In this case, a querying task on malaria control may consist of three views: One to return a point in a map situating a locality, another one to return basic information belonging to a geographic information system (GIS) and/or a database management system (DBMS), and the last to return deduced information stemming from an expert system (ES). All these data are called visual objects. All controllers within a task are given a link to the task object. Generally a task can be expressed as a workflow or a state machine.

Application developers do not have to care about associating each view with its controller. Views and controllers get connected

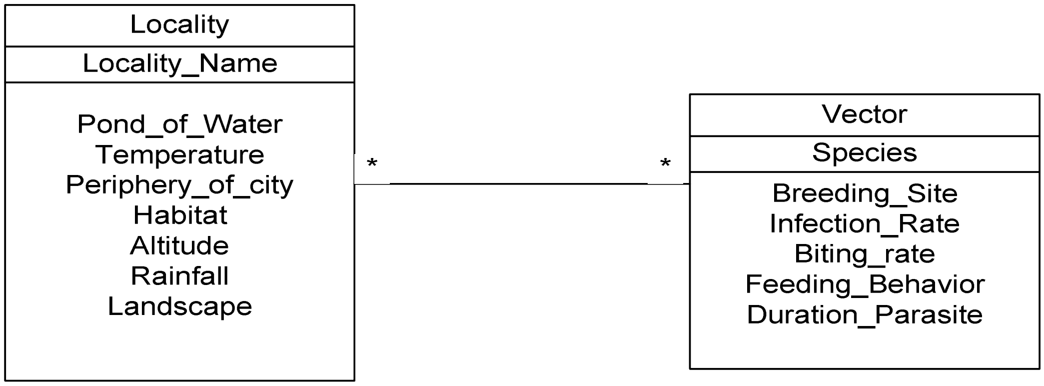

Figure 2. Class diagram.

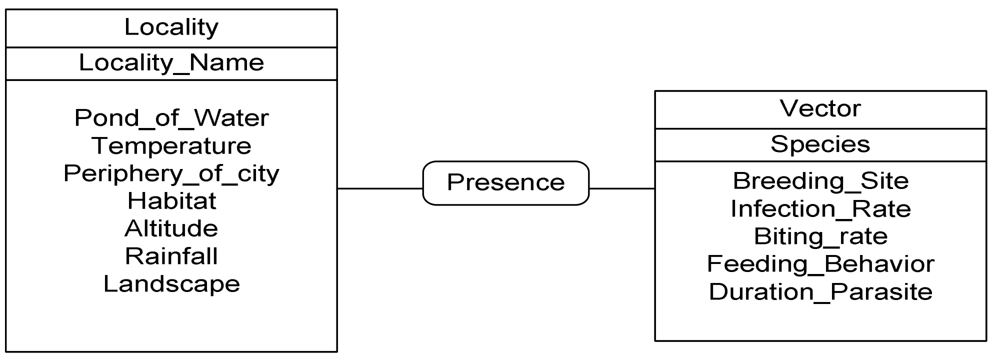

Figure 3. Entity relationship diagram.

automatically. This is the case of MVC# framework which automatically establishes links between views and corresponding controllers.

Since there are multiple controllers, the MVC pattern allows any number of controllers to modify the same model. The GIS, the DBMS and the ES are considered as the whole model. The dictionaries of the GIS, the DBMS and the ES are merged to create a single dictionary.

Interfacing GIS, DBMS and expert system

Interfacing a GIS, DBMS, and ES is a known exercise. In this prototype, the concern is to navigate through views generated from the interfacing of the GIS, DBMS and the ES. Generally speaking, operations that represent different working situations to the user should be kept in different parts of the user interface. The user interface is designed with usability and ergonomy in mind.

Basic data

The basic data are constituted of data belonging to the GIS and the DBMS (Contensin, 2004). The UML (Unified Modeling Language) class diagram of this association is as shown in Figure 2 (Fannader and Leroux, 1999).

Locality is a GIS class while vector is a DBMS class. A locality can comprise breeding sites of a variety of mosquito types such as ponds, marshlands and streams. A mosquito type can be found in many localities as well as a locality can contain a variety of mosquito types. When translating this class diagram in an entity/relationship model the following schema is obtained (Figure 3).

Using the normalization theory, the relational schema shown in Figure 4 through the transformation of the many-to-many association is realized.

The relation presence can contain a specific attribute called abundance. This attribute is deduced from the ES. The attribute period indicating the season must be defined in this relation, because the abundance of vectors usually depends on the season.

Deduced data

Deduced data are produced by the ES and indicate the level of malaria transmission through many factors. This choice provides measured feedback to appreciate the rate of malaria transmission. The malaria vector situation in a locality is given in Table 1. The locality name and the species name constitute a composite key of the table. The ES works very close with the table to deduce knowledge. This knowledge is expressed as points in the deduced view, showing the rate of malaria transmission.

Some of the rules used in the ES to predict the rates are:

1. If a locality has no ponds and if its temperature is higher than 40°C, then the malaria transmission rate is weak.
2. If a locality has ponds, with a forest landscape, then the malaria transmission rate is strong.

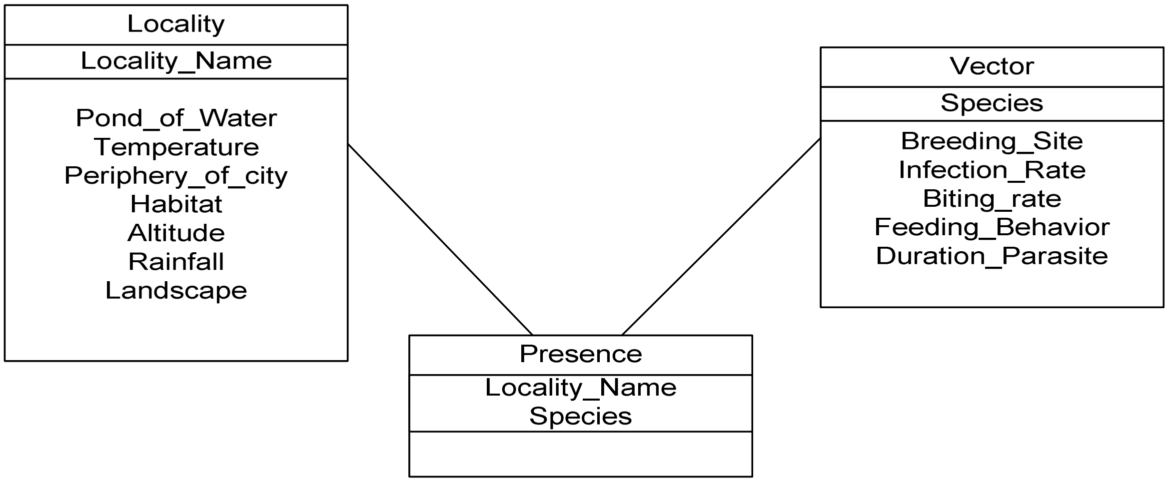

Figure 4. Relational diagram.

Table 1. Outputs explained.

Malaria transmission rate	Number of point
Weak	1
Average	2
Fairly strong	3
Strong	4

3. If a locality has an altitude more than 1000 m with an average rainfall, then the malaria transmission rate is average.
4. If the season is such that vector abundance is at its peak and the locality is urban, then the malaria transmission is fairly strong.
5. If the season is such that vector abundance is at its peak and the locality is rural, then the malaria transmission is strong.

Many other rules which belong to one of the categories aforementioned can be inserted in the ES. These rules are not visible to a user. The system administrator is the one in charge of handling them as he does for the DBMS and the GIS. The system administrator has as tasks to introduce rules and data in the system. The system is perceived as a mono-user system in its functioning but it is distributed.

In practice, problems can be found on environmental data concerning vegetation, land use, rainfall, temperature, and include:

1. The spatial scale of data may not be appropriate for many types of analyses (land cover may be appropriate for district-wide analysis but not for local/village analysis since small features such as ponds and localized wetlands may not be shown).
2. Weather data (rainfall and temperature) is not usually available at the scale needed for analysis, there are usually only one or two weather stations in a district and some parameters relevant to malaria transmission may not be measured at all, such as wind speed and direction which affects the vector-people interaction.

Solution

Generating the domain classes

Generating Java code: As in eclipse modeling framework (EMF) (Crane et al., 2006), two models, the ".ecore" and the ".genmodel" model can be created. Based on these two models, Java code is generated. So, the two domain classes, GIS class (Locality) and DBMS class (Vector) are generated in Java code. This creates the Java implementation of the EMF model in this application.

Review the generated code: The generated code consists out of the following:

1. Model: Interfaces and the factory to create the Java classe.
2. Model.impl: Concrete implementation of the interfaces defined in model.
3. Model util: The adapter factory.

The central factory has methods for creating all defined objects via createObjectName() methods.

Rule-based systems

Among the most popular rule engines, JESS (Java Expert System Shell) is probably of the most interest to Java developers. It is the reference implementation of JSR 094 Java Rule Engine API and it has plug-ins to support development of rule systems in Eclipse. It is helpful to introduce JESS and take a glimpse of its programming syntax. JESS is software that interprets rules and facts expressed in its programming language. Just as Java is a language for expressing objects and Java compiler is software that interprets Java code, JESS has a language for expressing rules and facts and a compiler to interpret the code. JESS is developed in Java by Ernest Friedman-Hill at Sandia National Laboratories. Here is what

Figure 5. Map of Cameroon.

the rules and facts in our weather example look like in JESS code.

```
(defrule rule-1 (rainy-season) = > (advise-people malaria))
(defrule rule-2 (ponds-many) => (advise-people hygiene))
(defrule rule-3 (rainy-season) => (assert ponds-many))
(ponds-many)
(rainy-season)
```

The last two lines in the list are the two facts. The first three lines are the three rules. Rules in JESS take this form: defrule rule-name conditions => actions. Rules are defined using the defrule construct. Rule-1, rule-2, and rule-3 are the names of the rules respectively. Rule-1 has a condition: rainy-season. In this case, rainy-season is also called a pattern. It is so called because the rule engine treats it as a pattern for matching facts. The pattern (rainy-season) in rule-1 will match only one fact: The (rainy-season) fact in the last line of the code list. When it is matched, the action (advise-people malaria) of rule-1 will be executed.

RESULTS

The model in the MVC comprising a DBMS, a GIS and an ES contains factual, geographic and graphic data. The application allows a user to query the system and displays all those internal objects which become visual. The intelligence of the system is due to the fact that derived data converted to points are obtained with JESS Rule Engine, and returned through maps. The number of points indicates the rate of malaria transmission in a given locality. For prototyping, trial data stemming from studies in Cameroon are injected into the system to give the results. The trial data is not exhaustive as it is limited only to the test localities.

Global results

The application displays a map of Cameroon through its ten regions according to the SVG format. While clicking on a region, the application may:

1. Perform a zoom. This operation is applied to the GIS. It represents one view of the MVC pattern. We call it geographic view.
2. Permit a user to enter the locality name as a parameter.
3. Display information on the locality and the vectors concerned.

Geographic view- geographic controller

The map of Cameroon according to the SVG format is divided in ten SVG files, each file corresponding to a region as follows: Adamawa.svg, Centre.svg, East.svg, Extreme-North.svg, Littoral.svg, North.svg, North-West.svg, West.svg, South.svg and South-West.svg (Figure 5). For each region, an SVG code is written that delivers a zoom on the region.

Deduced view- deduced controller

The malaria transmission rate is the relationship between the vector density contained in the Table 1 and some specific factors of the locality. JESS is used in this view as a rule engine for the Java platform; it is a superset of CLIPS programming language.

Rather than a procedural paradigm, where a single program has a loop that is activated only one time, the declarative paradigm used by JESS continuously applies a collection of rules to a collection of facts by a process called *pattern matching*. Rules can modify the collection of facts, or they can execute any Java code. The JESS rules engine uses the Rete algorithm.

The malaria transmission rate is then determined. We adopt its graphical representation through a number of points as followings.

Basic view - basic controller

The PHP code infosRegionVectors sends the request to the DBMS. The result is analyzed and then is displayed.

Figure 6. Mosquito picture.

The vector section receives this information. Mosquito data are factual and the application may be extended to store image data in this regard. Figure 6 is general and is not particular to a type of vector.

Detailed results

Here, we present different functionalities of the application. The prototype is web-oriented. So, it runs with the perspective to be under the n-tier architecture.

The essential basic functionalities of the application are the following:

1. Create a new locality (or region) in the table locality of the GIS
2. Modify a locality (to modify its features).
3. Create a vector in the table vector of the DBMS.
4. Delete a vector from the DBMS.
5. Add a vector in a locality.
6. Delete a vector from a locality.

The main interface of the application is as shown in Figures 7a and b.

In Figures 7, the application shows a map of Cameroon in the section called map of Cameroon and the map of a region in the section map of region. When a locality is selected, features are displayed in the locality information zone. When a user clicks on a region on the general map of Cameroon, the specific map of that region is displayed. The user is asked to select a locality. For this example, the locality selected is Ntui, the divisional headquarters of Mbam-and-Kim Division in the Centre region of Cameroon. This region appears zoomed on, in the section map of region. The distribution of the different vectors of this locality also is displayed as well as features of this locality in the locality information zone. The user can also visualize the list of vectors present in this locality with their properties in vector zone.

In this example, the Ntui town presents average malaria transmission rate. This is the reason why two points are displayed at the left of the vertical arrow. On the right of the arrow corresponding to the East of Ntui, there are two localities with one point each displayed; the malaria transmission rate deduced by the system in these localities is weak. *A. gambiae* is the only vector species studied here.

Comparison

Here, we compare the results of a longitudinal entomological follow-up on malaria transmission dynamics conducted in the town of Mbalmayo, in the centre region of Cameroon (Antonio-Nkondjo et al., 2005). Sampling was also conducted in the village of Olama, not far from Mbalmayo in a rural environment. This study assesses the impact of urbanization and deforestation on local malaria vector populations and their effects on malaria transmission dynamics.

Mbalmayo is an urban area situated along the river Nyong, 50 km south of Yaounde, the capital of Cameroon. The village of Olama is situated 15 km south of Mbalmayo, downstream on the River Nyong. The climate is a typical equatorial, characterized by two rainy seasons extending from March to June and from September to November. Average annual rainfall during the study period was 1600 mm. The average minimum and maximum monthly temperature recorded by the national meteorological services ranged from 18 to 25℃ in July to 20 to 29℃ in March.

In Mbalmayo, *Anopheles gambiae* was the most anopheline species caught throughout the survey period (Figure 8). The HBR (human biting rate) was 11.3 bites/person/night for *A. gambiae* varied with the season. The maximum HBR was 27.8 bites/person/night.

As Ntui town in our study, Mbalmayo is an urban area within the equatorial forest zone. The average HBR is respectively 7 and 11.3. This is quite normal. The climate is sensitively the same, as the annual rainfall. Some differences depending on the season are observed at the temperatures side. Mainly in our work, we deduce the

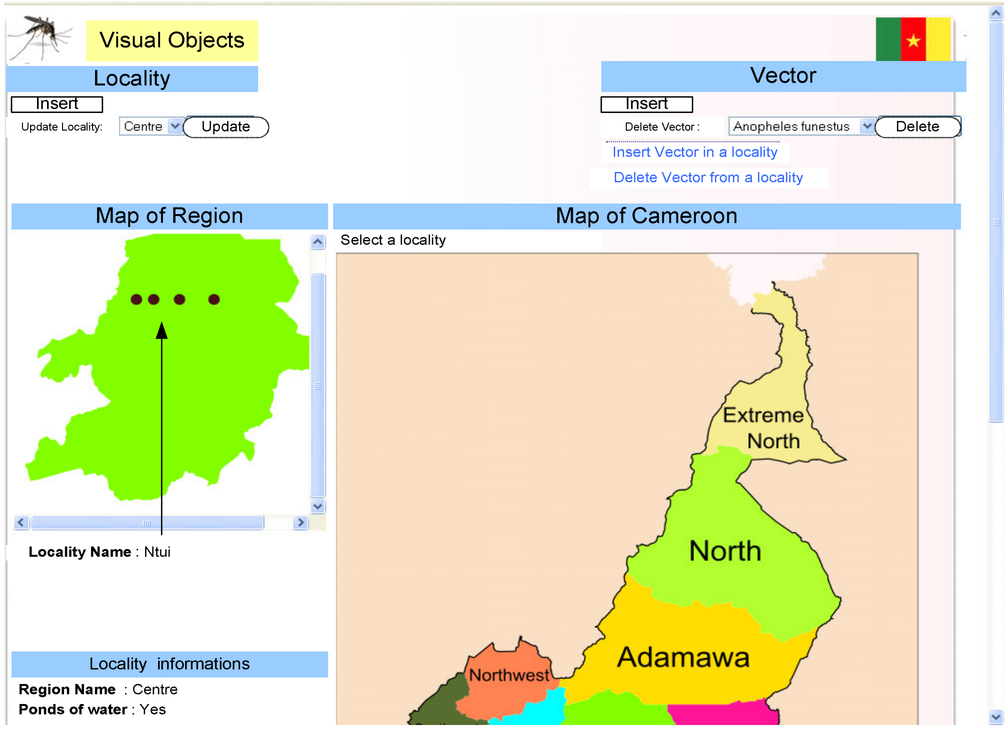

Figure 7a. Only localities information.

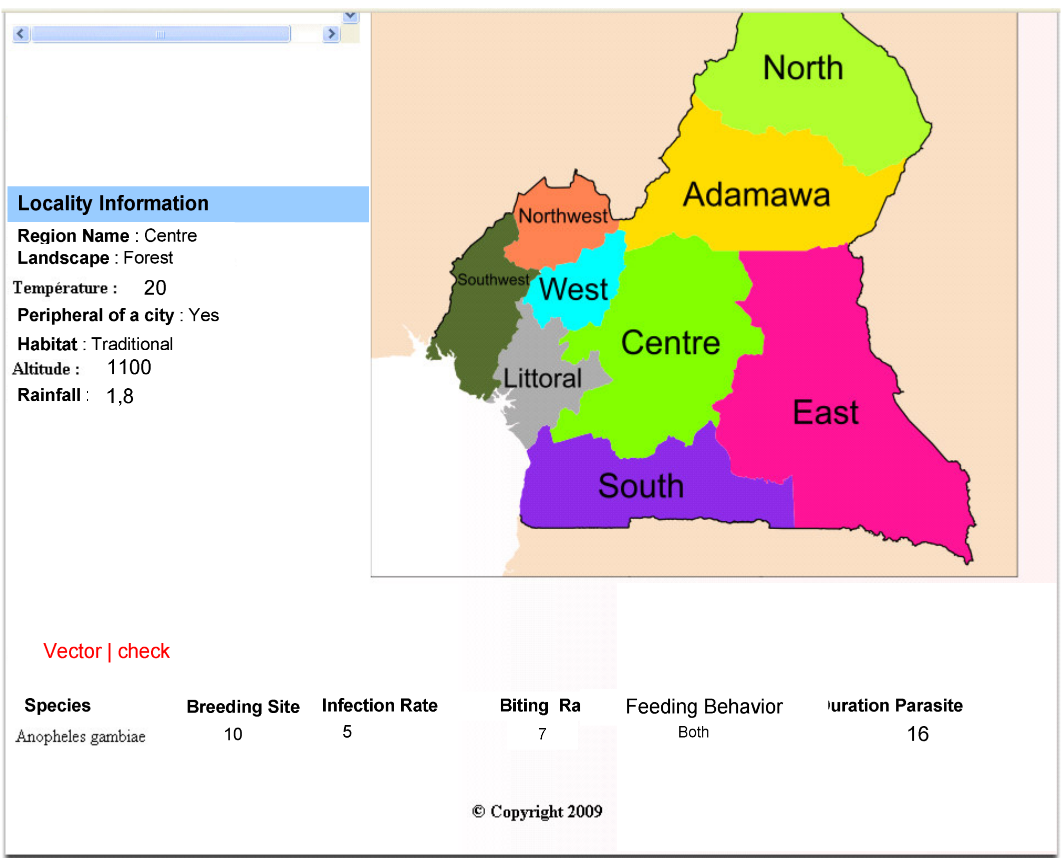

Figure 7b. Vectors information added

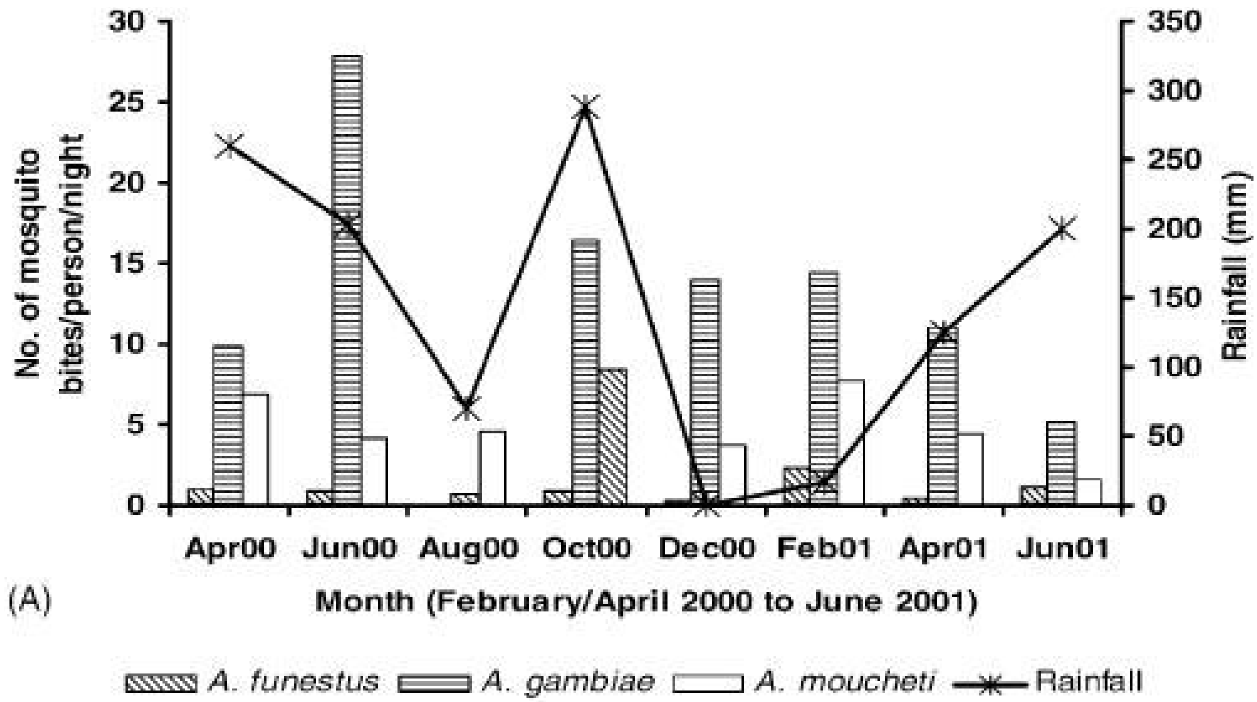

Figure 8. Rainfall and human biting rate for malaria vectors.

malaria transmission rate.

The results of the test for CSP (circumsporozoite protein) are shown in Table 2. They are infective rates *Plasmodium falciparum*. For *A. gambiae* in Ntui, the infective rate obtained by our system is 5%, whereas in Mbalmayo, the survey carried out in the current section gives 4.5%. In the nearby village of Olama, for *A. gambiae,* the CSP rate is equal to 10.8%. In our system the CSP rates in the localities at the east of Ntui were not calculated.

DISCUSSION

Maps generated by this application give indications on malaria transmission rate. The system analyzes parameters that determine malaria transmission. The peak season for the species is a period during which malaria transmission can be high. But in general, malaria transmission in Africa is a dynamic and complex system. Through this study, four levels of malaria transmission rate are established. It is an interesting factor in the fight against the disease. The risk of malaria transmission can be assessed in this consideration. This prototype can be completed with much more exhaustive data for the different stakeholders in the fight against malaria to use.

Conclusion

The lack of awareness on the part of communities to fight the malaria disease is one the most important issue in public health policies. Decision support systems or medical expert systems are created as an aid in decision making in health care.

The goals of such systems are to provide a methodological and accurate system that can mimic or model some aspect of health care knowledge. The system built in this paper gives an opportunity for decision makers to control the situation of malaria pandemic in the field in order to efficiently curb it. The system is intended to give visual information for a better understanding of the phenomena. The system is technically founded and obeys MVC patterns framework associating JESS environment. It displays graphically the malaria transmission rate in a qualitative approach expressed as points. The system may be extended by some functions like vectors spatial distribution, species identification, infected zones. Including a more exhaustive data set, developing the other functionalities previously listed will transform this prototype to a reliable application for malaria control.

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Table 2. CSP rates.

Location	Species	No. tested	Positive	CSP rate (95% CI)
	A. moucheti	299	4	1.3% (0.02-2.6)
Mbalmayo	*A. gambiae*	714	32	4.5% (3-6)
	A. funestus	44	2	4.5% (0.56-15.5)
	A. moucheti	4084	85[a]	2.1%(1.6-2.6)
Olama	*A. gambiae*	37	4	10.8% (1-2.6)
	A. marshallii	8	1	12.5%(0.3-52.7)

[a]Two were plasmodium malariae, all the rest were *P. falciparum.*

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