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Information Systems Step by Step Evolution Enforcing Object Constraint Language: Application to Malaria Control

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ABSTRACT
Insecticide resistance is one of the biggest threats to sustainable malaria control in Africa. Researchers are monitoring a worrying development for malaria-control efforts: the rise of insecticide resistance in mosquitoes in the region. Strategies to address the problem of insecticide resistance and to mitigate its effects must be defined and implemented. Information systems (IS) must evolve so that they are internally dynamic and every decision is important to the smooth flow of their operations. The aim of this paper is to study IS evolution in malaria control domain using Object Constraint Language (OCL). The application is related to insecticide resistance determined in various regions of a country. Making effective decisions depends on timely access to information about events and circumstances conducting to variation in resistance level.

Key Words: Malaria vectors, Object Constraint Language, Insecticide resistance, Information system evolution

INTRODUCTION

Insecticide resistance in malaria vectors is a major concern in countries where vector-borne diseases are endemic [1]. The emergence of insect resistance to insecticides may decrease crop productivity. With a long history of crop spraying, malaria vectors, mainly the deadly *Anopheles gambiae*, have developed increasing resistance to dichlorodiphenyltrichloroethane (DDT) and pyrethroids [2]. Control of *Anopheles* mosquitoes relies mainly on the use of pyrethroid-impregnated bednets and there are fears that the emergence of insecticide resistance will compromise their efficacy. Researchers found that the disease may be rebounding because the insects are becoming resistant to the increasingly resistant to insecticides. The rise in cases seemed to mirror the increasing proportions of malaria-carrying mosquitoes resistant to deltamethrin. DDT is one of the most well-known synthetic pesticides. It is used for indoor residual spraying in many countries. The four other insecticides can be added to the list: permethrin and deltamethrin (pyrethroids); bendiocarb (carbamate); and fenitrothion (organophosphate).

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It is not our goal to show if there could be marked variations in resistance levels between sites and collection seasons. For instance why deltamethrin resistance may appear to be a bit lower in frequency than permethrin resistance? Molecular analysis would identify the main mechanisms responsible and improve the detection and management of insecticide resistance in malaria-control programmes.

Our efforts consist to graphically represent steps that characterize trends of evolution in information systems (IS) in the resistance management. The evolution process is illustrated in a geographic information system (GIS). The insecticide resistance is observed in the field in order to provoke changes. Localities and periods constitute spatial and temporal constraints parameters. Resistance mechanisms are reported to update and monitor the system at every step and to entail IS snapshots.

This paper is organised as followings. After an introduction, the first chapter deals with IS evolution in terms of representation and the help of Object Constraint Language (OCL). The second chapter presents resistance management through data analysis and model elements. The third chapter is founded on the application results. The fourth chapter refers to software tools used for the system development. We finally conclude the paper.

I. REPRESENTING INFORMATION SYSTEM EVOLUTION

Information system (IS) evolution can be seen in two ways, planned and unplanned [3]. Planned evolution is the process by which strategic decision-makers work to determine the ways in which their information systems should develop over time. It involves issues of evaluating the impact and appropriateness of existing information systems; examining the value and 'maintainability' of legacy systems (ageing information systems that serve a purpose but are out of step with the needs or capabilities of the organisations that use them); decision-making about which changes to existing systems are appropriate; and understanding how future changes to the organisation's environment could require changes to information systems.

Unplanned evolution, by contrast, is a way of looking at changes within information systems that happen without them being intended by the 'owners' of those systems. The technology may change; the business needs may change; the people involved may change; the organisation may change.

This study is founded on both planned and unplanned evolutions because of pesticides use all over a country for cultivated crops and specification of devastating insects. Reports have mentioned the relation between public health or agricultural use of insecticides and the evolution of insecticide resistance in malaria vectors [4-5]. In addition to agro-industrial cultivation areas, market gardening areas, public health or personal protection, studies put forward forest exploitation sites (timber yards) as potential zones of insecticide resistance emergence in *An. gambiae*.

The evolutionary process can be triggered with pesticides campaigns throughout the planned evolution. However, large variability among gardeners in application dosages, the crop treatment cycles and the amounts of active ingredients used in the agricultural settings prevent quantitative analysis of the data. The unplanned evolution is launched when bomb sprays and coils containing insecticides with common active ingredients are mainly used for personal protection.

In what localities and in what time resistance situation is it to be clarified? The decision to introduce resistance measurements by software into the GIS should be determined by the need for information on pesticide resistance. The system must be able to determine how and when each step of the evolutionary progress takes place. The trick of deciding is staying ahead of the decision process by knowing what types of information are available and knowing the next action to be taken to bring that capability into the system.

The real world can be represented with Object Constraint Language (OCL). The Object Constraint Language is used to specify constraints on objects in the Unified Modeling Language (UML) [6]. It has the power (but not syntax) of the Lower order Predicate Calculus (LPC) plus simple set theory. Parts of the syntax seem to have been influenced by Smalltalk. The Object Constraint Language (OCL) is an expression language that describes constraints on object-oriented languages and other modeling artefacts. A constraint can be seen as a restriction on a model or a system. OCL plays an important role in the analysis phase of the software lifecycle. OCL is indicated to specify IS evolution because it can express side effect-free constraints. Thus, OCL has the characteristics of an expression language, a modeling language and a formal language.

II. RESISTANCE MANAGEMENT

II.1 Data analysis

Insecticide susceptibility data are analyzed according to WHO criteria: samples are defined as resistant if they showed less than 80% mortality; a mortality rate between 80-98% suggests reduced susceptibility but resistance needs to be confirmed, while mortality rates greater than 98% are indicative of complete susceptibility.

Figure 1. Anophele picture

There is evidence for intensive use of chemical insecticides for personal protection which may explain reduced susceptibility in some studied areas of South Cameroon. The level of resistance however, varies from one year to another, according to the proportion of the resistant S form in the populations where the two molecular forms of *An. gambiae* are found together.

For cotton area in North Cameroon, susceptibility is not reduced to DDT and pyrethroids. The controlled insecticide usage in agro-industry confirms values of susceptibility data. However when the domestic use is significant, the resistance level may grow.

II.2 Management system

The heart of object-oriented problem solving is the construction of a model. The model abstracts the essential details of the underlying problem from its usually complicated real world. The system is described with the Entity-Relationship model and then translated to UML class diagram. An interface is included to specify and visualize the relationship class Insecticide. OCL is then used in the meta-model. Preconditions are standard OCL constraints that can refer to arguments and the prestate of an operation. Postconditions can refer to arguments, the prestate, the result of a function, and the poststate of an operation.

- **@pre**: value of an expression evaluated in a prestate
- **result**: the value returned by a function call

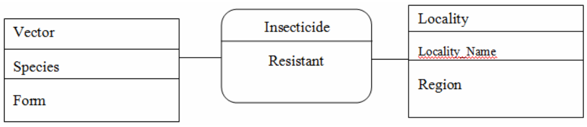


Figure 2. E-R Resistance Diagram

The application is built on component technology, visual programming, patterns and frameworks under the World Wide Web development. Specifications can also seek techniques to manage the complexity of systems as they increase in scope and scale.

Examples are about constraints on classes, but the same expressions are valid for components and other UML diagrams.

Resistance
- numInsecticides: int
+ getInsecticides(): List
+ acceptInsecticide(i:Insecticide)
+ removeInsecticide(i:Insecticide)
+ isInsecticideAccepted(i:Insecticide):Boolean

Interface Annotations

public class Resistance {

/** The Insecticides List contains
 * references to insecticides which
 * are registered with the resistance.
 */
private List insecticides;

/** Returns the current number of
 * resistant insecticides. */
public int getNumInsecticides() {…}
}

The usual laws of design by contract are followed with UML and OCL:

- preconditions may be ***weakened*** ('or' new clauses)
- postconditions may be ***strengthened*** ('and' new clauses)

Object Constraint Language Insertion

• **context** Resistance::acceptInsecticide(i)
pre: not isInsecticideAccepted(i)

• **context** Resistance::acceptInsecticide(i)
post: isInsecticideAccepted(i)

• **context** Resistance::acceptInsecticide(i)
post: getNumInsecticides() =
getNumInsecticides()@pre + 1

Object Constraint Language Removal

• **context** Resistance::removeInsecticide(i)
pre: isInsecticideAccepted(i)

• **context** Resistance::removeInsecticide(i)
post: not isInsecticideAccepted(i)

• **context** Resistance::removeInsecticide(i)
post: getNumInsecticides() =
getNumInsecticides()@pre – 1

OCL 2.0 supports messages. Messages can be sent to objects, and correspond either to *operation calls* or *signals* in a UML model. A signal is yet a stereotype but it is a class (with attributes, operations, etc) that represents communication. A signal will be instantiated (with values for attributes) and can generate state transitions in its recipient. The signal in the application is the trigger of IS evolution.

Here are examples of signal: InputEvent, MouseButtonUp, MouseButtonDown, etc.

III. RESULTS

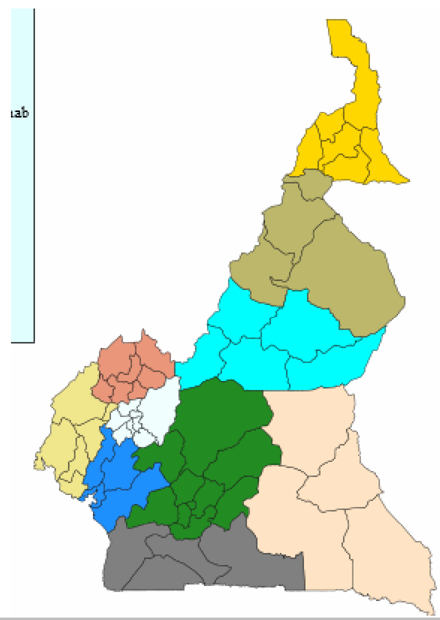
To specify that inter-object communication has taken place in the IS, the *hasSent* operator ^ can be used as follows:

context Subject::hasChanged()
post: observer^update

The *hasSent* results in *true* if an *update* message with the specified arguments was sent to *observer* during execution of the operation.

Information system step 1

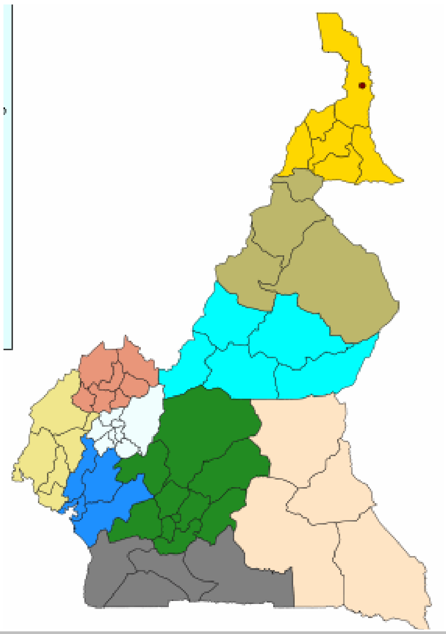
There is no resistance on the field. The resistant insecticides list is empty.



Initial Step with zero resistance

Information system step 2

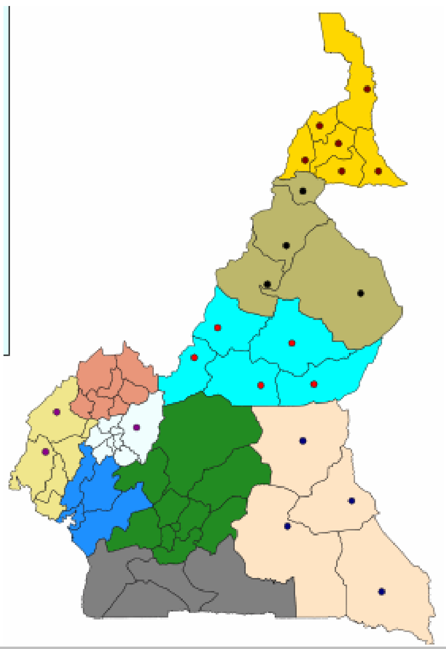
The resistance in regions level is displayed. It concerns at least one pesticide in the list as far as mosquitoes in the area are considered.



Resistance in Logone-and-Chari Division (Extreme-North Region)

Information system step number 3

The resistance is represented all over the country. This step corresponds to the fact that mosquitoes are resistant for at least one of the pesticides used. Vectors names or pesticides names are not mentioned. The important point is to present areas in the country where resistance occurs, so that the situation requires interventions.

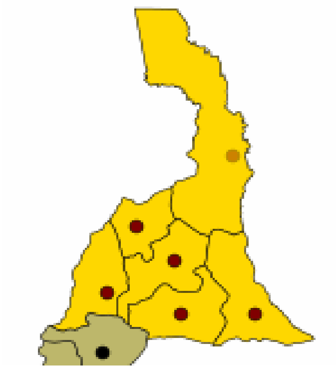


Resistance nationwide

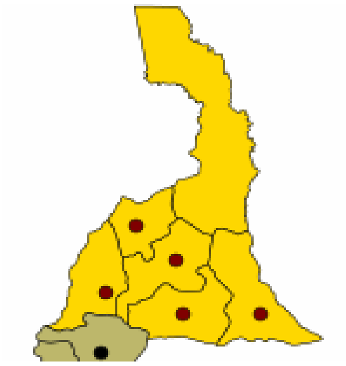
Information system step number 4

This step is attached to decision makers' initiatives when they take measures to fight against resistance phenomenon. The application allows the removal of pesticides source of resistance, because actions have been taken on the field.

The withdrawal of resistance in an area is performed when the resistant pesticides list in that zone becomes empty. The area where resistance is to be suppressed is double clicked.



Preparation of resistance suppression (Before double click)



Resistance suppression (After double click)

IV. SOFTWARE TOOLS

Among tools are PostgreSQL, PostGIS, Php, Javascript, Ecmascript, Html, Ajax [7].
PostGIS is an extension to the PostgreSQL object-relational database system that allows GIS objects to be stored in the database. In effect, PostGIS "spatially enables" the PostgreSQL server, allowing it to be used as a backend spatial database for GIS. Geo-data and application-data are inserted, updated and deleted with PHP scripts. PostGIS layers are also displayed in svg format.

Ajax code for the resistance visualisation

```
function saveResistance(phpFile)   // Resistance visualisation
    {

        var XMLHttpRequestObject = false;

        if (window.XMLHttpRequest) {
            XMLHttpRequestObject = new XMLHttpRequest();
        }
        else if (window.ActiveXObject) {
            XMLHttpRequestObject = new ActiveXObject("Microsoft.XMLHTTP");
        }

        if(XMLHttpRequestObject) {
            XMLHttpRequestObject.open("GET", phpFile + "?resistance=" + window.parent.insertResistance);
            // Resistance reinitialisation
            window.parent.insertResistance = "";

            XMLHttpRequestObject.onreadystatechange = function()
            {

                    if (XMLHttpRequestObject.readyState == 4 && XMLHttpRequestObject.status == 200) {
                            var reponse = XMLHttpRequestObject.responseText;
                            alert("Visualisation done");
                    }
            }

            XMLHttpRequestObject.send(null);
        }
    }
```

PHP code for insertion in Resistance table

```
<?php
        $resistance = (( isset($_GET["resistance"]) )? $_GET["resistance"]: "");
        // If there is resistance
        if($resistance != ""){
                // DB Parameters
            $pg_host = "localhost";
            $pg_database = "cameroun";
            $pg_user = "postgres";
            $pg_password = "password";
            $pg_srid="-1";
            $db_handle = pg_connect("host=".$pg_host."
                                        dbname=".$pg database."
                                        user=".$pg_user."
                                        password=".$pg_password."");

            $resistance_table = "resistance";
            // resiatance attributes are concerned

            if(eregi(':',$resistance)){
                    $split_resistance = split(':',$resistance);
            }
            else{
                    $split_resistance[] = $resistance;
            }

            for($Iter = 0;$Iter< count($split_resistance);$Iter++){
```

```
                // Resistance variables    (region, x, y, rayon)
                $one_resistance = split(';',$split_resistance[$Iter]);

                $data["province"] = $one_resistance[0];
                $data["x"] = $one_resistance[1];
                $data["y"] = $one_resistance[2];
                $data["r"] = $one_resistance[3];
                $data["type"] = $one_resistance[4];


                // Resistance insertion query

                pg_insert($db_handle, $resistance_table, $data);

        }

        pg_close($db_handle);   // Connexion closing

        echo "Insertion achieved";
    }

?>
```

CONCLUSION

Populations of insects can become resistant to any insecticide, according to insecticide usage for agro-industry or personal protection. In many sites, agricultural settings and human practices are sustained by pesticide application. The choice and usage of chemical compounds depend on cultivated crops and specification of devastating insects. The system presented in this paper reflects current web trends and challenges for effective monitoring. Topics include site management, updating databases, GIS interfaces development, monitoring and co-monitoring IS evolution assessments.

The implementation underlines the variability in the resistance level of *An. gambiae* s.s from southern Cameroon to the first-line insecticides currently used for its control. It also highlights the dynamics of *An. gambiae* s.l susceptibility to insecticides in northern Cameroon. In the absence of a malaria vaccine, prevention and control measures will continue to look at the ability of current insecticides to minimise resistance. The steps of management system can respond to insecticides resistance.

In perspective, we must dress an insecticide resistance map which can vary from one period to another in the year, and from one locality to another. IS evolution in this case should be more complex and determine the awareness of insecticide resistance.

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