An Architecture Supported by Georeferenced Services and Ubiquitous Computing for Controlling of Mosquito Aedes Aegypti Focus - Case Inhumas, Goiás, Brazil

Alisson Rodrigues Alves
Department of Computing
Federal Institute of Education, Science and Technology of Goias (IFG)
Inhumas, Brazil
alissonralves1@gmail.com

Rodrigo Cândido Borges
Department of Computing
Federal Institute of Education, Science and Technology of Goias (IFG)
Inhumas, Brazil
rodrigocand@gmail.com

***Abstract* —** *The cases of infections, hospitalizations and deaths from dengue in the world represent a scenario that involves a series of public policy. Among the hosts of the disease tropical countries, Brazil stands out with high levels of potentially alarming cases, mainly due to its environmental and social conditions favorable to the proliferation of the mosquito Aedes Aegypti. Given scenario, this paper presents the development of an architecture supported by ubiquitous and georeferenced technologies to assist in monitoring and epidemiological control of Dengue. This proposal provides a history of the incidence of monitored areas, allowing community health workers and others involved obtaining metrics for policy making and social control. The elaboration of maps and reports with important information about potential focus is also featured, culminating in greater agility and precision to the endemic identification process.*

Keywords— dengue; georeferencing; mobility; ubiquity

I. INTRODUCTION

Dengue is a major public health problem in the world stage, requiring special attention due to their relevant indices of infections, hospitalizations and deaths [1]. The World Health Organization (WHO) estimates that annually occur approximately 80 million cases. Brazil is highlighted among the countries with high rates of infestations, in function of its environmental and social conditions favorable for the proliferation of the mosquito *Aedes Aegypti* (which transmits the illness). In a survey conducted by the Ministry of Health of Brazil (MHB), at the beginning of 2013, 983 Brazilian cities showed growth in the proliferation of mosquitoes, and according to the Levantamento de Índice Rápido de Infestação por Aedes Aegypti (LIRAa) or Survey of Fast Index infestation by Aedes Aegypti (performed to identify the location of concentrated focus in the country), in January 2013, 487 countries entered into alert scenario.

Considering the potentiality of illness and its alarming growth, still lacking systems and tools to assist in monitoring, mapping and control of the focuses in the country. Grounded this troubled developed a software architecture supported in georeferencing (Global Position System) technology for GPS and ubiquitous computing.

The georeferencing services allows analyzing the geographic information of the terrestrial globe making it their known coordinates in a given reference system[2]. Therefore, after the geoprocessing (computer processing of geographic data) the system is able to provide resources for the preparation of maps and reports with important information about dengue by guiding community workers on the profile of the area *in loco* through its historical incidences.

Beyond the georeferencing technology, also has inert to this proposal technological lines of mobile and ubiquitous computing, contributing as accessibility and data distribution. Historically the idea of mobile computing that emerged the needs for users to be able to move with their personal computers keeping some connectivity with other devices, nowadays culminating in varied patterns and models for wireless connections (WiFi, Bluetooth), supporting the evolution of devices as tablets, smartphones and others [3].

Regarding ubiquitous computing, the term was first used by the scientist Mark Weiser of XEROX Park, in his paper "The Computer for the 21st Century [4]. This concept could follow with further technological advances occurred in device miniaturization and wireless networks. The vision of ubiquitous computing is that computing moves out of the workstations, becoming pervasive in our daily lives. If back then of mainframes we had "a computer for many users" with mobile devices have the concept of "one user to multiple computers", assessing each person to have a computer at work, at home and embargoed in mobile phones, household utilities, automobiles, among others. However, not just multiplies the number of stations and their ways, but also the way they carry out different tasks, resulting in an embedded computing in various units present in portable equipment.

Given the aforementioned development technologies, the system favors the monitoring of dengue focus through mobile devices that run autonomously, providing real-time information

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to community health workers. The survey database is performed with the aid of the computer system in order that the present process is customarily done manually and slowly. The tool provides epidemiological information on the vector with greater speed and accuracy, and thus can contribute to development of public health policies to combat dengue, allowing the preparation of an educational policy in the regions georeferenced recurrings.

In addition to this introductory section, the remainder of this paper is structured as follows. Section II presents theoretical references used for developing the architecture proposed in this study. Section III describes the research about related work. Section IV shows the development and evaluation of the architecture. Finally, in Section V are approached the conclusions and future works.

II. THEORETICAL REFERENCE

A. The Dengue

Dengue is a viral disease transmitted by the mosquito *Aedes aegypti* and *Aedes albopictus* infected with one of four serotypes of dengue virus, known as DEN-1, DEN-2, DEN-3 and DEN-4. The virus belongs to the family Flaviviridae, genus flavivirus and is rated in the scientific community as an arbovirus, in other words, transmitted by arthropods [5]. The manifestation gives four ways: undifferentiated fever, dengue fever (DF- classic dengue), dengue hemorrhagic fever (DHF) and dengue shock syndrome. Compose your symptoms: vomiting, diarrheas, red stains in the body, moderate slight fever, incapacitating high fever, severe headache, pain behind the eyes, muscle and joint pain, rash, gingival bleeding, nosebleeds, gastrointestinal bleeding, hematemesis, melena, hematochezia, hematuria, and increased menstrual flow.

His greatest occurrence is comprised between countries with tropical climates, as shown in Figure 1, however, is not only restricted to these, according to the World Health Organization, in 2013, the disease was present in 125 countries, striding to a possible global pandemic, with the potential to reach 80 million cases annually, approximately 550 thousand patients require hospitalization and 20 thousand die as a result of dengue. Alarming and significantly greater numbers than other ailments such as malaria, also transmitted by mosquitoes and high notoriety.

Fig. 1. Countries or areas in the world at risk of dengue transmission

In Brazil, the scenario of the incidence of the disease covers the entire national territory. His glance is during the months of December and May, result of sunny summer combined with the increase of rainfall (rain) and heat, ideal scenario for the increase of Proliferating firearms. Figure 2 illustrates the classification of the severity of occurrences in accordance with the respective months of the year.

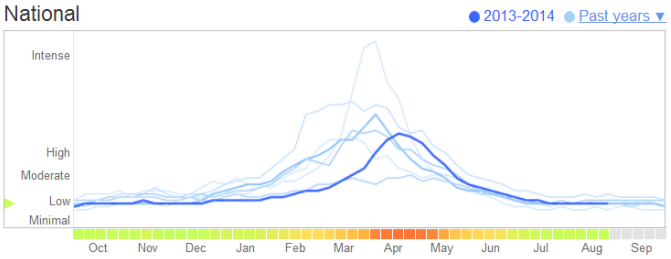

Fig. 2. Trends in the intensity of dengue in Brazil. Source: http://www.google.org/denguetrends/intl/en_us/br/#BR. Last acess Aug/2014

Situated in the Midwestern region of the country, near the federal capital of the union, state of Goiás, has 246 municipalities and estimated at 6,434,048 inhabitants population [6]. The state stands out for having three of the ten cities in the ranking of infestations dengue in the country, namely: Goiânia, capital of the state, Luziânia and Aparecida de Goiânia [7]. Nevertheless, due to its proximity to the capital, about 40 kilometers away, there is the city of Inhumas where is the scenario research and case of study of this work, because of the level obtained in Infestation Rates Index or Índice de Infestação Predial (IIP) was performed with the value of 1.1 in the months of January and February 2014, considered the case a warning to the population.

Inhumas is an inland city of state of Goiás, with the territorial extension of 613.226 km ² and 50,736 inhabitants [6] located at coordinates: latitude: 16 ° 21 '28 "S, Longitude: 49 ° 29' 46" W and 770m altitude. The city's climate by being in the state of Goiás is predominantly tropical, with striking division two seasons during the year: summer wet in the months from December to March, when the growth of outbreaks and dry predominant winter from June to August. The average temperature varies between 18 ° C and 35 ° C, with a significant temperature range, varying according to the prevailing regime in the Central Plateau.

B. Web Services

Web services consists of an interface composed by a set of operations (services) programmable that can be used or consumed by a customer via Internet. The operations in a web services are provided by a variety of different features, such as: objects, programs or databases. A web service can be hosted and managed by a web server to aggregate web pages or can be a service totally separated [8].

Among the features of web service, it is worth mentioning that the technology provides interoperability for different platforms to communicate and exchange information with each other. The guarantee of transparent communication that occurs between the platforms, for example, a Java application

consuming a service implemented in PHP language, is the result of the universalization of protocols that allow clients access operations on the interface of a web service by means of requests and responses formatted in XML, eXtensible Markup Language. The information is often transmitted via HTTP or HTTPS [9].

C. *Operating System Android and Applications*

Android is an Operation System developed by Google Company, maintained by the Open Handset Alliance (OHA), Linux-based, open source, objectified for mobile devices. The applications developed for this platform using the Java programming language, programmers facilitator factor because it is a widespread and comprehensive to mobile development, web and desktop language.

The development and implementation of the system compatible with Android mobile devices increase the range of application of the device and allows the user to multiple compatible devices such as mobile phones, palmtops, smartphones and tablets portable application. It is noteworthy that the development and operation of applications developed for the operating system in Java, it is also necessary to use XML markup language. Markup language is an aggregate of codes that can be applied to data or texts to be read by computers or people [10].

The choice of this platform for the development of the project was due to the massiveness of users, in 2014, the operating system reached the milestone of over one billion users worldwide.

III. RELATED WORK

Developed in the state of Rio de Janeiro, Brazil, Dengue Monitoring software aims to facilitate data capture visits by health workers. The system was developed using the C # programming language, with the framework .net and SQLServer database. The exhibition the web system is through browsers Internet Explorer, Google Chrome or Mozilla Firefox, while its mobile version is aimed at the Windows Mobile operating system. Despite being a solution geared to public health, the use of proprietary software requiring licenses for use becomes a barrier to its use in other localities or cities [11].

Another approach that aims at monitoring Dengue is named SIG-Dengue. Implemented in the state of Paraná, Brazil, the solution is at the basis of geographic information systems for monitoring and control of dengue. The approach employs as variables to study the spatial data analysis with the incidence of disease vectors through environmental, socioeconomic data and meteorological data of the region. The technologies adopted for its implementation consists in importing electronic spreadsheets fed the information collected in the field subsequently inserted into Access database from Microsoft, allowing then manipulate and model the spatial data in GIS[12].

The Observatório Nacional da Dengue consists of an initiative for monitoring and control of dengue in the state of Rio Grande do Norte. The proposal is developed in a web repository for storing information collected by mobile application also developed in the research. Web development framework, the PostgreSQL database, the platform for Android mobile devices, the architectural pattern REST over HTTP, GPS and Google Maps API protocol: as methodological structures were used. [13].

MI-Dengue is commercial software for mobile devices developed by Ecovec. The system allows the control of traps to capture Aedes mosquitoes distributed in an urban area. The traps are inspected by agents of endemic diseases that inform the central via mobile devices, the amount of captures in each of them. The collected data are processed and made available at a specific site that georeferenced locations of vector infestation allowing classification of the types of serums found in the region georeferenced maps. The project was developed in partnership with the Federal University of Minas Gerais, UFMG, responsible for analyzing samples bio molecularly in identifying viruses found [14].

Software development and initiatives to control Dengue are not restricted to the Brazilian scenario. [15][16] Present case studies in regions with outbreaks of Aedes aegypti.

Although the work related goals are aimed at monitoring and control of Dengue, none of those tenders above depict your source for the correlation between environmental factors and disease incidence. The following section will present the modeling and implementation of the architecture theme of this work. Georeferenced data, technologies focused on ubiquitous computing and collecting sensory data objectify offer agents monitored endemics an environment rich in information, assisting in making public health decisions.

IV. ARCHITECTURE DEVELOPED

The architecture was developed in order to provide greater ease and simplicity of use to the user. Its operation consists in filling the data by the health agents in the mobile application. After this process, are automatically linked to the geographical coordinates of the featured along with environmental data such as temperature, rainfall, and others, obtained directly from an external access to web services of the National Institute of Space Research (INPE) for web services architecture to further enable the crossing of the information previously mentioned and successively storing the data in the database.

In parallel to this action there is a standalone module that constantly checks at intervals of 60 seconds the location of the agent and information when triggers detected an area of high incidence. Figure 3 shows a sequenced manner of 1-6, the operation of the architecture.

The system as a whole module mobile - web module can be used to solve the problem of manual data collection, and can thus be a tool of control, as shown in Figure 3. In it there are willing endemic agents and components that compose the whole system such: web services architecture communicating with the database for storage and also with the web services of INPE, which collect environmental variables. The logical

operating architecture is illustrated in the scenario. Worth highlighting the suitability of the architecture to the client / server model. *(See fig. 3)*

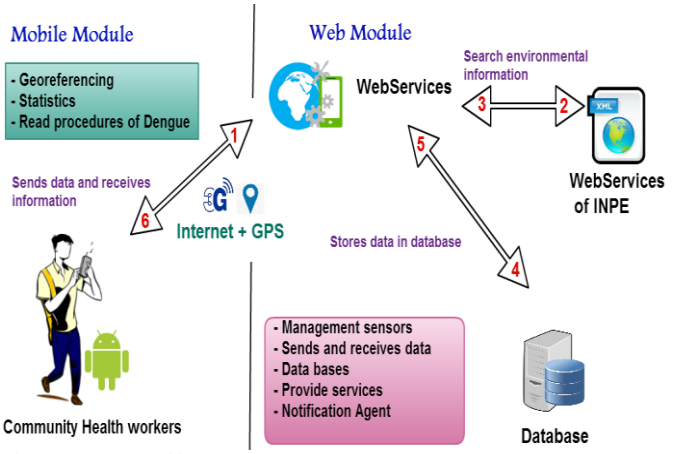

Fig. 3. System architecture

The architecture has two main modules: the Web Module (encapsulating web services) and Mobile Module (which aggregates the app for Android). Each module has its respective package groups, assigning specific functions to suit the functional units of the tool.

The previously mentioned packages consist of the following subdivisions:

- br.inhumas.comunication
- br.inhumas.statistical
- br.inhumas.managesSensors
- br.inhumas.georeferencing

The package *br.inhumas.comunication* represents the web module, composed of web services. It is responsible for containing the functions of communication, integration and control. Provides the application data through the methods to be consumed, they are, via. Xml or json object. The mobile application also sends the information via HTTP protocol using REST architectural pattern for insertion in the database to aggregate web services data.

The *br.inhumas.statistical* package is inert to the mobile module, responsible for managing the statistical information such as latitude, longitude, precision benchmarking, altitude, and other data that contribute to the control location for occurrences of focus. Besides this functionality, it is also contained interface for insertion of the procedures used to control focus by health professionals.

In *br.inhumas.managesSensors* package, in the present web module, collecting sensor data repositories available on the Internet by crossing them with focus recorded in the package georeferencing for later sent to the agent endemics occurs, allowing it to awareness so as real-time, about the characteristics of the area in benchmarking.

In *br.inhumas.georeferencing* package is located the components for editing and mapping, autonomic system functionality (automatic detection of the area to send their information) and resources for geographic orientation.

A. Adopted Technologies

For the development of the system exposed in this paper the following technologies to Mobile Module were used:

- Java IDE ADT Eclipse programming for Android programming, by allowing the graphical modeling of the mobile system interfaces.
- Google Maps API V2, Google project that provides resources for geographical mapping and manipulation of maps [17].
- SQLite database for Android mobile devices which are temporarily stored in the application data collected and later synchronized with the web service for no loss of data if a problem occurs in the Internet signal to impede synchronization with the web service.
- Global Positioning System (GPS) feature available in current smartphones.

Regarding the Web module, the respective technologies were used:

Programming IDE Java Enterprise Edition (EE) Eclipse (KEPLER) for programming web services in Java, for intrinsically contain the resources for its development. Figure 4 illustrates an excerpt from the call to the list of procedures in the web service.

```
13 @Path("/procedimento")
14 public class ProcedimentoResource {
15
16     @GET
17     @Path("/listarTodos")
18     @Produces("application/xml")
19     // @Consumes("application/json")
20     public ArrayList<Procedimento> listarTodos() {
21         return new ProcedimentoController().listarTodos();
22     }
23
24 }
```

Fig. 4. Method Web Serice in Java for listing procedures

- JavaScript Object Notation – JSON- format for exchanging data and widespread, universalizing of structured data that allow different platforms to communicate. It is a lightweight and easy to handle both for users and for computers that analyzes and generates standard to be consumed.
- PostgreSQL - the Database Management System Data-DBMS, relational database, which provides transactional integrity, high availability and support integration with programming languages like Java.
- GLASSFISH 4 - web applications Server, open source, maintained by the Oracle. Responsible for interpreting the pages in java web service.
- REST - A set of specifications defined on the HTTP / HTTPS protocol that allows patterning for communication between servers and applications, in

this research, web services and mobile application georeferencing. The technology provides scalability and flexibility in the format of the messages exchanged [18].

- HyperText Transfer Protocol - HTTP - transport protocol responsible for treating request and response messages between servers and clients on the Internet. The protocol also specifies the syntax (rules) for the exchange of information.

In order to present the mobile application, we highlight the interface georeferencing the right of Figure 5 and the left image the interface procedures for data collection dengue, encapsulated in the *br.inhumas statistical* package.

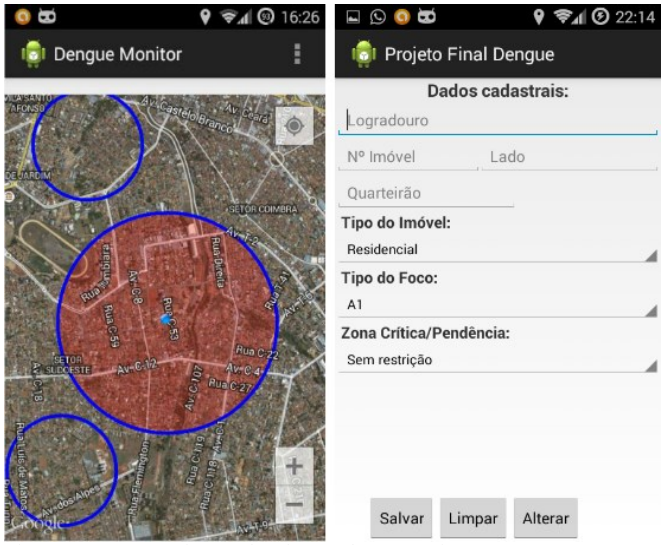

Fig. 5. Maps Georeferenced and Procedures Interfaces

B. *Evaluations*

To assess the architecture, initially the database and the Web module packages were installed and configured on a host server. Following the mobile application was installed in thirty-five mobile devices (smartphones and tablets) for analysis. Finally, questionnaires were applied to users collaborated to test the application.

It is worth noting that the requirements gathering and evaluation of proposal had the context of the city of Inhumas. Agentes area of municipal health cooperating effectively for the data reported here.

In questionnaires applied, issues that led each user to interpret the program in order to assess questions regarding their usability were guided. The questions were formulated addressing: the ease of use, layout, maps and efficiency. See Results in Figure 6.

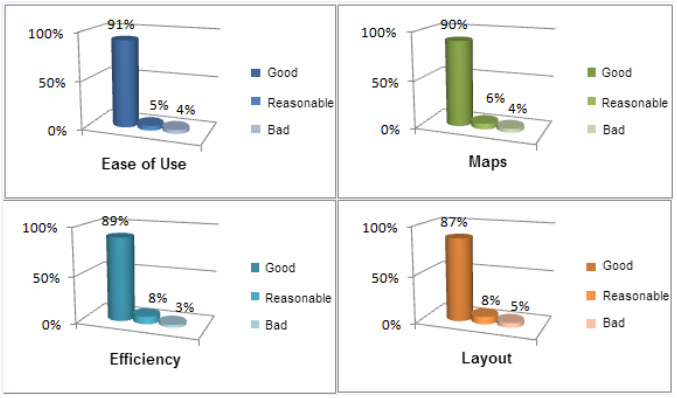

Fig. 6. Board of Results

Considering the ease of use, 91% rated as good, 5% and 4% as reasonable as bad. Figure 6 also shows related to other evaluation criteria data.

Another evaluation approach, that is vital to mobile devices, concentrated in power consumption of the GPS mobile application aggregate to the cellphone. In addressing about mobile computing, unsurprisingly there are limitations on the energy, might of its energy source and its computing resources [19]. Thereby, to measure such a premise, PowerTutor [20] it was used the software to obtain the images coming from the consumption in order to notice the energy application behavior.

Given the scenario of two minutes behavioral observation, results were obtained as presented in Figure 7 to the GPS activation intervals defined internally in th e automatic verification method, as follows: uninterruptedly (A), 30 seconds (B) and 60 seconds (C).The estimated consumption of GPS is highlighted in red, in highs in this figure. The smartphone used on tests was a Samsung Galaxy SII GT-I9100 model that possesses an energetic capacity of 1650 mAh.

Fig. 7. Intervals of the energy consumption of GPS: uninterruptedly, 30 seconds and 60 seconds, respectively.

After tests, was defined a 60-second intervals to the GPS measurement as the ideal scenario which yield given the operating voltage of 3.6V approximately after 14 hours running the application on the Smartphone. Such a proposition has

taken aiming to save the consumption of a scarce resource to portable devices.

V. CONCLUSIONS

The research presented is viable on its application by enabling the strategic management of public policies to fight focus of the mosquito Aedes aegypti, proposing to replace the current methodology adopted by the Secretary of Endemic City Inhumas for practical and reliable resources offered by mobile computing, resulting in reduced collection time, percentage of errors in relation to incoming data in the system and reducing rework.

Another point of great importance to report is related to the interaction of the application with the health worker, because the tool takes care of automatically control points autonomously and historical areas through GeoPoints defined in the system. The mobile application detects GeoPoints and calls to webservices information while waiting for the response, subsequently presenting historical focus, incidents and cases in a specific area of online manner. This perspective provided efficiency and acceptability health agents to be able to make people aware while performing getting data, feature not provided by other technologies.

The prominent technology also had available resources for the Crossing of variables sensors with information from cases to obtain prospect of possible future developments related to social environmental issues. The system as a whole demonstrated through questionnaires applied, based on the concepts of usability, with a strong tendency to accept in the use of everyday procedures as related to the quality of the maps, layout, efficiency and ease of use both obtained a grade higher than 87% as good.

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