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A System for Structuring, Storage and Georeferenciation of Dengue Vector Surveillance Data

Daniel B. F. Conrado[a], Vitor Ribeiro dos Santos[a], Alessandra C. Faria-Campos[b], José Carlos Serufo[a], Sérgio V. A. Campos[a]

[a] *Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil*
[b] *Instituto Nacional de Metrologia, Qualidade e Tecnologia – INMETRO, Brazil*

Abstract

Dengue is a main public health issue around the world and is an epidemic in Brazil. As part of the Brazilian national program to fight the disease, every municipality has a Zoonosis Control Center responsible for health and case surveillance, among other actions. The fieldwork includes routine visiting of houses and strategic sites (e.g. industries and vacant lands), water sampling, container elimination, and larvicide administration. However, the field data are gathered and summarized by hand. In this work, our goal is to ease the collection and visualization of field data to support decision-making. We have developed a mobile system to collect and georeference field data which could then be used to build geospatial and geo-temporal visualizations of indices such as House, Container, and Breteau[1] indices. This solution could enhance entomological surveillance and leverage action planning and evaluation.

Keywords:

Public Health Surveillance, Dengue, Information Systems

Introduction

Brazil has reported almost 1 million dengue cases in 2020 [7]. Being a tropical country where almost half of the population does not have proper sewage collection and treatment [5], fighting that disease is an arduous yet essential task. The country has an ongoing program called National Plan to Fight Dengue which aims at reducing the incidence of Aedes aegypti and Aedes albopictus, and the cases of dengue fever and dengue hemorrhagic fever. It comprises 10 components and two of them, case surveillance and vector surveillance, are operated by local Zoonosis Control Centers. One of their tasks is to map a region and its roads, passages, blocks, houses, churches, schools, empty lots, rivers, lakes, etc., and to assign a unique number to blocks and houses. Such activity is called Geographic Reconnaissance. The Zoonosis Center uses those maps as a basis for action planning such as visit plans, setting up a task force to clean a particular region, action targeting, and evaluation.

Despite the importance of having such accurate maps, up to this date the National Plan does not provide tools to facilitate that work, and most centers end up using regular paper and pencil to draw the maps and collect fieldwork data. The only tool to which the centers have access is a nationwide system to upload aggregated field data, like the number of house inspections, eliminated containers, and contaminated blocks. Summarizing the data is an error-prone time-consuming task since it is done manually. The problem could be better handled by using software tools to ease information storage and retrieval. A tool that could be adapted to this goal is a LIMS—Laboratory Information Management System.

A LIMS provides a way to structure and store complex laboratory data securely. It could enforce procedures and practices to guarantee the quality of the data. LIMS have been successfully used to manage dense biomedical data such as Genetically Modified Organism (GMO) experiments [1] and information of patients suffering from neuromyelitis optica disorder [2]. We believe that a LIMS is a powerful tool that could be used in the context of the Zoonosis Control Centers.

In this work, our objective is to model and implement the Center procedures as a LIMS and also to ease data collection and visualization. The system, called Flux-CCZ, is part of a solution that comprises three tools: a mobile app that field workers can use to collect granulated field data, a view system where managers can visually explore those data by building e.g. charts and choropleth maps, and a base system to organize and store the data and to interface with the National Plan's system.

Methods

The CCZ surveillance monitoring system was developed using the LIMS Flux. Using this platform, one can model systems as business workflows, in which every significant user action is modeled as an activity. The activities are linked together to assemble a flow specification that follows the domain logic. Every instance of the workflow is thus a particular flow that was followed by the user. One can think of an instance as one lab experiment, where a particular sequence of actions was taken (e.g. experiment planning, bacterium subculture, inoculation, and harvest). The Flux platform provides editors that enable the rapid development of such systems requiring little to no programming.

Although the dengue surveillance procedures were already established by the National Plan, we did not model them as is. Instead, we have strived for a system that not only is compliant with the plan but also addresses specific local needs, making it more purposeful. To accomplish that, we have adopted agile

[1] Breteau index: number of positive containers per 100 houses inspected.

practices to model the systems, which are good for eliciting and refining requirements. The Flux platform allows fast prototyping since it has built-in orthogonal functionalities like authentication, authorization, persistence, navigation, and reporting. It also is a web platform, so changes in requirements can be deployed almost instantly.

We have used loosely structured interviews with the Zoonosis Center staff to understand their needs and studied the official paperwork they use while in the field and when uploading data to the federal database. We then composed 10 user stories in which we outlined the user, the needs, and the values he/she would obtain if the needs are fulfilled.

The user stories we have composed unveiled needs that have been addressed by our solution. Some of them are simple, easily solvable problems that unfortunately hinder the Center's performance. The following list shows examples of such user stories:

- As a *fieldworker*, I want to record data from the houses of a block I have visited, so I don't have to manually summarize them.
- As a *fieldworker*, I want to classify some houses and establishments as problematic, so I can schedule a second visit to check whether dwellers have cleaned their properties as required.
- As a *fieldworker*, I want to know if water samples of the property I am visiting were collected in the past and whether they tested positive, so I can better adjust my course of action.
- As a *region supervisor*, I want to avoid the same property being visited twice by different fieldworkers, so I don't have to worry about data duplication.
- As a *manager*, I want to automatically consolidate weekly data, so I can efficiently feed it into the federal system.

The first deliverable was a LIMS prototype that represents the paperwork used by field workers. After delivering the initial version, the users tested it and began to share other specific needs and how they overcome the procedure limitations, as well as pinpointing corrections to be made to the workflow. It started then the refining process where the workflows are adjusted and tested again. The development process continues interactively, enabling the better understanding and refining of user requirements.

Results

The procedure we have modeled can be summarized as follows: every city region must be inspected every two months, forming a cycle; each cycle is divided into epidemiological weeks; each week targets a particular region or neighborhood, though large regions usually take more than one week to complete. Each region is divided by numbered blocks, which in turn is divided by houses and establishments. One or more fieldworkers are assigned to one or more blocks. During visits, a fieldworker performs a treatment, in which she may dispose of containers, collect water samples, take a pet census, administer larvicide, among other actions, and then fills the collected data into a paper form.

The conceptual model of the base system is shown as a UML class diagram in Figure 1. Each gray-colored class represents an activity, and arrow associations show how the workflow is arranged. First, a cycle is opened and epidemiological weeks are planned by the manager. A supervisor and a region/neighborhood of the city are allocated to one or more planned weeks. The supervisor in turn assigns fieldworkers to region blocks. The white-colored classes in Figure 1 represent a special kind of entity in Flux platform called record table, which serves as a repository of data that can be shared between activities and workflows. In Figure 1, there are three record tables, worker, region, and road, which stores worker data (e.g. name and position), region data (e.g. description and category), and road data (street name).

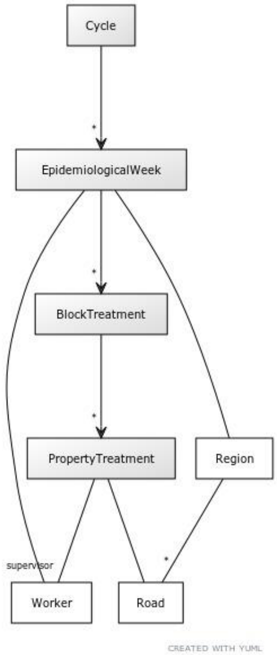

Figure 1– Base system's conceptual model as a UML diagram

In Flux platform, every cycle is shown as a rooted tree in which its nodes are the activities that were performed by the user. Figure 2 shows a screenshot of the system where the rooted tree is displayed on the left side panel and the activity data is presented on the main panel. All data in Figure 2 were arbitrarily generated. Parts A, B, C, and D are registered activities of a cycle, an epidemiological week, a block treatment, and a property treatment, respectively. Part E shows options to create activities of different kinds. And part F shows the data of the activity that is selected on the tree. Note that there are two block treatment activities under the selected one, and both of them are followed by property treatment activities (the ones under the second block treatment activity are hidden). Data from those activities

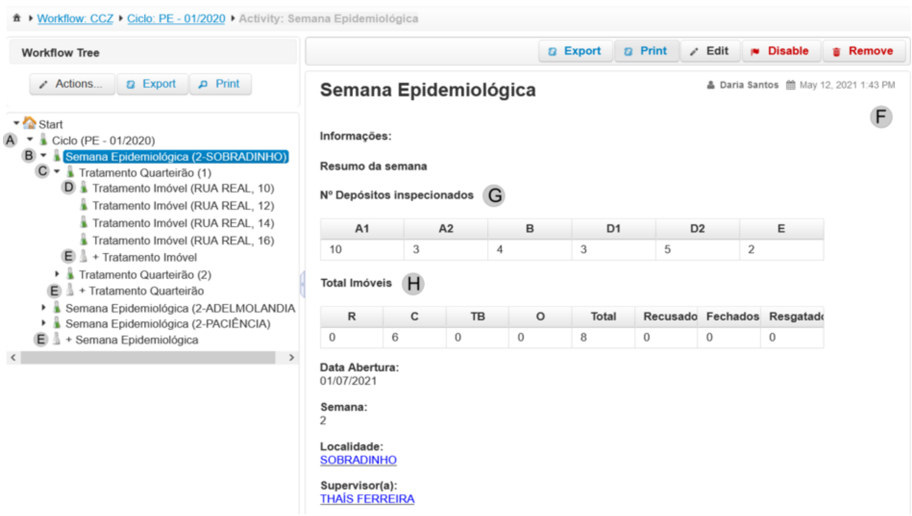

Figure 2– Screenshot of the base system showing a cycle as a rooted tree. The nodes represent epidemiological weeks, block treatments and property treatments that were entered. The main panel shows information of the selected node.

were aggregated and shown in two tables in the main panel (parts G and H). The table in part G shows how many containers were inspected during the entire epidemiological week. The containers are classified as: A1-elevated water tanks; A2-other water tanks; B-mobile containers; C-garbage containers; D1-tires and other rolling containers; D2-rubbish (plastic recipients, cans); and E-natural deposits. As for the table in part H, the properties are also summarized and classified as: R-residences, C-establishments, TB-vacant lots, and O-other properties. That view thus gives all the necessary information to fill a considerable part of the paperwork, saving hours that would otherwise be spent going through lots of paper sheets written by different people. Currently, we are developing a module that will enable the user to print reports that already are filled and in the required format.

The property treatment activity is a special activity since it is not meant to be created using the base system. Instead, those activities will be created by the fieldworkers using the *mobile app* while on field. The data entered in the app will be immediately transferred to the base system through Flux's REST API, allowing managers and supervisors to get updates in near real-time. Moreover, the collected data will also be georeferenced using the device's GPS function. The base system then will be enriched with data that could be used by the *view system* to plot thematic maps, enabling workers of the Center to view, for instance, the places that have been getting the most treatments along the year and whether their locations could reveal a pattern or a map of the regions with their respective Breteau indices. Such information could leverage action planning and targeting, as well as more efficient human and material resource allocation. The mobile app, which is still in development, has one important requirement in that it must be as lightweight as possible to run on low-cost devices. We are addressing that challenge by keeping the user interface simple yet complete and easy to use. Figure 3 shows a screenshot of the form that field workers will use to collect field data.

Figure 3– Screenshot of the treatment form implemented in the mobile app

Discussion

The literature has a variety of reports on using software technology to fight dengue. In [4], the authors developed a social media system for dengue prevention. An app is provided in which the user can report "breeding sites, symptoms and mosquito bites using […] social media such as Twitter". The information is then combined with computer simulations to build hotspot maps which then become available to health authorities. Gathering epidemiological data by community collaboration have been given promising results on monitoring disease outbreaks [8], and smartphone technology has leveraged what could be achieved by civic engagement; for instance, using Participatory Design, Lucena et al [3] have sketched a variety of apps that can be used to enhance disease tracking. Our solution also brings the power of smartphone mobility to disease surveillance, but additionally, the data collected could serve as official data, since it is systematically gathered by authorized health professionals.

Regis et al [6] propose an Aedes aegypti monitoring and population control system that performs spatial-temporal analysis of the mosquito's population. The data fed to the system are collected from georeferenced ovitraps distributed over the city. One advantage of that method is that it yields better population density estimates. This system can be used together with our solution as it serves somewhat different purposes. Our system digitalizes the routine procedures and also collects georeferenced data that could be used in combination with data from ovitraps. Also, our system captures particular user needs since it is built on Flux, enabling extensive and fast customization. For instance, in one of the user stories presented before, the user wanted to mark some properties as problematic. Using Flux, we can simply add a new boolean field to the form, and such information can be collected immediately, without putting the system down or performing any kind of database maintenance.

Conclusions

Dengue fever is one of the major health problems in Brazil and other tropical and semi-tropical countries. Coordinated actions must be routinely performed to mitigate the dengue transmission and propagation. Those actions need to be planned based on spatial-temporal epidemiological data to be more efficient.

We have presented a software system that allows the Zoonosis Control Centers to collect, georeference, store and visualize dengue surveillance data. The system models the official procedures for dengue surveillance as a workflow-based LIMS using the Flux platform while adapting the procedures to address user's specific needs. A mobile app that enables field workers to transmit field data to the system is being developed, as well as a view system that will be used to aggregate and plot georeferenced collected data in thematic maps. We hope the system will help the Centers be more productive, less error-prone, and able to plan actions more effectively.

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Address for correspondence

Daniel B. F. Conrado, danielbruno@ufmg.br. Departamento de Ciência da Computação, Universidade Federal de Minas Gerais, Av. Prof. Antônio Carlos, 6627 – Pampulha, Belo Horizonte, MG, Brazil.