National situation COVID-19 Costa Rica: an open source implementation for online map visualization

Situación nacional COVID-19 Costa Rica: una implementación de código abierto para la visualización de mapas en línea

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Keywords

COVID-19; Costa Rica; open source; map visualization.

Abstract

Geographic analysis tools have been used by the health sector for sanitary policy, epidemiological, surveillance and health promotion purposes. In order to track the COVID-19 pandemic, the Ministry of Health and the Technological Research and Innovation Laboratory (LIIT-UNED) of Costa Rica, launched a technological solution using open source software. The resulting web tool monitors the epidemiological behavior of the virus on a daily basis. The solution also serves to communicate epidemiological information of the virus to the general population. From April to September 2020, more than 200,000 people in more than 119 countries accessed the website. In this paper, we present the considerations of design, the workflows that followed for the implementation of the website, as well as a discussion of the type of Open Source solutions for working with geographic information systems in health.

Palabras clave

COVID-19; Costa Rica; código abierto; visualización de mapas.

Resumen

Las herramientas de análisis geográfico han sido utilizadas en el área de la salud para política sanitaria, vigilancia epidemiológica y promoción de salud. Con la pandemia de COVID-19, el Ministerio de Salud y el Laboratorio de Investigación e Innovación Tecnológica (LIIT-UNED) de Costa Rica, pusieron en marcha una solución tecnológica desarrollada con software libre para dar seguimiento al comportamiento epidemiológico del virus de forma diaria. La solución ha sido destinada para comunicar información epidemiológica del virus a la población general. Desde abril hasta septiembre del 2020, el sitio fue accedido por más de 200,000 personas en más de 119 países. En este artículo se presentan las consideraciones de diseño y flujos de proceso, que se siguieron para la puesta en marcha del sitio; así como una discusión de este tipo de soluciones de código abierto para trabajar sistemas con información geográfica en salud.

Introduction

In March 2020, The World Health Organization declared the coronavirus disease (COVID-19) outbreak a global pandemic due to its levels of spread and severity all over the world [1]. The contagion cases for COVID-19 were increasing rapidly, thus generating the need for efficient ways to communicate relevant and effective information in real-time.

Since then, many institutions and research centers have built information platforms to display relevant COVID-19 data for public use, for example pandemic map visualizations, mostly based on licensed software [2]. The first websites for COVID-19 geographic data were published by the John Hopkins University Center for System Science [3] and the World Health Organization site [4].

On March 6, Costa Rica registered its first COVID-19 case. The Costa Rican Ministry of Health chose to publish the data as part of its transparency strategy. To fulfill the requirements of an easy to maintain tool to make COVID-19 data available to the public rapidly, the “Situación

Nacional COVID-19" website was created as a new section of the already existing "Observatorio Geográfico en Salud - OGES" (Geographic Observatory for Health surveillance system). The official website was released on March 25 on geovision.uned.ac.cr/oges.

After that, many institutions in Costa Rica have developed their dashboards consuming the official information provided by OGES, including, The School of Geography at the National University, Geotecnologias (a geodata based business), and The National Emergencies Commission. Most of them were built based on licensed software.

"Situación Nacional COVID-19" web site became the main data source not only for visualizations but also for research and analysis by scientists and specialists in the subject. More than 200,000 people accessed the site in 4 months. The visits were recorded from different countries, being particularly important during June and July of 2020 when Costa Rica's cases started to rise.

In this paper, we will discuss the approach taken in Costa Rica by the Ministry of Health and Technological Research and Innovation Laboratory (LIIT) at UNED, considering the point of view detailed below.

GIS and Health

Medical GIS can be as old as antique civilizations. Early examples can be traced back to the English cholera epidemic in 1831 when Dr. Robert Baker mapped the incidence among the densely populated areas. Another example with cholera as well was made by Dr. John Snow. He mapped the deaths of Cholera disease in London in 1854 and is considered a precursor of epidemiology [5].

In fact, one of the earliest maps linking place and health was a visualization of 1964 on plague containment in Italy [6]. Geographic understanding of infectious diseases has been recorded with several diseases such as influenza, yellow fever, and cholera.

Furthermore, Medical geography had a strong influence on Jacques M. May who in the mid-20th century emphasized that diseases are a result of pathological and geographical factors. Then, from the 1960 to 1980's computer programming and analysis started to be applied in the field. Finally, in 1980 "attribute data" emerged. This allowed linking spatial and non-spatial data, enhancing the studies with the incorporation of more variables for research, policymaking or monitoring purposes [5].

Medical geography made a transition in the 19th and 20th centuries from a descriptive discipline to a more analytic one. The study of medical geography and spatial epidemiology has strengthened since then. Many of the applications are focused on the study of disease clustering, incidence, and prevalence. It also has been used in the surveillance and monitoring of diseases and health policies. It is also used to study other aspects of health like poverty, access to health, and other demographic indicators. An overview of these components as a whole can provide a lot of information about the disease and its social aspects [5].

COVID-19 maps

Mapping and GIS have long been considered as a tool to track and combat contagion. That explains how with SARS-CoV-2 several dashboards and applications were created to make disease information available to the public. Most of these tools, even though they are focused on map-based visualizations, provide panels with information and statistics. They are updated in real-time putting decision-making as a priority for the audience. Some examples are [6]:

- Johns Hopkins University Center for Systems Science and Engineering dashboard: map-based dashboard developed with Esri ArcGIS online service

- **The World Health Organization dashboard**: map dashboard made with ArcGIS Operations Dashboard for COVID-19.
- **HealthMap**: analyzing and mapping online informal sources: HealthMap is a software run by epidemiologists, researchers, and software developers at Boston Children's Hospital.

Costa Rican Ministry of Health and LIIT-UNED Collaborations

Costa Rica's Ministry of Health and the Technological Research and Innovation Laboratory (LIIT-UNED, for its initials in Spanish) had collaborated before on GIS health through OGES, where health surveillance maps of vector diseases, cancer, young mortality, and other topics were published originally. This project launched in 2016, and continues to serve data up to this date. Geovisión and OGES both are Spatial Data Infrastructures (SDI) and use geoserver as an open data server to share and publish geospatial data through services. Moreover, its persistence is based on shape files while visualization is powered by the Open Layers library tools [7].

In OGES, the Ministry of Health is the provider and owner of the information, while LIIT is responsible for the GIS data manipulation and web visualizations on UNED's Geovisión architecture [8]. For the COVID-19 pandemic, the collaboration was reignited with the same roles as before to take advantage of the previous shared experiences and acquired knowledge. However, the technologies were changed and adapted to make the data upload, approvals and maintenance faster. The workflow was also simplified for the same reason.

Methodology

The methodology was divided into three steps: design, technology, and workflows.

Design

To design the solution, a COVID-19 web tool to provide daily and updated information, several considerations were taken into account:

- Open Software: In spite of the urgent nature of the service, free software was required as the budget for the project was limited. Also OGES and Geovisión initiatives are both developed with free and open source tools, so it was expected to continue in this path for several reasons, especially previous knowledge of the tools. It is important to consider that even though the software was free the work hours of the people involved was recognized as part of the working day.
- Responsiveness: OGES maps are not responsive, i.e., have issues with different screen sizes. COVID-19 maps were required to be accessible from mobile and desktop applications alike. A change to the map javascript library from Open layers 2 to Leaflet was made to adapt the visualization tool into responsive mode.
- Development time: Costa Rica's first COVID-19 case was reported on March 6. "Situación Nacional COVID-19" was available on March 21. Adaptations, workflow, and decisions about the site were made in less than 15 days.
- Easy maintenance: The workflow was defined with phases and roles to publish daily information fast as a collaborative effort.
- Easy to migrate: Technology had to be able to adapt to any web server. For that reason, no specific tools beyond HTML and javascript are required for the site to run.

- No technical background needed: No special qualifications are needed to bring support to the environment, just plain HTML, javascript web knowledge and basic QGIS software use. This allows rotation of the team members through time with short training sessions.

Technologies

In Costa Rica, the economic and technical resources in the public sector are limited due to the fiscal situation, economic decline and the current pandemic condition [9]. For this reason, it was important to reduce the costs and take advantage of open-source alternatives that were used with OGES in the past.

Several technologies and tools were chosen for map layer construction and web map visualizations, following the four freedoms of GNU [10]. The selected software were:

- Leaflet: javascript library to create mobile-friendly map applications [11].
- ChartJS: javascript library to create interactive charts and add them to a website [12].
- Quantum GIS: GIS that allows the access, visualization, processing, and manipulation of geospatial data [13].
- Plain HTML: javascript and html files
- Geojson files: to encode the geographic data structure [14].

Workflow

A workflow was designed for weekly updates (figure 1). The Ministry of Health is in charge of producing and cleaning the whole dataset of COVID-19 files. Final users use some of the files as input to generate map layers and others to download directly from the site.

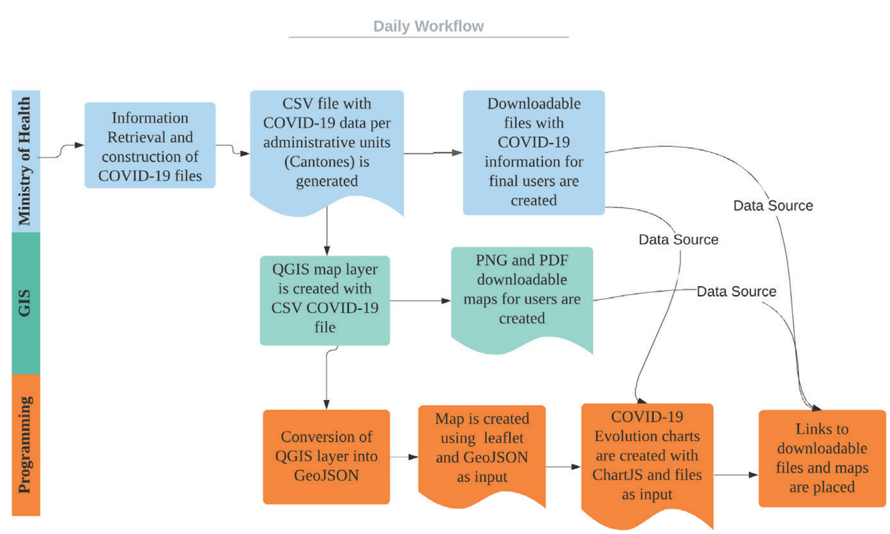

Figure 1. Daily workflow designed to update and visualize COVID-19 information daily.

A detailed example of the workflow systematically is presented as follows:

- First, get the base layer of Costa Rica, in our case it was: the Cantonal boundary at scale 1:5000, available from the National System of Territorial Information (SNIT) of Costa Rica [15].
- Load the Cantonal layer in QGIS and check the coordinate system to WGS84.

- Manually, using QGIS, update the attribute table for *total* and *active* cases, *recoveries* and *deaths* values per cantón with the data provided by the Ministry of Health. The original dataset has the same column names. To link the information from the file and the layer, the value "Cantón name" was used as the original file doesn't have coding for cantones.
- Maps were created using QGIS map designer (sample is shown in figure 2). The files were created in PNG and PDF format.
- It was required that the final layer was smaller than 500KB. To guarantee that size cap the layer was processed as follows:
  - Use the *Vector* → *Geometry Tools* → *Simplify* option.
  - In the tolerance field the value 0.002 was applied, this simplified the geometry of the layer and ensured the resulting file was under 500KB.
- The layer was then exported to GeoJSON and the extension changed to .js
- The prefix "cantones =" was added to the beginning of the file, in order to publish it as a global variable in the Javascript environment.
- The file was then uploaded to the javascript files folder in the file structure of the system. One GeoJSON was created every day.
- Finally, the main javascript file in charge of the map visualization construction uses the GeoJSON provided in the previous step as input.
- On the other hand, the evolution chart was manually updated in the corresponding javascript file. The process consisted in the addition of one registry to each json of the chart corresponding. One json for active cases, one for recovered cases, one for deaths and so on.

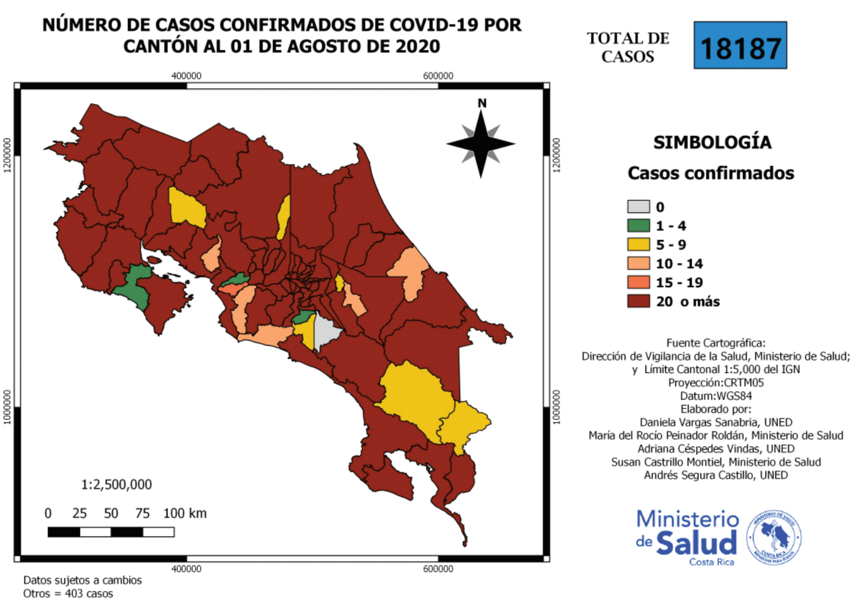

Figure 2. Downloadable PDF maps created with QGIS. The images show the map used for August 1, 2020.

Results

In terms of design, a robust web-based solution was created with different kinds of information. Some of the information was used for specific audiences (for analysis purposes), communication media or single use. The platform has become a transparency effort to provide information to the public, government institutions and social media developed entirely with open-source software. The following features are a result of the design process, technologies and selected workflow:

The Daily COVID-19 Map is presented by Cantones (second level of administrative division in Costa Rica). For each Cantón, a popup is displayed with total cases, recovered cases, and deaths (Fig 3). Downloadable information files such as: PDF maps, official communication summary, general statistics, positive cases, recovered cases, active cases, death cases, evolution cases per province, projections files and the anonymous database with comorbidities are also available. Other charts and sections include the evolution chart with total cases, recovered cases, active cases, and deaths, the evolution map slideshow, projection charts and history information.

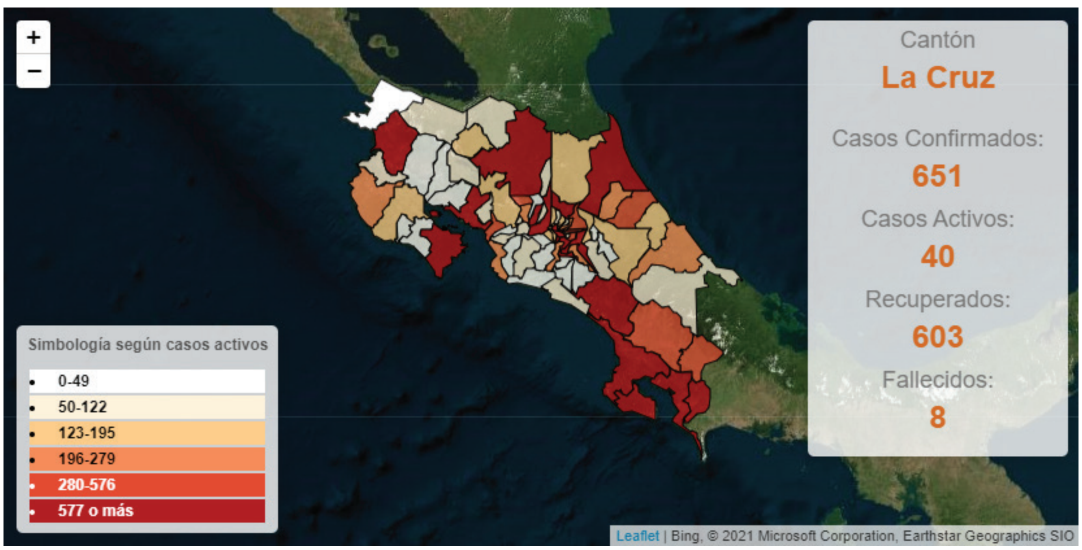

Figure 3. COVID-19 map sample, showing an active number of cases per cantón. Figures shows: "La Cruz· values.

Daily updates usually take an average of 30 minutes. The updating process includes map visualization and information files. By September 2020, the site reported more than 6 months of uninterrupted coverage, 11 daily detailed files, 7 evolution files by province, and 3 sets of projections.

The site was accessed by 202.715 people between April 1, 2020 and September 1, 2020 with an average stay of 1.38 sec minutes. The visits came from 119 countries; with Costa Rica (95.07%), United States (2.35%), El Salvador (0.44%), Canada (0.28%) and Panama (0.20%) were the top five visitors

On average, the number of visitors was constant during the first semester of the year. However, between June and July, a peak of visitors were recorded (figure 4), coinciding with the number of COVID-19 cases [16]. A huge increase of consults was noticed every day after official communications by authorities, showing that people were aware of "Situación Nacional COVID-19" site as a reliable source during that epidemiological moment.

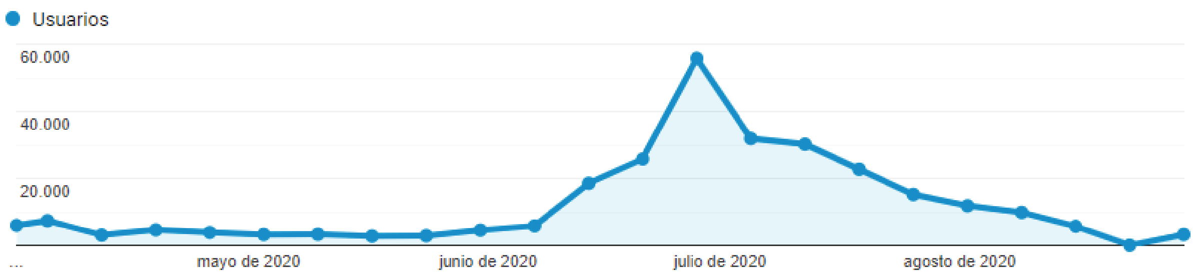

Figure 4. Visitation status of “Situación Nacional COVID-19” from April to September 2020.

Discussion

The rapid spread of the virus in Costa Rica prompted the implementation of a website to provide the general public data of COVID-19 situation. One of the biggest challenges was to develop it in a short time. In this work, we showed the potential of the “Situación Nacional COVID-19” website, as an official resource. Also, the competence to generate a tool and a methodology of daily interdisciplinary work between LIIT-UNED and Ministry of Health, to map COVID-19 cases in Costa Rica at that time.

In the region, many institutions and research groups developed several systems or dashboards based on licensed software that helped as a contribution to pandemic prevention [17, 18, 19]. However, “Situación Nacional COVID-19*”* became the best alternative in our country, because it was constructed rapidly and using open source software, which could be adapted to offer the same outcome as dashboards. Among the advantages of these technologies are the ability to customize pages and options. For instance, “Mapa de Evolución”, “Proyecciones” or “Histórico” options were easy to adapt within the workflow and overall solution. On the contrary, with licensed software that flexibility is limited to the options given by the provider [2].

Regarding the use of open source technologies, developers that are involved in geographic information system (GIS), geospatial and big data analysis should work towards opening up their online applications and designing software applications that operate in a user-friendly way [20], while responding to social concerns in situations as we are through.

It is important to highlight the achievement of “Situación Nacional COVID-19” was in part due to the correct use of the data to be visualized in a geospatial way. That is the most common problem of maps or websites of COVID-19 these days, forgetting the basic rules of making thematic maps [21] and mapping responsibly [22]. Often these factors affect the way people view information such as lack of transparency or difficulty in understanding [20].

Although it was initially thought the cantonal geographic data were insufficient to show the number of reported cases, the friendly use of the website and the way to display the data was one of the main successes in getting people to adopt the tool. Actually, we had periods of many visits such as Jun 19, July 1, and September 15. The most cases reported the most visits we had. Additionally, we noticed the data was used in many pages to inform the local situation, in official pages of governmental institutions and research projects [23].

Conclusions

An Open Software solution can solve complex and changing requirements as well as a licensed option. In our case, plain html and javascript provided more control over the solution requirements. For example, new options, visualizations, downloads or information pages were added as needed. When restrictions or limitations are set, the solution should be taught in order to fulfill those problems. We identified that front-end web solutions are a good approach even though they are not very common and the problems are easy to sort out as it does not involve the back-end environment with less changes in code required.

A site like the one described in this paper requires little maintenance. However, some basic training in the web programming language is ideal. The process of uploading the information is not automatic; it requires people to work on updates daily, which is an important fact to consider. This could potentially be viewed as an advantage because the data can constantly be cured and adapt to daily needs.

This site was created as an open solution to a common problem: how to communicate geographical data and numbers to the public in order to track and follow COVID-19 pandemic? The core of the site can be adapted and extrapolated to other fields of knowledge with very similar results. Therefore, the experience has brought a base of knowledge to construct similar solutions to show geographic information to follow diseases behavior and trends.

Map visualizations and charts are a friendly option to share and communicate information related to health surveillance and in this particular case COVID-19 pandemic spread. It could also be used to evaluate mitigation and health policies through the course of a particular disease. With this work, we have demonstrated a viable and sustainable approach for the Costa Rican context, and provide an example relevant to countries in the region, which given similar circumstances, might find our approach adaptable to their situation of interest.

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