Implementation of a Distributed System to Collect, Search and Manage Data of Patients with Leprosy in Hiperendemic Municipalities

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Abstract— **The state of Pará, in Brazil, with 2,351 new cases of leprosy reported in 2017, has an annual detection coefficient of 30/100,000 inhabitants, conferring it the classification of a hyperendemic state. A research group at a university in Belém, capital of Pará, develops a research work where a medical team do household visits to individuals who have been diagnosed with leprosy. The objective of this work is to present a distributed computer system that helped the team to collect and analyze the patient's data without the need of printed medical records. The system is composed of four components: a database, a mobile application, a server application and a reports application. Tests on the system were made by the team while doing their research. Patient's data were collected from three municipalities in the state of Pará. From the feedback provided by the team, there was a reduction in their costs by not having to use printed forms and reduction in the delay of having the data ready to be analyzed, since it was being registered directly in digital format. In total, the system was used to store data of 1101 individuals, of which 276 are leprosy patients and 825 are contacts of these patients. 149 new cases were diagnosed that had not been notified prior to the team's visit. Among these 149, 48 are under the age of 15; 122 have type multibacillary (MB) and 27 type paucibacillary (PB) leprosy.**

Keywords-Leprosy; Distributed System; Mobile Application; Decision Support.

I. INTRODUCTION

Leprosy is characterized as a chronic infectious disease caused by the intracellular bacillus Mycobacterium Leprae that has preference for cells found in the peripheral nerves and macrophages in the cutaneous tissue [1]. Its slow reproduction, about 2 to 7 years, results in an insidious clinical evolution of the disease, which manifests mainly through lesions on the skin and peripheral nerves, especially in the eyes, hands and feet [2].

In Brazil, there is a high incidence of leprosy in the states of the Northeast, Center-West and North compared to those in the south and southeast regions [3]. The state of Pará, in the North region, with 2,351 new cases reported in 2017, has an annual detection coefficient of 30/100,000 inhabitants [4]. This gives it the hyperendemic status classification.

A descriptive case study was carried out in which a computational solution was developed to solve a data management problem of a group of researchers from the Federal University of Pará (UFPA), who studied leprosy in hyperendemic regions of the state of Pará. This group used the solution *in loco* to collect data of leprosy patients and constantly provided suggestions for improvements and corrections to the solution in order to adapt it to their needs.

There are five sections in this paper: In Section 2, we present some works related to this one or used as base to develop it. In Section 3, we describe the materials and methods used to model and develop the system. In Section 4 is shown each individual component of the system, describing how it works and how it communicates with each other. In Section 5 is described how the system was tested on field with the help of the medical team. Also, a summary of the data collected during the tests is displayed in table format. Finally, in Section 6, we present the conclusion of the work and some concerns about the usability of the system.

II. RELATED WORKS

The base of this paper is the work of Barreto [6] that helped create a medical form to collect data from patients that were starting or were being treated for leprosy. This form was created based on the one used in Brazil [4] in a nationwide system to detected illness like leprosy. This form is used by health professionals to store patient's data temporarily before submitting it to an online system used by the government to know which areas needs more help to deal with the detected illness.

This methodology does not prove as efficient as it could be. Other works [10][11][12] that needed to access the data from this system to make some studies, reported that the data is very inconsistent due to the amount of noise that is possible to rise between the translation of the content in a

printed form to an online system [10]. This was one of the issues faced by Paschoal [11] when his team needed to create a database based on these data to make a study about the illness in a specific region in Brazil.

It can be seen in works such as from Rafael [12] that this problem can be reduced if the technology is used more thoroughly. Instead of using papers that later needed to be typed into a computer, his work proposed the use of a mobile application to serve as a digital form that could be taken by health professionals in household visits to collect the patient's data, which would be transferred to a remote server through the internet.

Barreto's work was used to model the data managed by the system. With the use of mobile devices, we extend his work by creating a distributed system that takes his original patient medical record and translate it into a digital format. Instead of using pens and markers to draw and paint crucial data of a leprosy patient, such as wound locations and sensitive degree points, a finger swiping a touchable screen in a smartphone is used, ensuring a better control over how the data is inserted in the medical record.

III.   MATERIALS AND METHODS

The system was structured in a client-server architecture [5] and consists of four components: database, server application, mobile application and reports application. All of these components interact with each other through the internet.
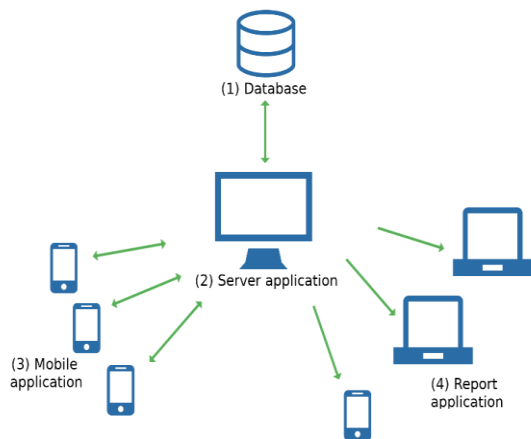

Figure 1.   The client-server architecture used in the system.

The server application (2) in Figure 1 accesses patient data in a database (1) which then passes it on to clients in mobile applications (3) and reports applications (4). The green arrows indicate data exchange. Bi-directional arrows indicate that data can either be received or sent by the component, unlike one-way arrows, where the component can only receive data.

The database will be the system data source. It will be responsible for storing and providing data on patients with leprosy and ensuring their integrity so that inconsistent data (e.g., preventing the insertion of an unnamed patient) is not available. The server application will be a web application

that connects the database and the other components of the system. It will facilitate access to data by providing an Application Program Interface (API) so that components do not have to worry about the specific access rules related to that database. The mobile app will be an electronic medical record that works on mobile phones or tablets with Android. It will have the responsibility of collecting the patient's data in the field and sending them to the server application. It can also request data for browsing and editing. The reports application will be a web application that provides reports of patient's data, which can be accessed from any device with an internet connection (cell phone, tablet, computer, etc.).

IV.   SYSTEM DESCRIPTION

For each component presented in the previous section, we will provide a short description on how it is modeled and how it can present data to users or other components.

A. Database

In order to include all the attributes of the chart created by Barreto [6], 31 tables were implemented in a relational database structure [7]. This set of tables represents one patient. Among the stored data, we can mention: personal data, household data, diagnostic data, location of lesions in the patient's body and neurological evaluation data.

B. Server application

Five endpoints were implemented in Representational State Transfer (REST) [8] that allow access to certain patient data from other system components. Each component performs a HyperText Transfer Protocol/2 (HTTP) request [8] to the server application through one of these endpoints, which will then process this request by collecting data from the database and arranging them in JavaScript Object Notation (JSON) [9] to be returned to the component that made the request. Some endpoints also have data synchronization capabilities, allowing the mobile application to send its database to have its data registered in the database of the system.

C. Mobile application

The application for mobile devices was implemented as an Android application that has an electronic medical record that allows the collection and browsing of data from patients with leprosy. This platform was chosen due to the number of free tools available in the internet that aids in the development of applications for it. Some screenshots of the application can be seen in Figure 2.

A patient form has more than 10 sections that are organized into tabs by which the user can navigate. The collected data is stored in a local relational database on the mobile device before being sent to the server application, thus allowing the user not to depend on a stable connection to the internet to perform data collection. The local relational database has the same number of tables and same structure as the main database of the system to allow the

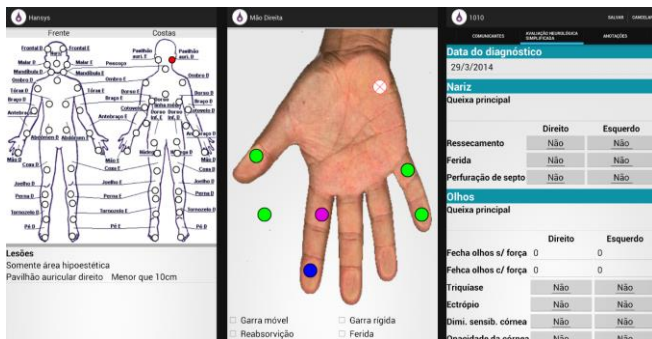mobile application to understand the data sent by the server application.

Figure 2. Screenshots of the mobile application. From left to right: record of skin lesions, record of touch sensitivity in the hand, record of neurological evaluation.

Some of the fields in the form make use of images and graphics that allows the user to better register and visualize the patient's data as he is filling the form.

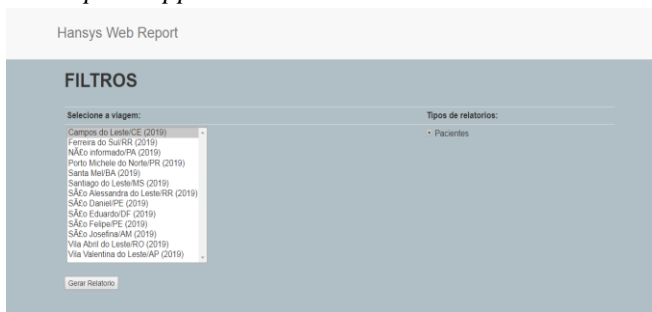### D. Reports application

Figure 3. Web interface of the reports application.

The reports application is a web application that takes the list of available cities and reports from the server application, displays for the user to choose and generates the report in Comma Separated Values (CSV) format for download. This report can then be used to aid in any analysis on the patient's data. As shown in Figure 3, when the user selects a trip (on the left) and reports type (on the right) and clicks the "Generate Report" button, the report is downloaded in CSV format.

V. SYSTEM TESTS AND RESULTS

The system was tested both *in loco* and in the laboratory. However, it was the tests with the research team collecting the data of the patients in their households that contributed the most to the maturing of the system modeling.

The research team was multidisciplinary. There were dermatologists, physiotherapists, nurses and community health agents. The data collection was carried out in hyperendemic municipalities in the state of Pará. Before visiting any municipality, they contacted the local health team of the municipality to collect the data of the patients who already had or are being treated for leprosy, to then

schedule with these household visits. During a visit, socioeconomic data and blood and lymph samples are collected from the patient and his/her contacts. To test the mobile app, one more member has been added to this team, which is the IT expert. This member was responsible for collecting data from the patient and his/her contacts.

The system was used to collect and visualize the data of 1101 individuals distributed among three cities in the state of Pará, Brazil: Breves, Redenção and Santarém. In each city, an average of one week was used to collect the data. Tables 1 and 2 show these numbers in more detail.

TABLE I. TOTAL NUMBERS COLLECTED AND MANAGED BY THE SYSTEM.

City	Individuals totals	Contacts totals	New cases totals
Redenção	432	311	29
Breves	311	229	75
Santarém	358	285	45
Total	1101	825	149

TABLE II. TOTAL NUMBERS OF CHILDREN AND MB AND PB TYPES FROM DETECTED CASES.

City	Students cases totals	Less than 15 years cases totals	MB cases totals	PB cases totals
Redenção	6	6	19	10
Breves	46	26	61	14
Santarém	8	16	42	3
Total	60	48	122	27

Students and children younger than 15 years old are a very important data to collect because they are a strong indicative of infected areas. For a child to develop an illness that takes up to 7 years to show symptoms, he/she had to be overexposed to the bacillus.

One big benefit brought by the system for the team that used it was the reduction of monetary costs. Before starting using the system, they needed to print roughly about $250 worth of paper forms for each trip they made to collect patient's data. Now, with a one-time investment in a couple of tablet devices, they reduced this cost to zero, only having to deal with possible maintenance in the electronic devices. Also, the time taken by the team to have the data ready to be used for its research was reduced from a couple of days to a few minutes. With the printed forms, after a week of collecting patient's data, the team had to manually type in the data in a computer. Now, after the collection step is done, they just need to sync the data with the server and access the reports application to access the relevant data for their research.

Instead of only working with diagnosis data and household contacts as in the system used in Brazil [4] and in the work developed by Rafael [12], the system also deals with socioeconomic data (monthly income, access to basic sanitation, help from government programs, etc.), household historic data (from where the patient came and where he

plans to go in the near future) and spatial information (Global Position System (GPS) coordinates). With this data, it is possible to have a greater knowledge about the patient's condition and how he is contributing in helping spread the disease in its region if not treated. As mentioned in the Related Works section, the difference from Barreto's work [6] is the use of technology. The main issue he reports in his work was inconsistency in collected data. Since he had to work with a big team, issues related on how each team member was registering each patient started to rise, such as illegible handwriting and important patient's details been taking as side notes. This kind of problem is reduced with the usage of a software that restricts how each patient data should be collected, imposing clear standards that are enforced in the workflow of the team.

It is worth mentioning that the system itself does not provide decision support for suitable treatments and follow-ups. This information should be provided by the responsible doctor evaluating the patient and the system will only store its data for historical usage to see how the patient is progressing. The system is well suited to manage patient's data thanks to its focus on diagnosis data, providing a well-defined mapping of the possible regions of the body that can present wounds and mapping of the areas of the hands and feet that are losing sensibility due to leprosy. Also, the form provides fields to store data about laboratorial analysis. All of these data are visible through the mobile application and reports application.

VI. CONCLUSION

The developed system completely replaced the use of the paper charts used by the research team that assisted in its modeling. This work presented a case study that proposed to solve a specific data management problem of a research team. The way the system is modeled may not make it practical to solve problems outside the scope of this team, but it has served to validate how computational systems can positively impact the management of complex data, such as data on leprosy patients. It is worth noting that the system is still only a tool. It is necessary the commitment of the team that will use this system in understanding its operation and restrictions and possibly even change its work process to be able to adapt the use of the tool in the collection of data of the patients. An electronic medical record actually helps reduce the chances of error in recording patient data, but it is up to the professional who is handling the medical record to take care and ensure that all data entered corresponds to the reality of that patient.

REFERENCES

[1] M. G. Araújo, "Leprosy in Brazil". Journal of the Brazilian Society of Tropical Medicine. 36(3): pp. 373-382, may. – june., 2003.

[2] V. D. Costa, "Experiences of Amazonian women living with leprosy". [s.l.] Dissertation. Federal University of Rondônia - UNIR. Health Center. Porto Velho, Rondonia., 2011.

[3] A. Figueira, "Evaluation of the coverage of basic health units in the fight against leprosy in the city of Santarém / Pa through spatial analysis". Postgraduate Program in Biosciences. Federal University of Western Pará. Master's Dissertation in Human Physiology, 2015

[4] Brazil, "National Health Surveillance System: progress report: Pará". Ministry of Health, Health Surveillance Secretariat. – 5th edition – Brasília: Ministry of health, 2017.

[5] G. Coulouris, J. Dollimore, T. Kindberg and G. Blair, "Distributed Systems Concepts and Projects". Bookman Editorial Company Ltd. 5th edition. 2013, Porto Alegre, RS. pp. 56-60.

[6] J. F. Barreto, "Spatial and Serological Epidemiology of Leprosy in the State of Pará". December 16, 2013. 151. PhD Thesis in Tropical Diseases - Federal University of Pará. Belém – 2013-12-16.

[7] R. Elmasri and S. B. Navathe, "Database systems". 6th edition. São Paulo: Pearson Addison Wesley, 2011.

[8] J. F. Kurose and K. W. Ross, "Computer Networking and the Internet - A Top-Down Approach". Pearson Education. 3rd edition, 2011. São Paulo, SP. pp. 23 – 204.

[9] Ecma, "International. Standard ECMA-404" – The JSON Data Interchange Syntax. Ecma International Standard Publications, 2nd edition, 2017.

[10] S. M. T. Nardi, L. H. S. C. Marciano, M. C. L. Virmond, and R. Baccarelli, "Information system and physical disabilities in leprosy". BEPA - Paulista Epidemiological Bulletin; 3(27): 3-7, mar. 2010.

[11] V. D. A. Paschoal *et. al.,* "Creation of a data bank for sustainability of leprosy post elimination". BEPA - Paulista Epidemiological Bulletin; 6(12): 10-15, mar. 2016.

[12] B. Rafael, "A mobile health information logging application by community agents" – Dissertation. Federal University of Rio de Janeiro - UFRJ. Health Center. Grande do Sul – Unijuí, 2012.