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Georeferenced and secure mobile health system for large scale data collection in primary care

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ABSTRACT

Introduction: Mobile health consists in applying mobile devices and communication capabilities for expanding the coverage and improving the effectiveness of health care programs. The technology is particularly promising for developing countries, in which health authorities can take advantage of the flourishing mobile market to provide adequate health care to underprivileged communities, especially primary care. In Brazil, the Primary Care Information System (SIAB) receives primary health care data from all regions of the country, creating a rich database for health-related action planning. Family Health Teams (FHTs) collect this data in periodic visits to families enrolled in governmental programs, following an acquisition procedure that involves filling in paper forms. This procedure compromises the quality of the data provided to health care authorities and slows down the decision-making process.
Objectives: To develop a mobile system (GeoHealth) that should address and overcome the aforementioned problems and deploy the proposed solution in a wide underprivileged metropolitan area of a major city in Brazil.
Methods: The proposed solution comprises three main components: (a) an Application Server, with a database containing family health conditions; and two clients, (b) a Web Browser running visualization tools for management tasks, and (c) a data-gathering device (smartphone) to register and to georeference the family health data. A data security framework was designed to ensure the security of data, which was stored locally and transmitted over public networks.
Results: The system was successfully deployed at six primary care units in the city of Sao Paulo, where a total of 28,324 families/96,061 inhabitants are regularly followed up by government health policies. The health conditions observed from the population covered were: diabetes in 3.40%, hypertension (age >40) in 23.87% and tuberculosis in 0.06%. This estimated prevalence has enabled FHTs to set clinical appointments proactively, with the aim of confirming or detecting cases of non-communicable diseases more efficiently, based on real-time information.
Conclusion: The proposed system has the potential to improve the efficiency of primary care data collection and analysis. In terms of direct costs, it can be considered a low-cost solution, with an estimated additional monthly cost of U$ 0.040 per inhabitant of the region covered, or approximately U$ 0.106 per person, considering only those currently enrolled in the system.

1. Introduction

Mobile health (mHealth) refers to the application of mobile devices and communication capabilities for expanding the coverage and improving the effectiveness of health care programs. These technologies are particularly useful for developing countries, where health managers can take advantage of the expanding mobile

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coverage to provide adequate health care to underprivileged communities. This huge potential has led to intensive research efforts focused on mHealth in many countries, resulting in a number of innovative solutions. Some recent reviews focused on emerging countries and challenges that hinder the evolution of pilot initiatives into real deployment solutions have been developed [1–3]. One of the main challenges concerns the lack of robust security features to deal with medical data, which are extremely sensitive and subject to a very strict legislation in most countries [4–6]. Besides, most pilot projects are isolated, address specific issues of information sharing and access, and are usually tested in small-scale deployments.

The National Health System adopted in Brazil since 1988, called SUS, provides free universal coverage, being the sole source of health care for almost 80% of the country's population [7]. An important part of this infrastructure is DataSUS, the Brazilian Ministry of Health institution responsible for gathering, processing and disseminating health care data [8]. For this purpose, it maintains several databases containing comprehensive information from different sectors of the Brazilian health care, ranging from primary care initiatives to complex procedures performed at specialized health centers. This data is expected to support decision-making, allowing health providers and managers to plan their actions more effectively [8,9], and is also commonly used in health-related research studies [9,10].

One of the main policies of SUS since its implementation has been the focus on primary health care, defined by the Brazilian Ministry of Health as "a set of individual and collective health care actions including health promotion and protection, injury prevention, diagnosis, treatment, rehabilitation, and health maintenance" [11]. Such activities are currently part of the Family Health Strategy (FHS), a program launched in 2001 by the Ministry of Health and adopted as the Brazilian model of primary care. According to this program, access to health care should be ensured via the enrollment of families (i.e, residents of the same household) from areas covered by regional Primary Care Units (PCUs). Health care is then provided by Family Health Teams (FHTs), formed by one physician, one nurse, two nurse assistants and up to six Community Health Agents (CHAs). A necessary requirement for working as a CHA is to be a resident of the area under the FHT responsibility, so that a CHA can act as a bridge between the health center and the population. These professionals are responsible for systematically gathering data related to the households, such as sanitation and dwelling conditions, number of family members, reported chronic diseases or pregnancy, immunization status, etc. All data are collected using standardized paper forms, which are later transcripted and sent on a monthly basis to the Primary Care Information System, called SIAB. The SIAB database can then be used to monitor the results of primary care initiatives in the country.

Even though SIAB has the potential for being used as a rich repository for decision making in the field of public health, the current data gathering process presents some issues, which cause serious limitations. A first issue is the long delay between obtaining data and making it available on the SIAB platform, which can be as long as 45 days. Although this delay may not impair long-term analyses, it prevents timely response to short-terms events (e.g., disease outbreaks) and negatively affects the planning of the FHTs' daily routine. A second issue is related to the quality of the input data. As with any paper-based process, it suffers from possible misinterpretation of handwritten data, lack of standardization in fields that can be freely filled, possible loss of filled forms, duplicated entries, among other issues [12,13]. This reduces the reliability of the database, a problem that often discourages its use by health practitioners and managers [14], and may lead to the impression that the whole process only creates bureaucracy instead of aggregating value [15]. The process also raises security and privacy issues, as lost forms can leak personal information about the families. Another negative aspect related to paper forms is their lack of flexibility, i.e., even if some information is highly relevant to a specific community, adding the corresponding fields into printed forms is a cumbersome task. Finally, a more subtle issue is that many families covered by the program have no formal address, which prevents the precise location of families, a common situation for those living in poorer urban areas of the country such as slums.

Aiming to overcome these issues, in Ref. [16] we introduced GeoHealth, a system for improving the processes of collecting and analyzing primary care data. For the data gathering process, GeoHealth uses a 3G and GPS-enabled smartphone with (improved) digital versions of the SIAB forms. This enables better data quality, since the system can easily validate the data input by CHAs and include the geo-location of families. It also allows for faster data delivery, via a 3G network, ensuring access to the gathered information soon after a CHA's visit. Since the preliminary study in Ref. [16], GeoHealth has evolved from a prototype used by 6 CHAs to survey 380 families (1200 people), to an established solution regularly used by 194 CHAs in their visits to 28,324 families (96,061 people). In this scenario, the main research questions addressed in this article are: (1) "what are the challenges when deploying the solution on a large scale and how can they be overcome?", the answer to which involves the need for continuous training and security mechanisms to prevent data disclosure, ensuring the required level of data security and citizen privacy [17,18]; and (2) "what are the measurable benefits of the system when fully deployed and the results for patients care and public health?", which includes gains in efficiency, data quality, flexibility, and visibility by health managers.

The rest of this paper is organized as follows. Section 2 discusses related work. Section 3 describes the target scenario and the corresponding requirements. Section 4 presents the GeoHealth system and its main features. Section 5 analyses the results obtained with the deployed system so far. Finally, Section 6 presents our final considerations.

2. Related projects in Brazil and worldwide

Over the last few years, Brazil has experienced continuous growth in its Information Technology (IT) market [19] and expansion in mobile network coverage, reaching 1.38 mobile phones per inhabitant in 2014 [20]. These advances led to the emergence of many solutions proposing the use of mHealth in the country (for a survey, see Ref. [1]), a trend that is also verified worldwide in developed and in developing countries [18,21]. In the latter, it is not rare to find applications for health surveys and surveillance [18,22], many of which are targeted at unserved or underserved populations [13,23].

Given the importance of the FHS in Brazil, it is natural that some mHealth solutions proposed for use in the country focus on data gathering for the SIAB database. Examples include commercial applications such as Easy SIAB [24] and research projects such as Borboleta [25,26]. However, the interest of such solutions consist almost solely on their ability to replace paper-based forms with digital ones, leading to the following limitations: (1) they lack support for remote data communication, obliging users to synchronize the collected data only when inside the health units; (2) they do not provide strong security mechanisms for protecting the data stored in the device; and (3) they have no feature for dealing with families having no formal address. These are probably among the reasons why, to the best of our knowledge, they have never been broadly adopted in practice.

Worldwide, reports of initiatives for replacing paper-based health care data collection procedures with mobile devices are