Borboleta: A Mobile Telehealth System for Primary Homecare

Rafael Correia
Dept. of Computer Science
University of São Paulo
rafaelj@ime.usp.br

Fabio Kon
Dept. of Computer Science
University of São Paulo
kon@ime.usp.br

Rubens Kon
Primary Healthcare Center
School of Medicine
University of São Paulo
rkon@usp.br

ABSTRACT

Public homecare programs such as the Brazilian Family Health program, initiated in the late 1990s, have proven to be a very effective tool for Preventive Medicine. The goal of these programs is to bring physicians, nurses, and social workers to the homes of the lower income population in lesser-attended regions within multi-million people metropolis.

However, there is practically no IT support for the operation of these programs, leading to inefficiencies. For example, in a particular Primary Homecare Program our group is involved with, nurses visit the homes of their patients carrying a pencil and a piece of paper and, during their visits, found themselves isolated from the Primary Healthcare Center, the University Hospital, and the physicians who could provide them with important information to improve the quality of the services they provide. Each visit associated with the program results in a three-page report, which is handwritten and stored in cabinets, with no possibility for information summarization, statistical analysis, or data mining.

In this paper, we describe the architectural design, the prototype implementation, and our preliminary experiences with the Borboleta system, whose goal is to use Mobile Computing technologies to promote digital inclusion as well as to improve the quality of Preventive Healthcare services offered by the public sector. We focus primarily in developing software that runs on PDAs used by health professionals while providing home healthcare. Currently, nurses of the Primary Healthcare Center are testing the system and starting to use it on medical visits.

Categories and Subject Descriptors

J.3 [**Life and Medical Science**]: Medical Information System

Keywords

Telehealth, telemedicine, homecare, preventive medicine, mobile computing, mobile databases

SAC'08 March 16-20, 2008, Fortaleza, Ceará, Brazil

1. INTRODUCTION

Telehealth is the provision of health care using telecommunication technologies. It is considered an extension of Telemedicine, which encompass preventive, promotive and curative aspects. In this paper, we present Borboleta, an innovative telehealth system, which helps health care providers in their regular visits to patients homes. Using the system, nurses or physicians can use their PDAs to access medical databases and the historical medical records of the patients. They also feed the system with new information about the patient's health, synchronizing the data later with the central database. The Borboleta system is open-source, multiplatform, and runs on commodity mobile devices (PDAs, TabletPCs, etc.). It is easy to use and eliminates the need for the cumbersome paper forms that are currently used in public homecare programs.

Blaser [4], after an evaluation of hospital discharge letters, concluded that there is a need for an IT solution to reduce the errors found in those documents. In this case, the research indicates that about 42% of the discharge letters have critical or major problems, such as, imprecise or incomplete data about the treatment. This situation is quite similar to the context in which our system is being deployed, where home visit paperwork, containing a large number of forms filled during the visits, have to be manually managed, leading to errors and information loss.

To the best of our knowledge, Borboleta is a pioneering application in telehealth systems as there are no similar work for large-scale homecare programs for low-income populations offered by the public sector. As Koch [7] has shown, the vast majority of publications on mobile technology applied to the medical area (72%) deals with remote monitoring of patients with specific diseases or conditions, more often than not making use of expensive hardware, focusing on solutions affordable only for higher income classes. For this reason, Borboleta can be considered a new approach in telehealth systems, which is aimed at improving the quality of the information gathered during the visits of healthcare professionals to the patient's home in large urban areas.

This paper is organized as follows. Section 2 describes the scenario and the motivation behind the Borboleta system. Section 3 describes some related works. Section 4 presents the system design and Section 5 its implementation. Section 6 shows some preliminary results. Section 7 presents our future goals for the system and, in the last section, we present our conclusions.

2. MOTIVATION AND SCENARIO

The Brazilian Government promotes a primary health care program, called *Saúde da Família* (Family's Health). Since its creation, about ten years ago, this program has proven to be a very effective tool for health promotion, reducing the occurrence of many diseases and decreasing child mortality significantly. To further enhance homecare programs such as this, the Software Systems Research Group at our university is carrying out a joint joint research effort with the Primary Health Home Care Group of the Family Health Project at the School of Medicine's Primary Healthcare Center (PHC). Our goal is to apply novel Software Engineering and Mobile Computing technologies to develop new tools designed to improve the quality of the services provided by home healthcare programs.

The Primary Healthcare Center nurses follow a routine when giving assistance to the neighboring shantytowns. The process starts with the selection of the patients that will be visited during that day. The selection follows a schedule defined previously based on the last visits and patient's necessities. As soon as this step is completed, the team seeks the pile of papers from each patient and goes to the field. Currently, they visit about four patients in four hours, with variations that depend on the type of the home visit.

During the visit, one of the members of the team takes notes and fills in some fields in the forms, but most of the information is filled in afterwards at the Primary Healthcare Center. While the health care providers are on the way to another house, they look at the historical data from the next patient in their paper forms. These steps are repeated until the last patient has been visited, then they go back to the Healthcare Center. At that moment, some information is still not yet registered; it is only filled out completely a couple of days later. According to systematic observations we made, sometimes the forms are only completely filled out up to a week later. The average is approximately three days. We asked some of the nurses to write down the time spent on filling in the forms. The result is shown in the Table 1.

Table 1: Time spent filling in the paper forms

Visit Type	Time Spent
New patient	30-40 minutes
Continuing treatment	15-20 minutes
Occasional assistance and Dressing	10-15 minutes

The Borboleta system will entirely automate this procedure not only making it quicker and less error prone but also opening a wide range of possibilities for information summarization, statistical analysis, and data mining.

3. RELATED WORK

Although the Borboleta System is an innovative approach in the use of mobile computing in Medicine, the project has similarities with a number of previous works in the field.

Ever since mobile technology became popular in the medical environment, many systems have been developed. One of the pioneers was the Constellation Project conducted by Labkoff [8] who developed and used it for the first time in the Women's Hospital at Harvard University in 1993 to provide interns with medical information. The project was successful leading to a more widespread use of PDAs in medical environments. But, differently from our project, Constellation was developed to a hospital environment, not for home healthcare.

Another example, the MEDIC System [9], uses mobile devices to access laboratory data via a wireless network as soon as they are available, decreasing the delay for receiving the results. This is an example of a software that improves physicians access to valuable information provided by the laboratory desktop system, using mobile devices through the hospital network. This approach is similar to one adopted in Borboleta, but the application of the MEDIC system is different. While Borboleta has been built to be a preventive medicine auxiliary tool for homecare assistance, MEDIC is a laboratory's report data access system to be used inside the hospital facilities.

Sá et al. [5] described a psychotherapist framework used to tailor specific therapies for patients. This framework was developed for mobile platforms such as PDAs and Tablet PCs, covering therapeutic tasks for both the patient and mental health professional. The idea of having a mobile device with the patient to follow his progress is quite similar to the use in Borboleta. However, in our case, only the health care providers use the PDA. Another difference is the data stored on the PDA: the framework proposed by Sá et al. has a completely different scenario where the patient uses the system during the therapeutic treatment while Borboleta is used by the healthcare providers team.

Baumgart [1] described how PDA applications can be used effectively in healthcare to support diagnosis and drug prescription. This study does not include among the most popular uses of PDA applications, the focus we have on the Borboleta project: tracking the condition of a patient throughout the treatment and the ability to store and review the patient's record at any location. Nevertheless, we believe that a system like Borboleta in the context of homecare treatment can bring very significant benefits to nurses, physicians, public health program managers and, most importantly, to patients.

4. SYSTEM DESIGN

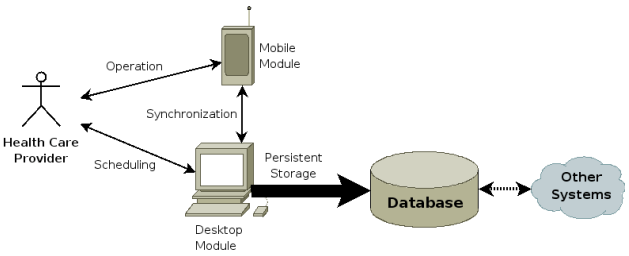

Figure 1: Borboleta Overall Architecture

The Borboleta System comprises a Desktop and a Mobile module. The Desktop module works as a bridge between the Mobile module and the Primary Healthcare Center (PHC) Database. The Desktop module is also responsible for defining the schedule and managing patient data. But the most interesting part of Borboleta is indeed the Mobile module, which is responsible for field operation. Figure 1 shows the relationship between the modules and the interaction with the users. In the following sections we describe each module in more detail.

4.1 Mobile Module

The Mobile module is the software installed in a mobile device, such as a PDA or smartphone. This module contains all the operations that are needed on the field. It has strict Human Machine Interface (HMI) requirements: it must be very easy to operate and enable filling in the form quickly. We sought to build the interface to require the least number of clicks as possible. This development approach ensured that the time spent filling the form is kept to a minimum, maximizing the chance of the system being well-received by end users. The development team designed the interface following the specifications provided by the nurses and doctors, containing field names, field types, and their possible values.

The features present in this module are:

- **Patient Data** – Present the personal data of a patient, i.e., name, date of birth, address, and others.
- **Patient Caregiver Data** – Patient caregiver is the person responsible for taking care of the patient, e.g., a relative living in the same house. This information is important considering that most people visited have movement impairment and, sometimes, with a severe degree.
- **Patient Socioeconomic Data** – Patient Socioeconomic Data contains patient data that refers to his social and economic situation, such as profession, educational level, nationality, religion. These data can influence the way the treatment is conducted.
- **Scheduled Visits** – Contains the schedule of future visits to the patients.
- **New Visit Registration** – This feature is the registration of what occurred during a visit, such as the disease that is being treated, which procedures have been undertaken and the current state of the patient.
- **Access to the Visit History of the Patient** – Provides a history of the visits that have been done to a patient.
- **Disease Catalog** – This catalogue is a translation to Portuguese of the worldwide known *International Classification of Diseases (IDC-10)*[10].
- **Medicament Catalog** – This feature provides a list of the drugs available at the PHC pharmacy.

This set of features were defined and validated by the doctors and nurses in our first assessment. It will be further refined as development continues and the system is used in the field. The usability of the system is especially important and can determine whether the system will be used or not. If a system with the scope of Borboleta demands too much time and effort to enter the data, the users will probably not fill in the entire form, and precious information might be missed.

4.2 Desktop Module and Data Synchronization

The Desktop module is responsible for the synchronization between the database and the mobile device. This process is triggered by the user through the Desktop module, which is a standalone graphical application in Java. The application then captures the information in the database and constructs an XML file that is stored in a Web server. The mobile module then downloads the information from the Web server and stores it into a internal record resource. The synchronization process is depicted in Figure 2. It occurs in two different situations:

- **Importing supporting Medical Information** – This is performed less frequently, for example, once per semester, to load data such as neighborhood addresses, disease and medicament catalogues, and additional information that will not be managed by the mobile application. This extra information is only used for inquiries and as values to fill the fields in the registration forms.
- **Importing/Exporting Patient Data** – This must be done whenever the records in the database are different from those of the mobile device, which can be as often as daily.

Figure 2: Synchronization Flow

The synchronization process is not yet automatic and has to be initiated by the user at the Healthcare Center.

5. IMPLEMENTATION

There are some important aspects to be considered for the development of the Borboleta modules. We have faced some challenges during the implementation, which we now describe.

5.1 The Mobile module

The construction of a mobile system is a challenging task due to several factors: small amount of runtime RAM memory, the development process itself, and the need to make the system more friendly to the user.

Figure 3 shows a screenshot of the Mobile module. In this form almost all fields have to be typed in, so we cannot use components to accelerate the filling process. This is not a big issue, though as the form has only a few fields. One solution we adopted to optimize the process of filling in the form was to build a database of 2000 street names that are within the PHC service area. Based on this database, Borboleta can offer a list of options from which the user can select.

The most important feature of the Mobile module is the registration of the home visit. Figure 4 shows the visit registration screen that contains the procedures carried out during the visit. Figure 5 shows the measurements part, which is the only form where the user needs to type some information during a regular visit. Figure 6 shows another part of the visit registration feature where the user enters the difficulties that the patient has to conduct some activities. Again, we tried to optimize the usability of the screen by using, as much as possible, components such as checkboxes and radio buttons.

The PDA software is developed with a test-driven methodology using an emulator that runs on a development workstation. However, sometimes the emulator does not behave exactly like the real device. This complicates the task of validating the system in fieldwork. Most of the time, it is easy to make the system behave in the some way in both platforms. But there are situations where the response of the emulator is very different from the real devices and we are forced to change the way we perform the operation.

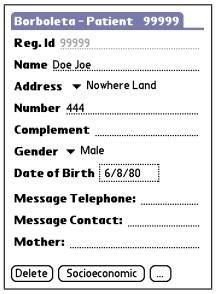

Figure 3: Patient Data Screenshot

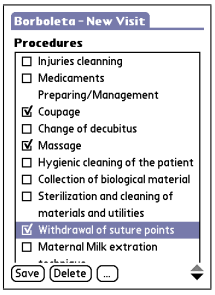

Figure 4: Visit Screenshot, Procedures

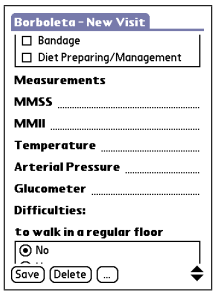

Figure 5: Visit Screenshot, Measurements

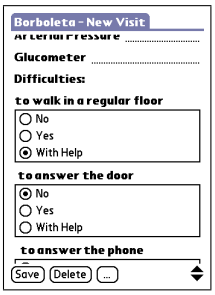

Figure 6: Visit Screenshot, Difficulties

The system currently uses a little more than 16 megabytes of RAM at runtime and there are many devices in the market that cannot afford more than 16 megabytes of RAM. We agreed to define a minimum hardware specification to use the mobile system with two characteristics: at least 16 megabytes of free RAM and WiFi connection for accessing the Web. Other characteristics are desirable but not a prerequisite to run the system, such as a high definition display.

5.2 Communicating and Synchronizing the Desktop with the Mobile module

Synchronization is the operation that enables persisting the data into a database. Borboleta performs synchronization by sending an XML file via a wireless connection to a server. A very thin Web server places the file on a shared folder. Then, the Desktop module loads this XML and stores the information in the database, as illustrated in Figure 7. The Mobile module obtains the information from the database in the same way. This approach for exchanging information is not the most flexible solution, but it was the fastest way to implement the PDA-Desktop communication and, currently, it is good enough for the scope of the system. We intend to change this way of doing the synchronization when the need for more flexibility arises.

We have chosen to use a wireless network connection to exchange information between the server and the PDA because different PDAs adopt proprietary solutions for communicating with desktop machines through wired channels. Wireless communication, on the other hand, is conducted according to international standards, independently of the PDA manufacturer. Moreover, Java ME, the platform we have employed to implement Borboleta, provides a uniform

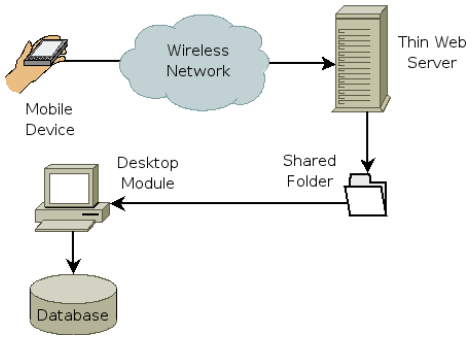

Figure 7: Complete Synchronization Flow

and machine-independent API for wireless communication.

It is important to stress that the synchronization between the PDAs and the desktop machines is asynchronous, enabling disconnected operations on both sides. This means that there is a temporal decoupling between a database update and the time at which the internal record of a PDA is updated with this new information. The PDA user defines the exact moment when this happens.

5.3 Technologies and Methodology

Borboleta is implemented fully in Java, and the Mobile module is targeted at the Java ME platform for mobile devices. We have chosen this technology due to several reasons: Java is in widespread use in several different application areas; Java ME provides easy support for wireless HTTP communication, which we use to synchronize the data between PDAs and desktops; and most importantly, it allows us to run the system in a wide variety of hardware platforms and different OSes such as Windows Mobile, PalmOS and Linux. Furthermore, to standalone applications, there is a myriad of open source libraries and frameworks that Java developers can use. We employ two among them: (1) Hibernate, to facilitate the interaction with the database; and (2) DOM4J, to manipulate the XML files.

The Borboleta system is being developed at the Department of Computer Science of our university using *eXtreme Programming (XP) [2]* as the development methodology. XP suggests two practices that are particularly valuable in our case: strong interaction with the client (in our case, the health care providers) and short release cycles. This is important because the software developers lack the necessary domain expertise to build a system that could be useful in real situations. Second, because the direct interaction with the users helps us prioritizing the most critical requirements to produce useful software rapidly. Third, because the short release cycle guarantees that we get frequent feedback from nurses about the features the developers implement in each new release.

6. PRELIMINARY RESULTS

We have deployed the Borboleta System experimentally on the School of Medicine PHC. This initial deployment aims at making the healthcare providers familiar with the system and with PDA devices, and to help assess whether the system actually meets their needs.

Even though the current deployment of Borboleta is still experimental, we have perceived a reduction on the time nec-

essary to fill in the forms. On average, considering all visit types listed in Table 1, healthcare providers could enter patient information using Borboleta in only 5 minutes. This represents a significant improvement over the time required to fill in the paper forms. We have conducted this experiment using a sample of 40 patient records that are available at the Healthcare Center. The health care providers also emphasized two benefits that we had not foreseen: (i) Borboleta reduces the time necessary to prepare for a visit, since the patient information can be obtained directly from a database, without the need to manually search in a cabinet filled with medical records; and (ii) PDAs are easier to carry than the dozens of medical records they use. Another benefit of Borboleta is that the information entered by the health care providers is stored at a database. Hence, it can be subject to future queries and statistical analysis.

In terms of usability, the team who helped us conduct the experiment found the Borboleta interface very intuitive. They also suggested some improvements and requested new features that we are currently in the process of incorporating into the system.

It is important to stress that these are not definite results, as we still have not evaluated the extensive use of Borboleta in fieldwork over several months. Further evaluation is required in order for us to be able to make claims about the usefulness of the system in the long term. Nevertheless, these preliminary results are promising and encourage us to pursue further improvements to Borboleta.

7. ONGOING AND FUTURE WORK

As we develop Borboleta, many possibilities for improvement arise.For instance, the PHC has a need for an integrated information system to help manage all the services provided by the center in a coordinated way. To be effective, this system would demand a strong integration with Borboleta; indeed, Borboleta would became simply the module responsible for the homecare portion of this system. The scope would gather all kinds of services provided by the Healthcare Center, enabling the collection of more comprehensive data from the tens of thousands of patients covered by the PHC. Having all these data in a single system would allow for various statistical analysis that could lead to improvements in the quality of the health service provided and, consequently, the quality of life of the population. In a second phase, it would be interesting to interconnect multiple PHC systems within a metropolitan area, allowing both for exchange of information and for statistical analysis within a large geographical region. These goals will force us to think more seriously about security, which nowadays is not so crucial because the environment is very restricted with very few people manipulating the mobile devices.

Nurses and physicians continue to request new system features, which we plan to implement in the future. These features include a drug prescription record, adding to the patient profile a list of medicines that has been prescribed. It also includes a picture storage function, allowing the PDA and the database to manage photos of the patient, showing, for example, a skin allergy or the evolution of a wound. Those pictures could be used, for example, by an expert physician back at the PHC or Hospital to follow a case remotely.

Currently, one of our most important concerns is the synchronization process, which has too many steps and depends on precise human interaction to be fully accomplished. We are studying the possibilities of adopting more user-friendly ways to exchange the information and of basing this interaction on Web Services and on international Electronic Health Record (EHR) standards, such as HL7 [3] and OpenEHR [6].

8. CONCLUSIONS

Public homecare health programs in developing countries have brought very significant results in improving the quality of life of low income populations. Further enhancing these health programs with Information Technology support would open a wide range of new possibilities for improving the quality and agility of the services provided. In this paper, we presented the Borboleta system, which offers a comprehensive mobile software infrastructure for collecting and providing medical information for doctors and nurses during homecare assistance. The system has been well received by physicians and nurses and is starting now to be used in real field work.

The Borboleta project is supported by a grant from FAPESP/ Microsoft, Proc. #07/54479-4 and is distributed freely as open source software an can be downloaded from http://borboleta.incubadora.fapesp.br.

9. REFERENCES

[1] D. C. Baumgart. Personal digital assistants in health care: experienced clinicians in the palm of your hand? *The Lancet*, 366(9492):1210–1222, October 2005.

[2] K. Beck and C. Andres. *Extreme Programming Explained: Embrace Change, 2nd Edition*. Addison-Wesley, 2004.

[3] G. W. Beeler. HL7 version 3-An object-oriented methodology for collaborative standards development. *International Journal of Medical Informatics*, 48:151–161, February 1998.

[4] R. Blaser, M. Schnabel, D. Mann, P. Jancke, K. Kuhn, and R. Lenz. Potential prevention of medical errors in casualty surgery by using information technology. In *ACM Symposium on Applied Computing*, pages 285–290, 2004.

[5] M. de Sá, L. Carrico, and P. Antunes. Defining personalized therapies for handheld devices. In *ACM Symposium on Applied Computing*, pages 163–164.

[6] D. Kalra. Electronic health record standards. *IMIA Yearbook 2006*, 1(1):136–144, 2006.

[7] S. Koch. Home telehealth - current state and future trends. *International Journal of Medical Informatics*, 75(8):565–576, 2006.

[8] S. Labkoff, S. Shah, J. Bormel, Y. Lee, and R. Greenes. The Constellation Project: experience and evaluation of personal digital assistants in the clinical environment. In *Proceedings of the 19th Annual Symposium on Computer Applications in Medical Care*, pages 678–682, 1995.

[9] E. McLoughlin, D. O'Sullivan, M. Bertolotto, and D. C. Wilson. Medic - mobile diagnosis for improved care. In *ACM Symposium on Applied Computing*, pages 204–208, 2006.

[10] W. H. Organization. *International Statistical Classification of Diseases and Health Related Problems (The) ICD-10 Second Edition*. World Health Organization, 2004.