# Software Engineering in Telehealth, an Extension of Sana Mobile Applied to the Process of a Routine Hospital*

Alfredo Veiga de Carvalho, Carlos José Pereira de Lucena, Elder José Reioli Cirilo, Paulo Henrique Cardoso Alves, Pedro Augusto da Silva e Souza Miranda, Gustavo Robichez de Carvalho, Fábio Rodrigo Lopes de Araújo, and Gabriel Vial Correa Lima

Department of Informatics - Software Engineering Lab – LES
Pontifical Catholic University of Rio de Janeiro - PUC-Rio
{alfredo,guga}@les.inf.puc-rio.br,
lucena@inf.puc-rio.br, ph.alves@live.com,
{ereioli,pedroampuc,fabiorodrigo.puc,gvclima}@gmail.com

**Abstract.** The patient's medical record, containing the reasons for hospitalization, clinical evolution, laboratory tests, prescription drugs and other relevant information is of utmost importance to medical management care. Information technology plays a key role in communicating and disseminating the patient's clinical data [1]. The Sana Mobile, originally developed by MIT (the Massachusetts Institute of Technology) for mobile platform, consists of an open source electronic medical record. It has revolutionized the delivery of healthcare services in remote areas in a clear and objective way [2]. The mobile device stores Sana medical data, text files, audio and video containing patient's clinical information while transmitting data over the mobile platform to a web server, the Open Medical Record System – OpenMRS. This system gathers information about medications, diagnoses, and others crucial data from a patient, making them available to consultations by many medical experts.

Our tests with Sana Mobile - OpenMRS focus on the development of an experimental extension of this mobile platform and its use in supporting education and training of medical students encompassing routine free ambulatory care and multidisciplinary research project. Participating in this study are researches and students of Software Engineering, Medicine and Design, respectively Software Engineering Lab - LES of the Department of Informatics of the Pontifical Catholic University of Rio de Janeiro - PUC-Rio, the School of Medicine and Surgery of the State University of Rio de Janeiro - UNIRIO which includes Gaffrée and Guinle University Hospital - HUGG, Laboratory of Ergonomics and Usability - LEUI of the Department of Arts and Design at PUC-Rio, under the coordination of LES.

**Keywords:** Software Engineering, Multidisciplinarity, Telemedicine, Learning, Mobility, Usability, Collaboration.

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# 1 Introduction

This document presents the results of this research, the product of human-computer interactions among these three groups with different characteristics and experiences to improve the education and training of medical students in ambulatory care, in this case, patients of Gaffrée and Guinle Hospital - HUGG, with the support of this mobile platform extended to achieve this purpose.

# 2 Survey

This work is part of a three year project [3], started in January of 2011. The context of Software Engineering tells its evolution to the present day, with the conception and development of the Sana Mobile's extension and respective applicability in experiments performed in a hospital routine.

The starting point was the interaction between the project coordinators LES, UNIRIO and LEUI in the area of health, the possible scenarios for applicability of the research considering particularly the target corresponding characteristics, constraints, opportunities and difficulties in light of the achievement of the project. Between the various analyzed scenarios, the experiments considered the most important are: **Indigenous Populations, Health Care Workers, Nursing Staff and Medical Teams**.

The main points considered presented below led to the choice of Medical Teams, which does not prevent new scenarios to be incorporated.

- **Indigenous Populations**: Difficulties in ranging and restrictions on usability that require additional time to search for participants and adequate training.
- **Health Care Workers**: Dispersion of the target audience and its particular interest in the location of the population served led to a massive use of voice communication that alone does not characterize research activity.
- **Nursing Staff**: Needs of the population for laboratorial attendance considering statistical data, include the use of equipment already established for data collection, not relevant to the goals of this project.
- **Medical Teams**: With teams of doctors and students of medicine, it was easier to concentrate different target groups in this region. Another favorable aspect, relevant to the applicability of this scenario, is its alignment with the goals of the research currently carried out in the Lab. of Software Engineering - LES PUC – Rio.

In parallel, other important interactions of the coordinating group were made, considering besides the LES visits to the Center for Telemedicine UNIRIO and also to the Department of Arts and Design at PUC-Rio, the surveys of:

- Equipment requirements for specific infrastructures;
- Human resources for students to be engaged, experiments needed to develop the project;
- Mobile devices to be acquired for the various types of experiments.

About the last item and its use in multiple medical settings, several references were raised and made available for further research studies conducted by multidisciplinary group of participants [4, 5, 6, 7, 8, 9, 10].

## 3 Studies

As a result of the previous phase, equipments for the infrastructure and various mobile devices were purchased as well as the completion of a multidisciplinary team with the incorporation of students in three areas linked to the LES, UNIRIO and LEUI. These actions will potentialize the subsequent studies and research.

Considering the scenario of Medical Teams chosen to lead the experiments, software systems that contemplated all or part of the following segments of the medical field were studied: **Monitoring**, **eHealth** and **Electronic Medical Record**.
The following examples illustrate but do not exhaust the possibilities of use.

- **Monitoring**: Patient connects Bluetooth device attached to its home mHealth device that receives and sends the results to other doctors mHealth from its social network of telemedicine system that can visualize and analyze the results graphically, instructing the patient.
- **eHealth**: The patient arrives at a hospital with a serious injury caused by trauma. The emergency medical team does not have much experience in this case, but immediate surgery is required. The alternative is a high-level monitoring surgical distance by experts on call who would be "biped" to connect their devices mHealth to the sound, images and electrocardiographic parameters, pulse oximetry, heart rate produced by telemedicine system that would guide Local team.
- **Electronic Medical Record**: Built from the monitoring that sends to the patient profile in its network of telemedicine system data files, graphics, photos and videos and exam reports, informing in real time to authorized physicians about the exam which in turn can make diagnoses and prescriptions that are sent to the patient profile that immediately can start the new treatment.

  The patient records "how are you doing" and includes ancient laboratory tests in its electronic medical record system in telemedicine.

  The largest laboratories (three or four) of clinic and image of the city would make an agreement with the telemedicine system and send the results (diagnoses, photos and videos) in standardized formats, from the patient's request, to the cloud of social network making them available immediately to the patient, referring physician and all other doctors already authorized to receive them in their respective mHealth's and so they could interact soon after in order to obtain the optimal collaborative diagnosis.

In these studies, besides Sana Mobile - OpenMRS, Open Source Platform for Patient Monitoring Medical distance, developed at MIT, two additional significant platforms were available:

- **D2L - Capture**: A Cloud platform for creating, recording, editing and publishing Web presentations live or on demand, with perfect synchronization between media, audio and video, developed by the Canadian company Desire2Learn Innovative Learning Technology - D2L [11].
- **Nokia Data Gathering - NDG:** Open Source platform that enables the creation and sharing of forms (for Patients, for example) for quick use at a distance, developed by Nokia [12].

We must remember that, while Sana Mobile Platform - OpenMRS is crucial for experiments and project development, Capture has a significant role in the project documentation as a whole. The NDG assisted in the preparation of the initial draft of the forms of new records. For the operation of Sana Mobile - OpenMRS, we performed a set of installations:

- In mobile devices, Sana Mobile on the Android operating system;
- On the server, the OpenMRS.

After configuring the Android mobile devices purchased for the research, we installed the Sana Mobile in each one, and then we tested some of its native functionality through query simulations. The collection of data in text format and image occurs from a procedure materialized by a succession of screens on the device where the user of the Medical Staff selects the options according to the evaluation of the patient, like a normal consultation. Upon completion of data collection, you can try to connect the device to the Internet to send data to OpenMRS. If there is no connectivity at the moment, the data is queued and sent when the device restores Internet access. The next step was the installation of OpenMRS server to establish the connection to Sana mobile devices. With this goal, we use the operating system Ubuntu 10.04 server and follow the step-by-step installation of OpenMRS documentation MIT, which covers the installation of System Management Databases - DBMS MySQL and Tomcat webserver 6 for its proper operation. Finally we see how the receiving of the OpenMRS data collected is done by the devices and how they can be manipulated by the medical staff on the server. The Sana Mobile, installed on an Android mobile device, works in conjunction with the OpenMRS server as follows:

- A user of the Medical Staff enters the medical records of a patient through Sana;
- These records are sent to the server via an Internet connection;
- Another member of the staff receives data through the OpenMRS interface;
- The health care provider performs the necessary steps so that the patient has the appropriate care.

Upon completion of this phase, this Sana Mobile - OpenMRS Platform original MIT was made available for initial tests by the group of researchers and medical students of the UNIRIO, the set of people that shapes the scenario of the Medical Staff of the project.

# 4 Tests

The results of the experiments follow the different phases of the evolution of the project and the multidisciplinary group interactions. The first refers to those obtained by initial tests with the original MIT Platform. The second, the presentation of the definition of Sana Mobile Extension. The following, the new tests conducted after the development and installation of the extension. The subsequent, the presentation of changes in extension with the adjustments recommended by the application of the previous tests. The final results, obtained after installation of updates in Extension, are the subject of the next item - Results that leverage new experiments to be conducted until the end of the project.

## 4.1 Initial Tests

The Sana original MIT was used extensively by the medical staff, particularly by medical students of the Gaffrée and Guinle University Hospital - HUGG through mobile devices of the project (Android tablets and smartphones), to understand its methodology and usability in collecting data and at the same time, see this data transmitted via the Internet server platform, the OpenMRS. We studied the various models of pre-ready medical records of Sana, covering different topics such as oral and cervical cancer, patient care with TB and HIV, ophthalmological and dermatological screening, Image exams and Prenatal. It was found that for the creation of a new patient form you must fill in the fields with the patient's first and last name, its registration number in the clinic and its date of birth. With these data, you can enter the patient's clinical case since this is already established in the system. Each model of clinical medical records follows its own pattern in recording information, indicating for example the main complaint, the onset of the disease, signs and symptoms relevant to that disease, the patient's medical history, family history, co-morbidities, request and laboratory test results, medications and diagnosis. You must take a picture of the patient through the mobile device associated with the file being created. With all this data filled in, you can save the file on the device and later send it (upload) to the server where it is stored in OpenMRS database platform and can be viewed by the medical staff at any time.

The use of Sana in this first phase of testing has brought new experiences to the multidisciplinary group, but there were difficulties concerning data collection and usability of the models pre-ready medical records of Sana Platform, as described below.

Regarding this last item, the problem of initial use of Sana Platform - OpenMRS was caused by storing dates in the original system MIT (U.S. format "mm/dd/yyyy"), which led to inconsistency in DataBase Management System - DBMS, with the dates of birth of patients (Brazilian format: "dd/mm/yyyy"). This was solved by students of software engineering project with the collaboration by exchanging messages with the Sana MIT team, particularly Erick Winkler.

Experiments using the Sana made by medical students at this early stage were performed by compiling data from patients already registered with HUGG paper forms.

The difficulties of data collection were caused by organizational problems, such as missing documents and exams that should be attached to the form of the patient, as well as filling in the paper forms with errors of language (Portuguese) and illegible orthography. Moreover, it was found that the models pre-ready Sana did not cover most of the needs of data collection for patient care at HUGG, given the scope and variety of medical topics, restricting its usability, signaling the importance of defining an Extension of Sana and their development in the project.

### 4.2 Sana Extension

The experience gained in the previous phase was the starting point for the definition by the Medical Team, particularly the group of medical students from the HUGG, of a new model medical record that encompassed the needs of registering patients in ambulatory and infirmary of the HUGG and could print their records soon after registering through OpenMRS. Through the Nokia Data Gathering - NDG, quoted above, the group of students from UNIRIO created the model of two medical records, called First Step, which covers initial care, and Second Step, for subsequent registration. The records contain the following information about a patient:

- **First Step**: Identifier (Patient registration), First Name, Last Name, Date of Birth, Sex, Photo of the patient (may be more than one), the main complaint, other complaints, comorbidities, other comorbidities, Blood Pressure, Body Temperature, direction, Other Exams and Observations.
- **Second Step**: Identifier (Patient registration), First Name, Last Name, Date of Birth, Sex, Photo of the patient (may be more than one), Provenance, Prescription Drugs in use, Blood Pressure, FR IRMP, Situation, Other complaints, Red blood cells and Creatinine.

The LES team, particularly the group of software engineering students, design software from these medical records created in NDG by medical students of HUGG – UNIRIO, implemented the corresponding medical records in Sana Mobile. The development of this Sana Extension includes new elements called Concepts in OpenMRS server. Each Sana medical records item is associated with a given Concept in OpenMRS. For example, to create a new field - Heart Rate in the medical record on the mobile device with Sana, this concept needs to be inserted before in OpenMRS for the data about Heart Rate can be stored in the mobile device Android with Sana installed, and later, after its transmission via Internet at the Database of the Platform in OpenMRS server. The eXtensible Markup Language - XML was used as the primary tool in the process of building this extension.

### 4.3 Tests with the New Version

The group of medical students from UNIRIO used extensively the initial Sana Mobile Extension to test the whole before putting it into practice in patient care at the Ambulatory and Infirmary of HUGG, which, as planned in the project, will happen only after the development phase and installation of the Extension Settings.

The group HUGG – UNIRIO found two types of problems with the massive use of the Sana Extension: **Operational** and **Usability**, as reported:

- **Operational**: At this stage, the interactions between UNIRIO students (users of Sana) and of LES (the developers) resolved the following problems:

— "Upload unsuccessfully", i.e. the records generated in Sana were not sent to the OpenMRS: Solution with the explanation that the new version of Sana was accompanied by a new server.
— "Reload Database": This option must be executed only at the very beginning of loading the new version and not all the time causing the loss of data transmitted from Sana to OpenMRS.
— The Portuguese orthography caused errors in the data. This is corrected by the current configuration using Portuguese words in English orthography.
— Topics in OpenMRS were out of order which hindered the clinical thought. This was solved by explaining the use of commands in OpenMRS server.
— Delay in data transmission from Sana mobile devices to OpenMRS server, which was caused by low speed connection to the Internet that HUGG had at the time.

- **Usability**: The following problems reported in detail by medical students of UNIRIO, users of the platform, served as input for the next phase of adjustments in the Extension. They are:

— **New version of Sana**: The extension Sana, containing only the records created for the first and second attendances (called First and Second Stage, respectively), both have limitations in their use in the Ambulatory and Infirmary. Relating to First Stage was found the need to insert a field that could detail the aspects related to the patient's pain near the field of the same name present in this medical records regarding to the use in the Ambulatory. In Infirmary, an adaptation should be made, since it is not a first attendance. It is to replace the main complaint of the first call for the motivation of hospitalization because very often the patient already has a diagnostic exam and brings it. Therefore, not all the information found in the patient of the Infirmary can be placed in the medical record first attendance developed in Sana. The second attendance record of these patients was adapted for use as the latest clinical performance made in the patient. The data from their medical records, such as test results, vital signs and medications during hospitalization complete the registration.
— **Form of the Second Stage**: In this medical record, in a determined topic the setup is geared for entering only numbers and not letters, which prevents the addition of other relevant exams, with their names and results. In another, the patient's condition should be added to the existing options of improvement, deterioration, new complaints and healing.
— **Medical records of the original Sana**: The records of the original Sana were discarded in this new version. However, in despite of having limitations, they are useful in the patient record of the Infirmary. The addition of some of these original records of the MIT model is complementary to the current model of Sana.

### 4.4 Adjustments in the Extension

Every phase of this project, as the previous and the following, were accompanied and developed in an integrated manner between the teams of LES, UNIRIO and LEUI. The group LEUI interacted more strongly in the phase of adjustments of the Extension. Effective communication among project participants was done through various interactions via the Internet (including teams of discussion groups – Google Groups and sharing of data and information - Dropbox), and meetings both at PUC-Rio (in LES and LEUI) and at the Gafrée and Guinle Hospital - HUGG (UNIRIO).

From the above interactions, adjustments were performed by students of LES, developing topic images for exams, adding and altering records to other topics of the First and Second Step, and incorporating the medical records of HIV, Tuberculosis, Prenatal, Dermatology, Radiological Exams of the original Sana, according to the requests Medical Staff - UNIRIO.

With the adjustments developed, the LES team delivered the final version of the Sana Extension for use by Medical Staff UNIRIO with patients at the Ambulatory and Infirmary of the HUGG Hospital. The results obtained with this are presented in the following section.

## 5 Results

Along four months, data from 136 patients of the Ambulatory of HUGG were collected by medical students. It was observed that the time spent in completing a medical record using the Extension Sana on mobile device gradually narrowed, because medical students have gained experience with the weekly practice using the system installed in tablets and smartphones, developing assertiveness and also security approach for patients. It was concluded that Sana Extension works as a true facilitator in collecting patient information, optimizing this process, and had contributed greatly to the academic development of the students.

After this period, the multidisciplinary group focused on interactions between UNIRIO and LEUI with the intermediation of LES related to tests using the new platform by medical students of HUGG - UNIRIO. As a result, students test participants showed great familiarity and usability of mobile devices in Sana Extension (as detected in the previous phase above), but not so much with the OpenMRS that until now had not been properly tested, solely for storage purposes of records registered by Sana Extension in its database.

Therefore, the proposal of the new usability test was covering OpenMRS basic functions, such as searching for medical records of patients, organization and editing. We used as parameters the guidelines of students in software engineering of the LES that intermediated the contact of students LEUI and UNIRIO. They were created by LEUI students testing scenarios in OpenMRS with pre-set tasks for students of medicine HUGG - UNIRIO.

During testing, the medical students showed unexpected agility with OpenMRS, because once warned of the test on the system, they studied and learned many of their functions. Therefore, these tasks were performed with reasonable ease. The comments

and behavior of the participants during testing the scenarios showed that the domain about the system is more concerning due a sequence of memorized actions than intuition and understanding of an interface.

It was concluded that the OpenMRS offers valuable resources for physicians, but its interface is not yet able to serve this audience. With a language and mechanics facing to software developers and not for doctors, it shows itself unnecessarily complicated and inhibits the insertion of this tool on a doctor's everyday, which does not occur with the interface Extension Sana Mobile.

We should remember that the primary purpose of using Sana Mobile by medical students of UNIRIO, with its extension developed by the project, was experiencing Platform as a fixation method of learning, especially for:

- Practice what was learned in lectures;
- Develop security of medical student towards the patient and
- Evaluate the preparation of the students coursing the first year at HUGG hospital.

All this set has been fully satisfied, understanding that these results will lead to a positive conclusion of the project, signaling the incorporation of new facilities from the continuity of ongoing experiments, as described below.

## 6 Conclusions

The Extension Sana brought a great contribution to the academic development of medical students engaged in the project. They tested their knowledge acquired in the classroom making medical records and collecting data of patients, through a little anamnesis and basic physical examination such as measuring blood pressure, measuring respiratory frequency and cardiac, capillary glucose and axillary temperature. With this practice, security in managing patients had increased, bringing other good results, including more quickness and efficiency in dealing with them.

Regarding the latter point, it seems that the experimental platform developed besides responding positively to the objective of this part of the project within the context of fixation method of learning for medical students, brought the light of the results, the viability of its incorporation in the process of the daily routine of patient care, particularly in ambulatory care, bringing gains already described as well as the preservation of the patient's history for future visits and possible interactions with other health professionals through the Platform, for example, to share patient data.

For the end of this project, which finishes late this year of 2013, we intend to include also the extension options using GPS, filming and sound recording, existing in original Sana. In addition, a new challenge: incorporating to the platform Sana - OpenMRS the Medical Records Builder which would include the role now performed in a non-integrated mode with the NDG system, as was previously used to define the forms of the extension, as well as the automatic generation of new Concepts in the Platform. This facilitates the definition provided by the construction of new medical records, for example, they can track additional data obtained in the diagnostic investigation of unsolved cases by stages (first and second) established by the project so far,

as they were loaded and the use of them in mobile devices with this new Sana installed.

Simultaneously, we intend to survey the computational resources of OpenMRS, through interactions of groups of LES and UNIRIO defining Use Cases that the medical staff would like to use in OpenMRS. With this result and new interactions between these groups together with the LEUI, a software layer interface on OpenMRS will be built by the team of LES with the design of LEUI for the Medical Staff of UNIRIO can use the cases previously chosen.

With this interdisciplinary research project and their interactions, we intend to contribute effectively for the education and training of students in medicine and facilitate the routine care in hospitals, particularly the poor people without costs, integrating health, usability, mobility and collaboration.

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