Dynamic adaptation software for virtual interconsultation

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Abstract: One of the most important problems in the interconsultation system originated in the rural sphere is to customize the behavior for each specialty, in order to achieve an efficient exchange among the health system actors. In previous experiences with application prototypes, the specialists participants in the requirements engineering process elaborate their specifications as a guide for rural health agent, resulting in so many interfaces as specialties they were consulted. This work present an application web design based on multilayer architecture that allows dynamic adaptation of behavior and user interfaces according to context conditions (such as specialty, interconsultation intended use, consultation, etc). The design also contains a system of electronic health record that essentially serves as a single repository of data from patient encounters and the consultations. The context conditions and the interconsulted specialty are described by metadata which determines the modules that are instantiated, composition of user interfaces and the parts of the patient medical record involved.

Keywords: Telemedicine, eHealth, Health Informatics, Software Architecture

Introduction

The medical information management is complex for several reasons, the variety of the languages used, the variety of submission format, the criticality of the information handled and the multiplicity of scenarios in which it operates.

In the Argentina’s northwestern region and much of the country is scattered in offices, clinics and hospitals, and is present in various forms, from traditional one in paper, to different degrees of computerization, but without the adoption of standards that allow interoperability that makes it very difficult to reach.

On the other hand, as well as from the medical point of view it is desirable to have, under ethical and legal conditions that are required, as much information as possible to describe the situation of a patient. The representation of this has to be effective, providing what is needed in each case quickly and under an intuitive format to each specialty. These requirements, in the context of scenarios such as outpatient clinics, intensive care units, interconsultations as specialists, are just a few examples of different
interaction needs of patient information. For these reasons standards like HL7 CDA [1], OpenEHR [2], define specifications at an abstract level.

A very particular scenario is the medical interconsultations where the information exchanged among health workers is focused on a particular specialty. More specifically, in the interconsultations made at the health rural centers [3] is particularly important to make decisions about attending on site or derive, and whose resolution may be more or less urgent according to the patient care capabilities of the place, specialty, etc. Each specialty has particular aspects that are relevant information to make appropriate decisions. At the same time it depends on the capacity in terms of human resources, care’s complexity level, transfer possibilities, etc.

In this paper we present a web application design based on multi-layer architecture that allows behavior dynamic adaptation and user interfaces according to context conditions (such as specialty, interconsultation intended use, consultation, etc.), which are described by metadata which determine the modules that are instantiated, the composition of user interfaces and parts of the medical records involved. An electronic health record was developed which serves, in interconsultation context, as repository of data from patient encounters and the consultations.

**Rural interconsultation’s scenarios**

The dual phenomenon of isolation by the medical staff and the lack of accessibility for patients has been addressed in previous work which showed prototypes intended interconsultations multimedia web in general and specialized in dermatology [4][5]. The typical scenario posed for these prototypes is shown in Figure 1, where the actors are, on the one hand: a patient and a Rural Hospital’s health worker, which require support service system providing information about the patient’s condition. On the other hand, specialists or specialized institutions provide their points of view as interconsulters.

![Figure 1: Medical interconsultation scenario](image)

Regarding the information entered, one part comes from the data loaded in rural hospitals on web forms present in the application, designed by referents of each specialty. Another part comes from the output of diagnostic equipment, with different characteristics, which are integrated into the patient information (personal data, clinicians, etc.) that sets the basis of exchange between the actors. The web application manages information between the actors and the repository of electronic health record (EHR).

In previous experiences with the development of prototypes and then working with other specialties, was found that, under the scenario of rural interconsultation, they develop their specifications in a form that
serve as a guide to the information required for health workers that establish the consultation. An example of this is the set of user interfaces developed for teledermatology [6], with attributes such as: Reason for visit, number of relatives with the problem, number of deaths with the problem, previous treatments, date of previous treatments, medications during treatment, photographs of injuries, etc, that are not necessarily specific to dermatology, and that can be shared by a group of specialties. Cardiology however, resulted in a more specific set: heart sounds, femoral pulses, palpation of the liver, plus some attributes are also shared as part of physical examination: heart rate, respiratory rate, blood pressure, etc. Specialized interconsultations from pediatrics usually share perinatal data.

In short, from different specialties are generated some common and some specific attributes. In addition, many of the attributes are compounds: blood pressure (minimum, maximum, patient status, instrument, etc), Heart sounds (1st, 2nd, etc.), and such as, indivisible units.

These different points of view are given in the context of the goal of an unified medical record that can be raised in the current application or be part of a more general system of electronic health record, so regardless of specialty, they are part of a whole. The developed web application design is mainly oriented to rural teleconsultations that have two main parts. The first one: a contextually customized medical record ad hoc and the second one: interconsultations system that works synchronously or asynchronously, in which health workers hold conferences. Both the medical record and the interconsultation application are multimedia. The application, which is in use as a prototype, is developing parallel issues such as security and confidentiality of information. In this paper we address the first part architecture, the second one has been developed in previous work [5][6].

To complete the scenario of discussion is important to consider the available technology and its evolution. In rural areas it is important to have flexible adaptation systems for different interfaces such as PCs, tablets or notebooks without impacting the usability of it, allowing the use of the widest possible range given the limited choice.

**Application Architecture**

The web application is developed based on a multilayer architecture, showed in figure 2, with persisted data in MySQL relational database and XML (eXtended Markup Language) metadata files [7]. A DAO (Data Access Object) is responsible for the management and the access to both types of data using specific objects. The control layer manages the events that occur at the interface and connect them to the layer containing the business rules of the application.

![Software Architecture Layers](image)

**Figure 2:** Software Architecture Layers

On the basis of the architecture, we found the data that is structured into a relational database implemented in MySQL. All information generated by the application is in this part. But this layer is also
part of the data structure corresponding to each of the specialties in metadata XML files, which contains information about which of the structure elements should be instantiated. Other metadata file contains information for the presentation’s construction of the user interface in strict correspondence with the above, that is to say, according to each specialty profile. In both cases the metadata is organized into two layers: one composed of XML files that describe information units on clinical observations, called Minimal Unit Descriptors (MUD) and another with the XML files comprising the above according to each specialty, called Integration Descriptors (ID). Figure 3 shows a diagram of metadata layer (the same is repeated for the user interfaces), each integrator generally uses more than a minimum unit.

![Figure 3: Metadata structure. MUD: Minimal Structure Descriptor. ID: Integration Descriptor](image)

The data management layer, developed in Java, contains a DAO (Data Access Object) that consists of a set of classes that map the tables in a relational database with EclipseLink framework support and another set that solves data management built ad-hoc. This layer is also responsible, with the JAXB (Java Architecture for XML Binding) framework’s help, for processing the XML files metadata that characterize the particularities of each specialty and each point of view that the application evolves.

The business layer, also developed in Java, contains the application’s logic, by combining and processing the information. This can be deployed in different points of view: interconsultation problem oriented, patient-oriented medical records, statistics, etc. In this case the first was developed. The business layer manages the dynamic integration of information, which is the way in which the application is dynamically specialized, depending on one or more aspects of the context and it enables to guide the rural health worker in relation to the particular information to develop in the interview.

The control layer is composed mainly of JavaBeans that process the presentation layer’s events, based on Java Server Faces framework.

**Application operation**

Figure 4 shows some examples of data types that describe clinical observations. In the example some of the data is shared between the profiles of medical history of diabetes and cardiology, and others are specific. In both cases the observations are integrated in the profiles described in the metadata.
Classes are minimum units (MU) that are at the data model’s basis and they are reused at a higher level. They represent measures (blood pressure, etc.), specific parts of the medical history (personal background disease-specific families, diagnostics, etc.), And they have one MUD in the metadata. The composition of these units, to be part of a specific medical record, is done at runtime, with background information that allows to instantiate the integration descriptor.

Figure 5 shows XML descriptors, which are part of the metadata. In part A, the descriptors refer to classes that represent blood pressure and Apgar. In part B, is shown an integration’s descriptor portion for pediatric cardiology.

Figure 6 shows the assembly in operation. On the left it is a diagram of the integration descriptor’s relationship (ID) and descriptors of the minimum units (MUD). On the right is shown a similar descriptors’ relationship, obtained from an engine of existing interface generation in the business layer, generating the components of the presentation file representing patient data.
Figure 5a: Minimal Unit Descriptor MUD example, 5b: Integrator Descriptor example

Figure 6: Architecture running. MUD: Minimal Unit Descriptor. UI: User Interface. DAO: Data Access Object. HER: Electronic Health Record.
This architecture can be adapted to the requirements of each specialty, specified by its integration descriptor, adding or removing minimum unit descriptors.

Besides adaptability achieved by integration descriptors and minimum units descriptors, the control layer instantiate different prior descriptors’ points of view such as: a medical record according to patient encounter events with some element of the health system (medical consultation, emergency, etc.), a medical record focused on the problem, statistics on some specialty, illness symptomatology etc. In this case we have developed the first aspect, exemplifying it in Figure 7 with a user interface where the integration descriptor contains general components for any specialty, as the event tree on the left that displays queries, medical records’ general parts concerning each health system-patient encounter. Also the central and the left panels, which contain specific information, are a part of this descriptor. The content of these panels is shown with a dermatology example, which also has multimedia information.

![Figure 7: Dermato Panels](image)

**Conclusions**

The architecture of a multilayer web application was presented, whose development was based on requirements derived from the rural telemedicine experience, particularly of interconsultation. The developed architecture is characterized by its flexibility, in the sense that its layers there are modules that are dynamically instantiated to achieve a particular behavior.

The adaptability model follows two ideas: the first one, it must behave according to the pre-established by specialists fulfilling the interconsultor role, the second one, still in development, refers to that the same application must be used from different points of view. The application is developed on a unique electronic health record system, regardless of whether the profiles adjust to the specialty that is consulted [8].

One of the most important challenges is to reconcile the common aspects to more than one specialty avoiding redundancy of information. This issue is being addressed through the creation of an information model from the smallest units, which refer specifically to clinical information elements, closed to openEHR archetype ideal[2], but without abstracts reference models such as HL7 RIM [9] or the reference model openEHR [10]. From the point of view of future work orientations, immediate ones refer to the
experiences development with various converged specialties, testing the application’s adaptability and flexibility. Another aspect has to do with the system interoperability. While it was not the medical record development the initial target, the lack of electronic medical record reference in the healthcare system, led us to the development of this, with an evolutionary approach, guided by the needs of our application.

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