A Web Application to Support Telemedicine Services in Brazil

Ana Karina P. Barbosa(1), M.Sc.; Magdala de A. Novaes(2), PhD;
Alexandre M. L. de Vasconcelos(3), PhD

(1) Master, Researcher of TIS, Federal University of Pernambuco (UFPE), akpb@lika.ufpe.br
(2) PhD, Associate Professor, Clinical Medicine, Federal University of Pernambuco (UFPE), Researcher and Coordinator of the Research Group on Information Technologies for Health (TIS), man@lika.ufpe.br
(3) PhD, Associate Professor, Clinical Medicine, Federal University of Pernambuco (UFPE), Informatics Center, amlv@cin.ufpe.br
TIS/LIKA-UFPE, Av. Prof. Moraes Rego S/n, Cidade Universitária, Recife-PE, 50.670-901, Brazil, Tel. +55 81 32718489, Fax +55 81 32718485

Abstract

This paper describes a system that has been developed to support Telemedicine activities in Brazil, a country that has serious problems in the delivery of health services. The system is a part of the broader Tele-health Project that has been developed to make health services more accessible to the low-income population in the northeast region. The HealthNet system is based upon a pilot area that uses fetal and pediatric cardiology. This article describes both the system's conceptual model, including the tele-diagnosis and second medical opinion services, as well as its architecture and development stages. The system model describes both collaborating tools used asynchronously, such as discussion forums, and synchronous tools, such as videoconference services. Web and free-of-charge tools are utilized for implementation, such as Java and MySQL database. Furthermore, an interface with Electronic Patient Record (EPR) systems using Extended Markup Language (XML) technology is also proposed. Finally, considerations concerning the development and implementation process are presented.

1. Introduction

The complexity that characterizes health information management has motivated enterprises and institutions to develop technological solutions to hasten and improve the quality of patient attendance, to prevent diseases and foster greater health awareness.

In Brazil, the high costs of diagnosis and therapeutic procedures, the lack of control of service usage, the growth in, and aging of, the population are some of the problems affecting national public health. Apart from these issues, the large concentration of health services in urban areas, the lack of specialists in more remote areas and the low number of professionals trained in family medicine have made health delivery less accessible to poor people. The Brazilian government has taken stock of this situation and has started to invest in pilot projects to evaluate Telemedicine usage as a complementary tool to health services by considering both national and international experiences[1,2,3]. One of these initiatives is the Telehealth project, which is to be deployed in Pernambuco, a state in the northeast of Brazil. The HealthNet system[4] described in this paper is the core of this project. This integrated system was defined to support Telediagnosis and Second Medical Opinion.

The HealthNet Telediagnosis service will allow health practitioners who live in rural, out-of-the-way places, to interact with medical specialists in order to correctly diagnose their patients. The interaction will be digital, thus eliminating the need for participants to travel. The connection with a Health Reference Center will initially be made via Integrated Services Digital Network (ISDN) channels and subsequently via the Internet. The HealthNet Second Medical Opinion service will allow doctors in Reference Centers that are geographically separated to cooperate in clinical patient cases. The main benefits of this service are its potential to reduce treatment costs as well as the incidence of risks and errors. In the HealthNet environment, doctors will be able to discuss patient cases though the second opinion service with other doctors. The patient cases will be generated via the Telediagnosis service or they will be generated by the doctors who collect data within their own institution. Generally uncommon cases or cases that comprise more than one medical specialty are dealt with in collaboration. The Reference Centers will be connected through an Asynchronous Transfer Mode (ATM) network and will form what will be called an *Integrated Network of Cooperation in Health*.

2. Methods

Fern and Pediatric Cardiology were chosen to be the pilot area to the project. This area has large social repercussions and presents situations where attendance must be immediate in order to diagnose, plan and treat many serious cardiac diseases.

The system's conceptual model regarding remote diagnosis and second medical opinion was based upon requirements obtained by a literature review of Telemedicine development and system usage, and on information collected from both sides of the attendance: the basic service and the Reference Center, in this case the Fetal and Pediatric Cardiology Unit (UCMF) at the Real Hospital Português, one of the partners in this project based in the state capital, Recife.

At first, a system model prototype[5] was implemented using Delphi language working in a point-to-point network using ISDN channels Through this system a health-worker could send patient information by e-mail to a Reference Center in order to be evaluated by a medical specialist. The patient data was organized into demographic data and clinical cases. The application was customized to allow the capture of images and videos of echocardiography examinations which could then be attached to patient case history. The application was deployed and tested at Saint Efigênia Hospital in Caruaru, 136 km inland from Recife, the state capital. Telediagnosis service requests were made to the Fetal and Pediatric Cardiology Unit at the Real Hospital Português in Recife. This initial experience revealed that the transmission of multimedia data is effective in the diagnosis of congenital cardiology diseases in patients.

It was clear from the results obtained from this first prototype and a more detailed requirement analysis that apart from having a tool capable of supporting remote diagnosis others would also have to be developed in order to manage Telediagnosis and to manage medical second opinion. This is particularly the case once the Telemedicine system has been incorporated into clinical practice. This kind of system could also generate relevant information for the public health information system. In this new context HealthNet was proposed.

HealthNet Architecture

HealthNet was designed to be a Web based system, supporting not only the Telediagnosis service, but also medical cooperation between Health Reference Centers. A decentralized architecture was proposed in order to allow each Reference Center to have its own database and independent telediagnosis services, thereby guaranteeing institutional autonomy. To support this architecture, two subsystems were designed: HealthNet User and HealthNet Manager[6]. HealthNet User is the subsystem installed in each Reference Center that interacts directly with the user. The HealthNet User itself is a complete and independent system which supplies Telediagnosis services and internal second medical opinion (within the same institution). Through it, the user will also have access to the functions provided by the HealthNet Manager. The HealthNet Manager subsystem consists of a group of objects that will be distributed in the Asynchronous Transfer Mode Network that will support the second medical opinion service among the Reference Centers.

The HealthNet User subsystem is object oriented, having followed the layer architecture described in Viana[7] in order to guarantee reusability, portability and easy maintenance. There are three layers: the interface layer, the business layer and the data access layer.

The Interface Layer, presented in figure 1, is responsible for the user interaction with the system. This layer presents an instance of *HealthNet Interface* class and a set of instances of *HealthNet Handler* classes. The *HealthNet Interface* object receives all the operational requests and data from the user. For each operation requested, this object starts a specific *HealthNet Handler* object to answer the request. The *HealthNet Handler* object receives the parameters introduced by the user through the *HealthNet Interface* object and requests the business layer to accomplish the specific operation. After receiving the answer from the business layer the object presents the answer to the user.

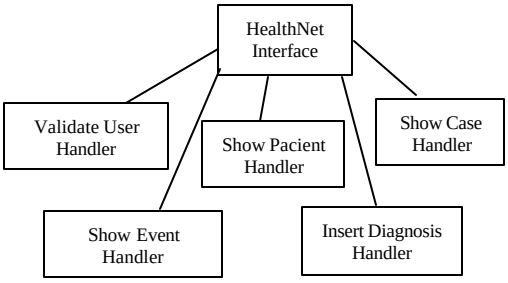

Figure 1 – Interface Layer

The Business Layer is responsible for the system's logic and comprises of the objects inherent to the application domain. Figure 2 represents this layer.

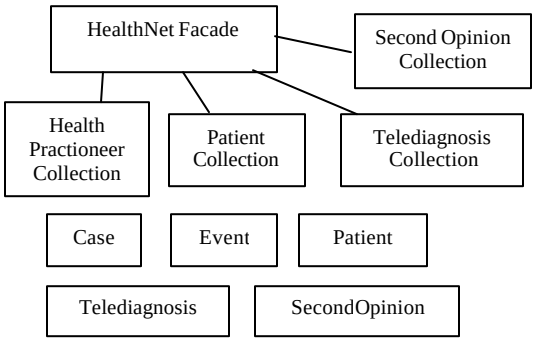

Figure 2 – Business Layer

The Business layer comprises objects from the following classes:

- **Basic Business Classes:** represent basic concepts from the application domain. These can be persistent or not. Figure 2 presents some of the basic classes. Figure 3 illustrates the complete model of basic classes and their relationships.

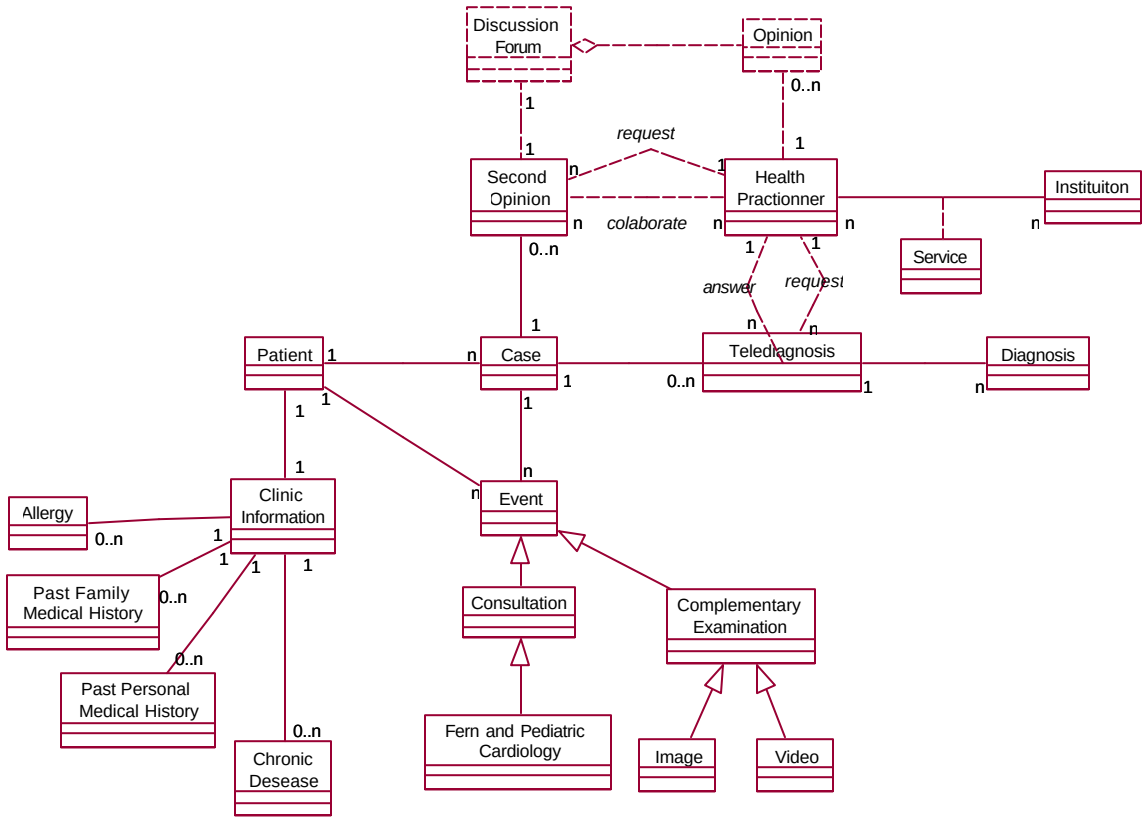

Figure 3 – Basic Classes: Complete Model

- **Business Collection Classes:** represent basic class collections. These collections are responsible for the insertion, deletion, updating and querying of instances of the basic classes.

- **HealthNet Facade Class:** there is only one instance of this class in the Business layer. This follows the design standard *Facade*[8]. It represents all the services of the system, centralizing the business collection instances and encapsulating the restrictions among them. It manages the system transactions.

In order to guarantee usability, the business layer object model is designed to be easily adapted to support a great number of medical specialties. Information on each patient is recorded. This includes demographic information, a set of general clinic information such as allergies, chronic diseases, past personal and family medical history and clinical cases. Each case is formed by a general description

and a set of events that can be office visits, and exam results, such as medical images and videos. The office visit data model will be specific to each medical specialty.

The Data Access Layer is responsible for accessing the data storage medium. It contains classes that actually implement the interface for a specific storage medium. In the case of HealthNet, these classes will store the system data in a relational database. Figure 4 shows this layer.

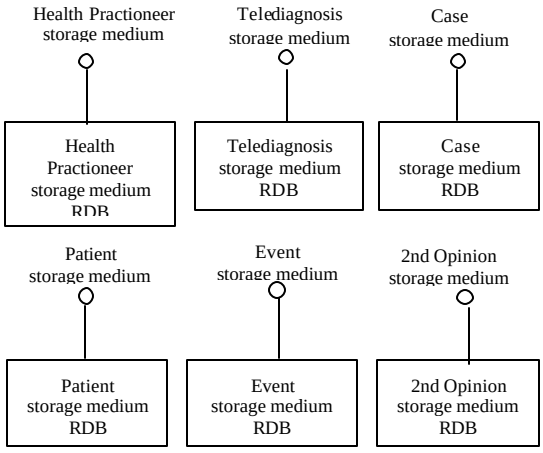

Figura 4 – Data Access Layer

The HealthNet Manager subsystem is composed of a set of objects that will be distributed in the Asynchronous Transfer Mode network to support the second opinion service. These objects allow a doctor to visualize a case and offer an opinion without having to worry about which database the case is stored in. For the implementation of HealthNet Manager, two types of objects were considered: the HealthNet Mediator and the

HealthNet Institution Server. There will only be one instance of the mediator object in the whole network (this object can be started up in any node of the network), whereas there will be an instance of the HealthNet Institution Server object for each institution that participates in the Integrated Network. The mediator object will have knowledge of all HealthNet Institution Server objects available in the network. Every time a user of the system requests a second opinion service, their request will be directed to the mediator object. The mediator in turn will activate and control the HealthNet Institution Server objects needed to answer the request. The HealthNet Institution Server objects execute the requested operation and return the result to the mediator, which finally relays it back to the user of the system. The HealthNet Institution Server object is responsible for consulting and inserting the second opinion process data into the HealthNet database of the respective institution. It stays on stand-by, waiting for some request from the mediator object.

Collaborating Tools

During a collaborating process, the doctors have access to the patient case and are able to interact through both asynchronous and synchronous conference tools. The Discussion Forum is an asynchronous tool in which opinions sent by the collaborators are stored and made available for visualization by all the participants. Synchronous tools include Chats and Videoconferences. The videoconference is a sufficiently easy and efficient means of conducting a long distance discussion due to its visual and audio identification. In order to have a high quality videoconference suitable equipment and trained operators are required. Yet more economic and simpler options can be adopted. One of these is to use the VIC/RAT developed in Berkley. Apart from already having been tested in several high speed networks in Brazil, this system is free and multicast.

HealthNet interoperability

In order to better evaluate patient cases it is important for the doctor to have access to the largest amount of information about the patient history possible. Patient records can be stored in Electronic Patient Records in hospitals that are part of the Integrated Network. So with the agreement of the participating Hospitals in the Network, there will be the creation and standardization of an access interface to the Electronic Patient Records, through which HealthNet will be able to get information about a patient. This interface will be constructed by each Hospital and will be able to generate Extended Markup Language (XML) files containing the data requested by HealthNet. A language described in a Document Type Definition (DTD) has been established so that the hospitals will be able to construct the XML files.

3. Results

This project has been running since 1999. The first HealthNet module related to the Telediagnosis Service has already been implemented and is to be deployed in Clinical Hospital at the Federal University of Pernambuco and used to support the Family Health Program. The good results obtained so far have helped win further government grants for the project and to continue the development of the entire system.

Once the Telediagnosis service has been set up and is operating work will begin on the Second Medical Opinion service. Usability aspects will be evaluated throughout the utilization of the Telediagnosis

service in order to fine-tune the system. This will be followed by setting up a project to incorporate new services into the system which foresee the management of clinical cases for clinical research ends and continuous medical education assistance. It is expected that the bases of clinical cases generated contain relevant information for the production of health indices. This project also forecasts the implementation of patient safety and confidentiality policies based on international regulations and adapted to Brazilian policy.

The HealthNet system design has been validated and its development process has allowed some points related to the development of Telemedicine systems to be inferred. Telemedicine can be conducted with the most modern and sophisticated technologies, however, the costs of implantation and maintenance of these systems can make this activity impracticable in routine medicine. In many circumstances cheaper options are available. Both the medical community and information technology and telecommunication professionals must share the responsibility to identify the most appropriate technologies for each application. HealthNet was implemented with free-of-charge technologies such as Java programming language, the Apache Web server, the Tom Cat Servlets Server and the MySQL data base. Although the tests were not exhaustive, such technologies have shown themselves to be suitable for this type of system.

Apart from being affordable, a Telemedicine system also needs to be carefully planned and designed. The HealthNet data model was designed with the minimum of information necessary to support the Telediagnosis and Second Opinion services without overloading doctors with unnecessary information that could harm the process. The choice of an architecture that allows the management of complexity, while guaranteeing easy development, portability and ease of maintenance, was also of great importance. The object oriented architecture structured in layers presented in the HealthNet allowed these qualities to be achieved.

In order to turn a Telemedicine system into reality some non-technical points must be clarified. It is important to emphasize that any Telemedicine project must define mechanisms that make it self-sustainable. One of these is undoubtedly the formalization of second medical opinion using a digital medium as an assistance activity that is legally recognized, payable and supported by ethics. The first steps towards achieving this have been taken with the announcement of two resolutions on Electronic Patient Record and Telemedicine by the Brazilian Medicine Federal Council. Another point is the acceptance of digital medical assistance provision. Telemedicine implies changes in the way that health professionals give medical assistance and cooperate. As resistance is a frequent problem when new technologies are introduced it is important to allow the participation of medical teams during the process of the system development so that they get used to the new methods and feel part of the changing process. Once the system has been deployed it is also important to accompany the system utilization by doctors and health agents for continuing training purposes and system evolution. The experience gained during this project has been used as a reference by institutions in other regions of Brazil with similar features.

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