The New Navigators: from Professionals to Patients
R. Baud et al. (Eds.)
IOS Press, 2003

A Dynamic Web Application within an n-tier Architecture: a Multi-Source Information System for End-Stage Renal Disease

Mohamed Ben Saïd[a], Ana Simonet[b], Didier Guillon[b], Christian Jacquelinet[c], Franck Gaspoz[b], Eric Dufour[d], Claude Mugnier[a], Jean Philippe Jais[a], Michel Simonet[b#], Paul Landais[a#]

[a]Service de Biostatistique et d'Informatique Médicale, Hôpital Necker, Université Paris 5, France
[b] TIMC-IMAG, Université J. Fourier, Grenoble, France
[c]Etablissement français des Greffes, Paris, France
[d]R2i Développement, Caen, France
[#] both authors equally contributed to the work.

Abstract

A Multi-Source Information System (MSIS) has been designed for the Renal Epidemiology and Information Network (REIN) dedicated to End-Stage Renal Disease. Interoperability has been considered at 4 levels: semantics, network, formats and contents. An n-tier architecture has been chosen at the network level. It is made out of a universal client, a dynamic Web server connected to a production database and to a data warehouse. The MSIS is patient-oriented, based on a regional organization. Its implementation in the context of a regional experimentation is presented with insights on the design and underlying technologies. The n-tier architecture is a robust model and flexible enough to aggregate multiple information sources and integrate modular developments. The data warehouse is dedicated to support health care decision-making.

Key words
Dynamic Web interface; n-tier architecture; Multi-Source Information System; Data warehouse; Business logic; end-stage renal disease

1. Introduction

Nearly 42,000 patients suffering from end-stage renal disease (ESRD) have been treated this year in France. However, no coordinated information is available. The Renal Epidemiology and Information Network (REIN) is dedicated to respond to this information need [1]. The REIN program is organized at a national and at a regional level. It was experimentally developed via a regional feasibility study in 4 regions: Limousin, Languedoc-Roussillon, Lorraine and Rhône-Alpes. A national committee for guidance and follow-up involves several organizations: Société de Néphrologie, Société francophone de dialyse, INSERM, Paris 5 University and J. Fourier Grenoble University, Institut de Veille Sanitaire, Etablissement français des Greffes (EfG), and representatives of patients' associations. In a collaborative work, guidelines for the REIN program and for the MSIS-REIN system have been specified [2].

2. Material and Methods

Patients and organizational support

The Multi-Source Information System (MSIS-REIN) is currently being tested in two administrative regions: Limousin and Languedoc-Roussillon. In the Limousin region (710,939 inhabitants), the target population was easy to identify since the number of ESRD treatment units was limited. There was no prior information system dedicated to ESRD patients and the potential commitment of the professionals was important. Languedoc-Roussillon, (2,295,648 inhabitants), is a larger administrative region with diversified health care structures for treatment of ESRD. Local proprietary information systems dedicated to ESRD did exist in some units of this region.
A regional relay brings together decision makers, health professionals including a nephrologist as the regional representative of the Multi-Source Information System (MSIS-REIN), an epidemiologist who ensures the control of exhaustiveness and quality, and patient representatives. Local agreements, federating the actors, have been signed in each region. They have been documented in a "User Agreement Document" followed by bilateral conventions between EfG and the partners.

MSIS main objectives and architecture

MSIS-REIN is dedicated to collect continuous and exhaustive records of all ESRD cases and their clinical follow-up. It collates in a standardized representation a minimal patient record elaborated by health professionals. MSIS aimed to fulfill the following requirements: scalability, portability, reliability, accessibility, and cost effectiveness oriented toward non-proprietary software. The use of standard references, the respect of privacy, confidentiality and security [3] of patient information were required as well.
The architecture of MSIS-REIN, represented in figure 1, is based on an n-tier architecture [4]. The client tier connects to a middle tier that is in relation with several databases. The client tier uses a Web browser to communicate. The middle tier supports client services through Web containers and business logic services through component containers. The information system tier may access 3 types of database: the identification database, the production database and the data warehouse. Business logic components in the middleware support transactions toward the databases.

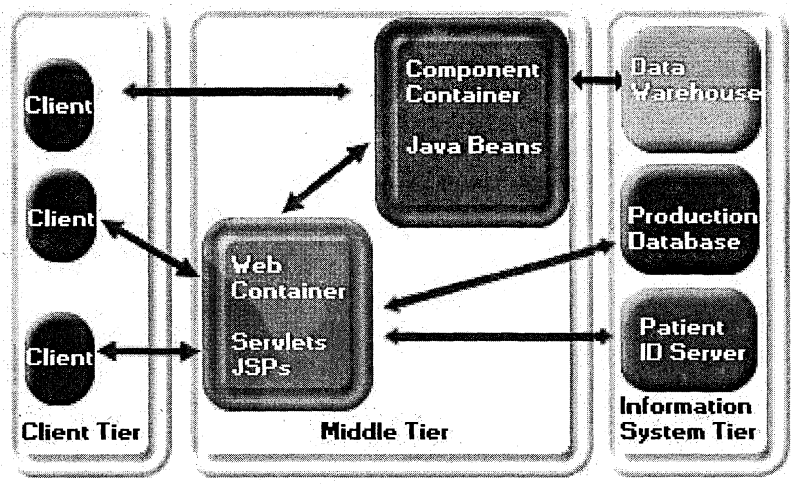

Figure 1 – MSIS-REIN n-tiers architecture

Web server application

As part of the MSIS-REIN, a Web server application has been developed to interact with the production database system. It consists of a collection of Web components: Java Server Pages™ (JSP), Servlets and other resources (graphics, scripting programs or plug-ins) organized in a directory structure. Web components interact within a Web container, which corresponds to a runtime environment providing a context and a life cycle management [4]. Tomcat is the Web container used in MSIS-REIN. It is free and available as open source software. JSPs have been used, an extensible Web technology that uses template data, HTML or XML elements, custom elements, scripting languages and server-side Java objects to return dynamic content to a client, usually a Web browser. Servlets have also been used. A Servlet is a Java program that extends the functionality of a Web server, generating dynamic content and interacting with a client using a request-response paradigm. JSPs are compiled into Java Servlets at the server side. As the source file is modified, JSPs are compiled and run "on the fly", while Servlets need to be compiled first into Java classes. In MSIS-REIN, Forte For Java Community Edition™ is used to compile Java programs. The Web application has been developed under Windows™ and deployed in a Linux environment.

Screen layout design and user interface

Once a connection with the MSIS-REIN server is established and the user authenticated, a first screen with the principal navigational possibilities is displayed. It introduces the screen structure, and the different functionalities represented in figure 2. Customized areas for the region and for each ESRD treatment unit are illustrated by specific logos. A palette-menu area is provided for browsing the main chapters. Patient information can be accessed within 2 mouse clicks whatever the user's position in the application [5, 6].

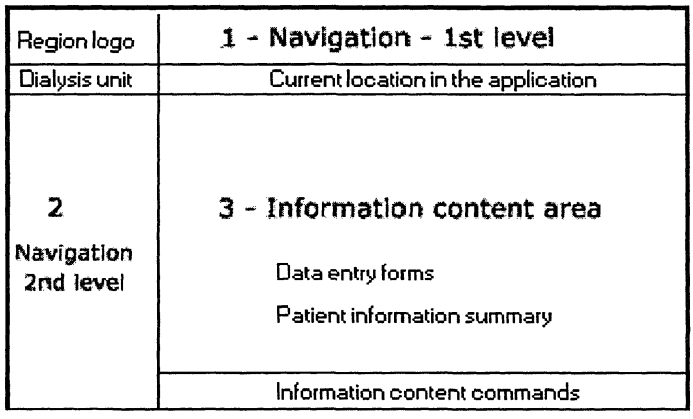

Figure 2 – Screen layout structure

Production database

Designed to support day-to-day operations and updates, a production database system is transaction-driven and requires a rapid response time and a high availability. It deals generally with few records and is accessed by multiple users connected using a large network. It is a domain-oriented application. MySQL™[7] was selected as database server in the experimentation phase for its reliability in the context of Internet and its free availability as an "Open Source" software, supported by a large community of developers.

Data warehouse

A data warehouse [8, 9] has been created which builds up unified views of patient information, generated from distinct databases. Unlike the production database, the data warehouse is a collection of data which are subject-oriented, integrated, time variant, non volatile and organized to support analytical and decision processes. Data are not created "de novo" by end-users, but derived periodically from the production database considering cautiously privacy, integrity and confidentiality. The updating process identifies the necessary information to transfer, aggregates and integrates data into a new state or in a new version of an existing state. The update process has also been designed to yield the extensions of the persistent views, to check the consistency of the integrated information, to manage message acknowledgements and to update data warehouse dictionaries. When the state of the data warehouse changes, new persistent views and data presentations are generated and made available to the users.

Information fluxes and networking

MSIS-REIN is oriented towards interoperability at three levels: local, corresponding to the ESRD treatment units, regional and national. Information is transferred through a secured extranet enabling confidentiality and data availability. Interoperability at the networking level refers to integrating heterogeneous hardware, software and computer environments taking into account security requirements and communication protocols. MSIS-REIN takes advantage of the capacity of multiple information systems to exchange and analyse information. MSIS-REIN integrates four paradigms: semantics, networking, formatting, and contents as presented earlier.

A rapid connection such as Asymmetrical Digital Subscriber Line (ADSL) connection or faster like Renater, the French inter-university network, is recommended to use MSIS-REIN. Data is encrypted and transferred via a secure connection, which requires Web browsers, 6.0 or newer for Internet Explorer and 6.2 or newer for Netscape. Older Web browser versions do not support the encryption level used in MSIS-REIN.

3. Results

The client interface was successfully tested. Data entry forms are highly structured and separated into blocks, requiring either scrolling or section links in order to "jump" to different sections, as represented in figure 3. A number of controls aim at making data entry easier and at making sure that the information, which will be sent to the server, is consistent. Some controls check data format, field length and the range of possible values. Other controls check contextual and logical consistency within subsets of information such as co-morbidities, methods of treatment or dates. To avoid free text entry variations and typing errors, requests are sent to online dictionaries and the user selects thesaurus items. This facility was first developed for medical diagnoses entry. It refers to the thesaurus of Nephrology or to the International Classification of Diseases 10^{th} version (ICD10) thesaurus. It has been extended to administrative information such as city of residency or birth. A checklist reminds the user of the minimal requested information to create or update a patient record. Additional controls delimit the way to submit data to the server.

Confidentiality issues and functional specifications have influenced the design of the production database. A conceptual model was implemented to document patient clinical events such as: admission in ESRD treatment unit, follow-up, change in the treatment modalities, and transfer from one unit to another or death. Once validated and consolidated, patient information is processed in such a way that anonymous data is generated and periodically exported to the data warehouse.

In Limousin, data collection is exhaustive, including patients treated for the first time this

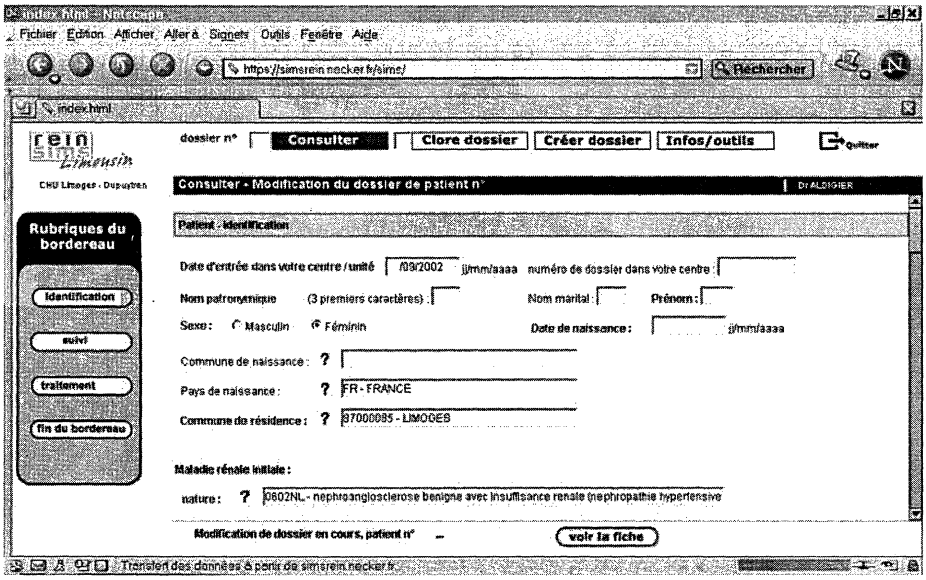

Figure 3 – Example of MSIS-REIN screen: patient data entry form.

year (2002). Average entry duration per patient record is about 5 minutes. This experimentation has also made it possible to simulate data transfer between the production database and the data warehouse, to develop queries interfaces and persistent views, and to generate dynamic responses with geographical representations.

The use of MSIS-REIN in Languedoc-Roussillon has showed its ease of use and efficiency to respond to local needs of information management. The regional experimentation enabled us to refine the Web application and facilitate the information flow between the MSIS-REIN components. A particular improvement was reached for the entry form at the client side.

4. Discussion

For the users, the objectives of an efficient networked information system are to avoid redundancy, to reduce data entry tasks and, in return, to obtain structured results. Users work on different platforms and use different software. Our focus during the design and experimentation of MSIS-REIN was to adapt to existing environments and habits and to introduce as few changes as possible. The paradigm of interoperability has been privileged in particular on the networking part. The overall architecture is based on an n-tier architecture, which separates production from analytical systems and integrates a component organization approach. This n-tier architecture offers new possibilities to manage the information flow. On the end-user side, a universal Web browser allows users to interact with the system. Data is encrypted and transferred via a secure connection. The advantage of this solution is its portability. The middleware provides the system with necessary dynamics to transfer information to the databases and allows user interaction. If required, adding databases to the information system tier will not introduce major changes in the general architecture. MSIS-REIN has been designed to support a greater number of regions and ESRD treatment units, without major work overload.

The attention of the professionals in Limousin is drawn to the quality control and consolidation of the information entered in the system. Using MSIS-REIN in Languedoc-

Roussillon, where ESRD dedicated information systems are partially used, is often looked at as a work overload rather than a potentially helpful process. Such difficulties raise the issue of interfacing MSIS-REIN with existing systems, and a generic solution based on publishing an XML data model used in MSIS-REIN has been proposed.
The implementation of the identification server in the next release will help to guarantee the uniqueness of patient representation in MSIS-REIN. Automatic reminders will assist the professionals in consolidating information and updating annual follow-up information. The data warehouse functionalities are also bound to grow to respond to the needs of health care professionals and decision makers.
The success of an information network such as MSIS-REIN is highly dependent on human factors. Beside technology improvements, it is necessary to identify resistance to changes and to deploy didactic skills to help users in understanding and adapting to this new interactive information network.

5. Conclusion

The n-tier architecture is a robust model and flexible enough to aggregate multiple information sources and integrate modular programming developments. The data warehouse is the core of the data that supports health care decision-making. The MSIS-REIN model developed for ESRD might be exported to other domains of medicine, particularly for the follow-up of other chronic diseases.

6. Acknowledgments

The nephrologists in charge of the ESRD units of Limousin and Languedoc-Roussillon are acknowledged for their fruitful cooperation and comments. JP Necker and X Ferreira are acknowledged for their skillful help and Ms D Bernhard for rereading the manuscript. This work was supported by a grant of the Ministère de l'Education Nationale, de la Recherche et de la Technologie N°99B0625 and by University of Paris 5.

7. References

[1] Landais P. L'insuffisance rénale terminale en France : offre de soins et prévention. *Presse Med.*2002; 31:176-85.

[2] Landais P, Simonet A, Guillon D, Jacquelinet C, Ben Saïd M, Mugnier C, Simonet M. SIMS@REIN : Un Système d'Information Multi-Sources pour l'Insuffisance Rénale Terminale. *CR Biol* 2002;325:515-528.

[3] Rindfleisch TC. Privacy, Information Technology, and Health Care. *Communications of the ACM* August 1997; 40; 93-100

[4] Kassem N, Enterprise team. Designing Enterprise Applications with the Java™ 2 Platform, Enterprise Edition. *Addison-Wesley* New York 2000, pp 341.

[5] Marcus A. Graphic Design for Electronic Documents and User Interfaces. ACM Press. New York. 1992. pp 266.

[6] Nielsen J. Designing Web Usability . New Riders Publ. Indianapolis. 2000. pp 419.

[7] Dubois P. MySQL. Campuserve : Paris, 2000, pp 750.

[8] Jones K. An Introduction to Data Warehousing: What Are the Implications for the Network? *Int. J. Network Mgmt* 1998; 8:42-56.

[9] Kimball R. The Data warehouse Toolkit: Practical Techniques for Building Dimensional Data warehouses. *John Wiley.* 1996; pp 416.

8. Address for correspondence

Dr Paul Landais, Service de Biostatistique et d'Informatique Médicale, Hôpital Necker-Enfants Malades, Université Paris 5. 149, rue de Sèvres, 75743 Paris cedex 15. e-mail : landais@necker.fr