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A Hypermedia-based Medical Records Management System

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Abstract

This article presents a new way to manage computerized medical records, based on a totally-hypermedia system. As a matter of fact, the classical use of a database limits the necessary variability of the medical record, in function of both the patient profile and the care practitioner habits. The system we propose is based on a hospital Intranet, and on the XML language. This language allows the definition of semantic tags in hyperdocuments, and thus information retrieval is ensured through semantic tags indexation.

Keywords

Medical Record, Information Systems, Hypermedia Documents, Flexibility

Introduction

Computerization of the medical record is still a difficult point. The reasons for this are numerous :

- computing in hospital has been introduced by administrative staff, to get an easier management of the administrative information concerning the patient. This first computerization has induced additional work to the medical practitioners, without bringing any advantages to their daily practice.
- computing is still synonymous to structure and codification of activities and information. This state is not compatible with the medical practice, which requires one different behavior for each patient.
- in the classical computerized systems, communication needs between different entities (services) in hospital is antinomic with specificities of each entity. As a matter of fact, sharing information is done based on a unique model, which has to be followed by each entity. This is not applicable in hospital, where each service is highly specific.

From these points, one can notice that the most important characteristic of the medical record is its variability in function of both the patient and the service in which he is taken in charge.

The aim of this article is to propose a new way to computerize the medical record in hospital, so that each service (and even each medical practitioner) is able to manage the medical record of each patient in a totally adapted manner, without having to follow restrictions due to the computer.

Let us first have a look at the classical paper-based record. This record is the memory of the medical history of the patient. It contains a huge amount of documents. These documents are of very different types, come from various care practitioners, and may be accessed by many different persons. The medical record in hospital is thus a set of interconnected documents which are transmitted from one care practitioner to another. This way of working is very close to the Intranet concept. An Intranet is an internal network which allows the sharing of documents of many different types among the users having a connection to this network. The documents managed in an intranet can be hypermedia documents, that is to say they allow the management of any type of data, and links between these documents allow the navigation across these documents. The first step in our research group has thus been to choose to manipulate the medical record as an Intranet [1]. We thus have used the Web techniques and the HTML language to implement a computerized medical record system in the hospital private network. This approach has also been used in other research groups [2, 3].

The main advantages of the hypertext technique is the following : hypermedia permits the presentation of any type of data ; it can get information from a database and/or a file system ; the hypermedia documents are most of the time a simple translation of paper-based documents and thus no adaptability efforts are required from end-users ; hyperlinks are intuitive means of navigation in the hypertext network.

Behind the hypermedia user interface, the use of a database has been chosen to store data, first to allow the connection of the intranet to the administrative database of the hospital, and second to ensure security and organization of information (and thus retrieval and query of information). The documents which are provided to the end-user are not classical documents, but are built on demand from two elements :

- data extracted from the database,
- a presentation skeleton, which provides the appearance of information in the document.

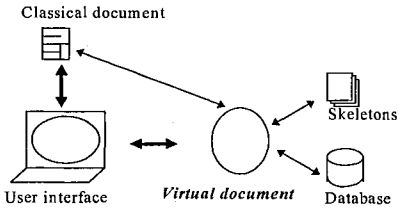

Figure 2 - Virtual documents-based system

These are virtual documents (see Fig. 1).

In such a system, even if the user interface looks greatly like paper-based records, only half of the problem has been solved : the documents should be adaptable to each user group of the system. Adaptation of a software to each service is a critical research issue in computer science. As a matter of fact, the development of one application for each service is the best solution, but it is highly expensive, and puts communication problems. The other existing solution for the adaptation of a software is the use of software packages, but these are most of the time not adaptable enough, or require important modifications (and thus increase the costs).

We thus have proposed a new way to develop information systems based on generic systems [4]. In a generic system, the computer scientists team develops a canvas of software usable for a whole application domain (e.g. medical records management). This generic system contains the most representative elements of the application domain, but does not make any thing compulsory. A specific future end-user of the system (the user-designer) thus gets the generic system and adapts it to the particular needs of his service. The generic system is composed of two elements : a generic model (the database model, in a form understandable by the user-designer), and the generic user interface, which uses hypermedia concepts. The user-designer can adapt the generic system by modifying the generic model, and also by defining his own hyperdocuments (see Fig.2).

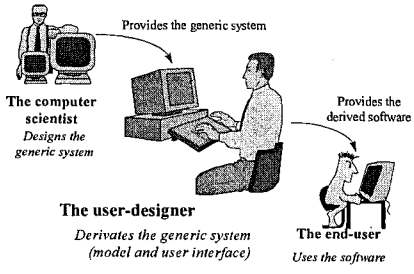

Figure 3 - Generic system

Genericity has thus many advantages for the medical record management.: It follows the hypermedia techniques for the user interface ; it allows adaptation of the medical record form to each service in hospital ; it does not cost as much as specific developments ; as adaptations are made by an end-user, they are highly close to the specific needs of the service targeted.

The two ideas of using hypermedia and using generic systems have proved very interesting, as physicians and nurses who have seen our prototypes have been greatly interested. Moreover, these concepts have been used by Bull for its hospital medical information system called TakeCare™.

But these propositions may be enhanced. As a matter of fact, the hypermedia we have used is based on the Web, and its documents language (HTML) is quite poor, and does not provide all the possibilities that paper-based documents do. Secondly, the genericity we have defined is based on a database, and thus strict structure of information still exists. Moreover, the generic system may be adapted to each service (end-users groups), but not to each individual patient record. This paper presents our proposal for the management of medical records assuring a totally hypermedia system, and adaptability of the documents for each individual medical record. The next section presents the specificities of the medical record in hospital, and the following one presents our proposal for the management of adaptable medical records.

The specificities of the medical record

"The medical record is the memory in which all the data necessary for the surveillance and to take in charge the patient are stored [5]". The medical record does not only contain the observations of the doctor or the nurses remarks. It includes all that can be stored concerning a patient, from demographic data to electrophysiological captures or sophisticated images. The patient record is and will stay the main tool for the centralisation and the coordination of the medical activity.

We already have introduced the fact that the classical paper-based medical record is composed of a set of documents. These documents contain any type of data : numeric measures (e.g. temperature), graphics (e.g. electrocardiograms), texts (e.g. nurses remarks), codes (e.g. diagnosis classification code), images (e.g. X-ray), films (e.g. echography) and/or sounds (e.g. surgeon's dictated report). The manipulation of all these data may be very specific to one service, but their consultation may be done by any practitioner of any other specialty (the nurses or the medical secretaries do not have access to all information).

The medical record is a particular information system in the fact that the information which is stored in this system cannot be deleted nor replaced. Information is only added to the system. This fact comes from legal reasons but also from the medical way of working, which considers that all information concerning a patient may be useful later.

In hospital, the medical record has the following specificities

A multi-sites domain. Each service in hospital is highly specialized, and the medical record is very different from one service to another

- *A multi-actors domain.* Within each service, there are different categories of actors : physicians who take in charge the treatment of the patient, nurses who ensure the daily following of the patient, the medical secretaries who are interested in the administrative part of the patient sojourn, and also other actors who are transversal to services like physiotherapists, social welfare workers, nutritionists... The function and the way of working of each practitioner group are highly different from the

other, and even within a category, one can find differences.

- *Communication needs at different levels.* Communication between the different actors in hospital is essential for a good and efficient care of the patients. This communication exists according to two axes :
  - within a service, communication appears between actors of the same or different categories for the management of the patient.
  - between services, communication allows the coordination between services and the following of the patient in the hospital.
- *Sojourns, episodes and encounters.* The sojourn is an important concept in hospital, which concerns the time interval when the patient is taken in charge in hospital. This sojourn may be a simple consultation, a punctual action (e.g. dialysis), hospitalization in a clinical unit... The sojourn is an important notion for the administrative management of the patient : it is the invoicing unit. Episode is a totally medical concept, as it refers to all the information concerning the treatment of one illness of a particular patient. An episode may thus contain many sojourns. At another level, the encounter refers to the meeting between one patient and one care practitioner. The medical record can be augmented during an encounter.

All these characteristics show that the Intranet features are very close to the medical record management way in hospital : the medical record consists of linked documents, and requires communication means on a network.

Architecture

The main idea of our proposal consists in 2 points:

- the use of hyperdocuments to both store and present information contained in the medical records,
- the use of an adaptable medical language for the description of these documents.

The main idea here is to allow the adaptability of the medical record for each individual medical record, and with specific structures for each service, all that with ensuring communication means for the sharing of the medical records and information retrieval techniques for accessing the information stored. The architecture of our new system is based on 3 main parts :

- the documents description language,
- the documents servers,
- the clients.

The following paragraphs present the documents description language and the client tool.

A language for medical hypermedia documents

In our purpose, the language we need for the description of documents should :

- *include all hypermedia characteristics* : the medical record consists in a set of linked documents.
- *allow the definition of any kind of document* : the flexibility of the paper-based document should also be ensured (e.g. margin annotations), and all types of data should be supported.
- *allow the adaptation of the documents lookup to each end-user* : the presentation of information to a particular care practitioner may be totally different from another, even if all the information provided is the same.
- *allow semantic information retrieval* : retrieving a document, or a specific information concerning a patient should be possible. Semantic requests require the association of semantics to each piece of information.
- *allow the derivation of the semantics by end-users* : as there may be very different needs in the semantics description in documents, each service must be able to specify new semantic "tags" to be added in documents, or to specialize existing ones.Hypermedia documents ([6]) are modelled as graphs where nodes represent information chunks, and edges represent the composition and/or reference links between the nodes.

The norms for the representation of structured documents distinguish two types of structures :

- the logical structure represents overall organization of information,
- the layout structure represents presentation of this document to the end-user.

SGML [7] is a norm for the definition of logical structures of documents (Document Type Definition, DTD). It is the most widely used norm for the description of documents, and the most complete one (and also the most complex) but it is dedicated to linear documents, and does not manage reference hyperlinks. SGML is a markup definition language, that is to say chunks of information are separated by tags in the text, which may precise the logical and/or physical presentation of the documents. These tags are defined in each DTD.

Hytime and HTML are the two main languages for the description of hypermedia documents. Hytime [8] is mainly dedicated to the management of time for synchronization of temporal media. HTML [9] is a specific DTD of SGML which allows the definition of hyperlinks. It is the language used on the World Wide Web, but this language is not a pure hypermedia language, and is really poor for the management of the semantics of the information stored.

As a matter of fact, our first experience with the HTML language (described in the introduction) showed that this language is limited in the following ways :

- *domain-independant.* HTML is dedicated to structure all documents that are on the Web. It thus cannot include domain specificities, and keeps as general as possible.
- *no semantic tags.* As it keeps general, HTML does not contain semantic tags (which would necessarily be domain-dependant, e.g. "temperature"), and thus information retrieval cannot be done at the semantic level

(cannot ask for the list of "temperatures" of patient X easily).

- *a fixed (even if still evolving) standard.* HTML is a standard DTD that is fixed, and cannot be extended for specific purpose. Thus, one cannot add his own tags.
- *highly simplified hyperlinks.* HTML contains only one type of hyperlink, while hypertext in general may include many types. Moreover, these hyperlinks cannot be qualified (no attribute associated to a link).XML [10] is a new hypertext language that has appeared in the beginning of this year. It is a markup definition language which inherits from SGML, but has simplified some elements, and really includes many types of hyperlinks. It is dedicated to the Internet, and more precisely to WWW applications. Its layout structure uses DSSSL (Document Style Semantics and Specification Language) [11], which is a language to define the style of the information chunks in documents, but also includes a query document language and a transformation language (reorganisation, groupings..). As in SGML, XML allows the definition of DTD, so that we can define a set of semantic tags dedicated to medical records.

We have chosen to use the XML definition language to specify a medical markup language for the specification of the medical record documents. The specification of the semantic tags used in medical records is done by the specification of a DTD, as they form the logical structure of the documents. We have called this DTD XML/Med. The layout structure of documents is done using DSSSL.

Figure 3 gives a summary of the relationships between SGML, HTML, XML and XML/Med.

We are currently defining a general DTD which could be used by all care practitioners in hospital to consult and create documents in the medical record. Figure 4 provides an example of definition of semantic tags in the medical DTD. The construction of a document based on this DTD would have for example the logical structure of figure 5. Associated to the logical structure, the layout structure defines the presentation rules of each tag in the DTD. It is done in the DSSSL language. Figure 6 provides an example. It may be presented to the end-user as on figure 7 (depending on the layout structure).

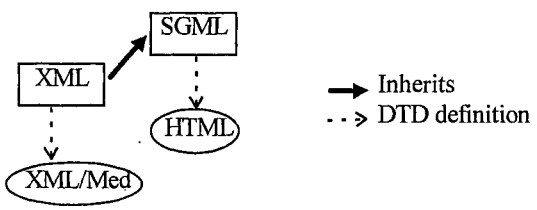

Figure 4 - SGML, XML, HTML, and XML/Med

```
<!ELEMENT report (patient, content, keyword)>
<!ELEMENT patient (#PCDATA)>
<!ELEMENT content (#PCDATA)>
<!ELEMENT keyword (#PCDATA)>
```

Figure 5 - A piece of the medical DTD

```
<report>
  <patient>John Smith</patient>
  <content>The patient presents an acute diabetis, which must be cared urgently</content>
  <keyword>diabetis, hospitalization required</keyword>
</report>
```

Figure 6 - A logical structure based on the medical DTD

```
<STYLE TAG="patient">
<FONT-WEIGHT V=Bold>
<FONT-SIZE V=18>
<BREAK-BEFORE>
<BREAK-AFTER>
</STYLE>
```

Figure 7 - A layout structure based on the medical DTD

Report

Patient : John Smith

The patient presents an acute diabetis which must be cared urgently

Keywords : diabetis, hospitalization required

Figure 8 - A document presented to the end-user

To ensure adaptability of the document structures to each service, we allow the definition of specific DTD specialized from XML/Med, and of individual DSSSL definitions associated to the DTDs. Using XML/Med as a starting point, each service can define new semantic tags in a specialized DTD which will be used by this service care practitioner to create their own documents. A service can also specialize existing tags, by adding subtags. Figure 8 provides an example, based on the previous DTD definition.

A tool for the end-user

The client tool for the end-user has to allow the visualisation and the edition of XML hypermedia documents. It has to provide a WYSIWYG (What You See Is What You Get) way of interaction with the end-user.

```
<!ELEMENT report (patient, content, keyword)>
<!ELEMENT patient (#PCDATA)>
<!ELEMENT content (indication, details, in brief)>
<!ELEMENT keyword (#PCDATA)>
<!ELEMENT indication (#PCDATA)>
<!ELEMENT details (#PCDATA)>
<!ELEMENT in brief (#PCDATA)>
```

Figure 9 - Specialization of XML/Med

For the consultation of documents, the client has the following roles :

- it gets XML documents from the server and presents each document with the reader's logical and layout structures.

- it manages a standard toolbar offering the classical hypertext functionality's (navigate, search, print, back...)
- it manages the end-users profiles, and by this way decides on the logical and layout structures to use on a document request.

For the edition of documents, the client has the following roles :

- it allows the edition of XML documents
- it offers a contextual toolbar which presents in a WYSIWIG manner the semantic tags of the specific DTD of the service, that can be added in the document.
- it manages the end-users profiles to check the edition rights of the end-user
- it ensures the validation of the documents by their creator

Conclusion

This article has presented a new way for the management of medical records in hospital. The main idea of this approach is to use a specific medical markup language (XML/Med) for the logical description of documents. The logical and the layout structure of documents can be adapted to each service using the system, without empeding the sharing of documents. Not using a database allows much more flexibility, and does not build a mismatch between the user interface paradigms and the underlying system. We are developing a prototype in order to validate our system. The physicians from the Lyon hospitals (Hospices Civils de Lyon) we work with have been very interested in this proposal, which according to them greatly enhances the variability of the computerized medical record without empeding communication.

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