On the Use of an Ontology to Improve the Interoperability and Accesibility of the Electronical Health Records (EHR)

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Abstract. In this paper we present a proposal to conceptualize the EHR, based on the semantic description of the information, according to the documentary structures and the clinical aspects of the EHR contents. Our aim here is to perform a formalization with a double purpose: on one hand to enable the interoperability; on the other hand, to improve the accessibility to the EHR, according to clinical or assistance contexts, provi-ding the clinical data retrieval system with flexibility and operativity. To this purpose we propose the use of an Ontology to represent this conceptualization, and include properties and relations between the components of the EHR.

1 Introduction

Every day more the Electronic Health Record (EHR) is an extended reality in the majority of the Hospitals, with different degrees of development. It has opened the access to new uses of the EHR, optimized and with more benefits for the medical acti-vity. However, new problems and perspectives have also arisen, related to the management of the clinical information [1].

As the use of the EHR spreads over the different medical specialities and assistance acts, it must integrate more documents and information items, from different sources and types. It is unavoidable to think on the risk that the EHR runs of becoming as unmanageable as the old health records in paper: with such a quantity of information and documents, the access to concrete data items required in relatively simple situations can be really difficult.

Another main problem is the interoperability, with the aim is to communicate and make possible the understanding between different models of EHR from different hospitals and providers. The ISO 13606 [2] regulation establishes the basis and general framework of the semantic interoperability model [3], to allow the univocal interpretation of the information transmitted during the capture of the context where it was generated. The ISO 13606 regulation proposes a dual model where the first model is the *reference model* and the second one is the *archetypes model*. Both of them will be commented later.

In addition to the above mentioned problems, there are also several important is

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sues that must also be addressed and solved, like:

- The Mobility: The use of mobile devices (tablet PC, PDAs, …) requires agile and summarized navigation models on the EHR.
- The Contextualization: The contextual use of the information would provide the doctor with information pertinent to the assistance act where he/she is involved.
- Access Focusing: The idea is to allow the navigation through the EHR directing the search according to a semantic purpose.
- The personal access of the owner: Every day more the patients demand the access to their clinical data since, as owner of them, they have the right to access them. However, at this moment nor the systems are ready for this purpose nor the citizen have the technical knowledge to use them.

The bibliography reviewed shows a great concern about these problems of the EHR systems, specially the interoperability one. In particular about the use of Ontologies as a means to represent models capable of understand and communicate to each other [10]. However, though in the literature most of the proposals are mainly focused on the interoperability and its tools, they do not propose explicitly applications towards the accessibility, use and management of the EHR at a local level.

In this paper we offer a different point of view, more focused in this latter line, offering different alternatives of use of the EHR for the doctors, making more efficient the accessibility to the information needed. It is quite important since the great volume of documents and information contained in the EHRs, is so extensive that usually one of the main causes of complains from the users is related to the difficulties to navigate through them.

It all have lead us to think that the EHR can be considered as a universe of knowledge that can be conceptualized in such a way that each individual information item can be defined in a semantic family, according to its properties and relations with other information items [6].

In addition, this paper provides with a novel point of view, applying the Ontology based representation models to make easier the use and navigation.

It is specially interesting, since opens the possibility of performing semantic retrieval of information, through the construction of Agents that interpretate the queries and allow the access to the pertinent data items.

Our proposal then, is an approach to the conceptualization of the universe of clinical data contents of the EHR, through the use of an Ontology, based on our own EHR model. Starting from this conceptual formalization and on the basis of the generated knowledge we can construct “agent procedures”. These procedures approach the user to the information items that, due to their semantic value, can be more useful according to the access model.

2 Background

Before presenting our proposal we are going to point some notes about the framework from which we have started our research, specially the information system and the legal framework.

2.1 System Used

To perform our proposal we have based on the system "*ARCHINET*", the EHR system developed and implemented in the Universitary Hospital San Cecilio of Granada (Spain) [1]. This system was implemented 10 years ago, is continuously improved and counts on around 1.000.000 of EHRs. It is organized according to the highest level structures: "assistance episodes" and "pathological processes".

The EHR (Figure 1) is a set of documents (e.g. cardiograms, analytical tests, etc.), and each of them may consist on a set of data groups (e.g. some variable in an analytical test, each of the images in a TAC, etc).

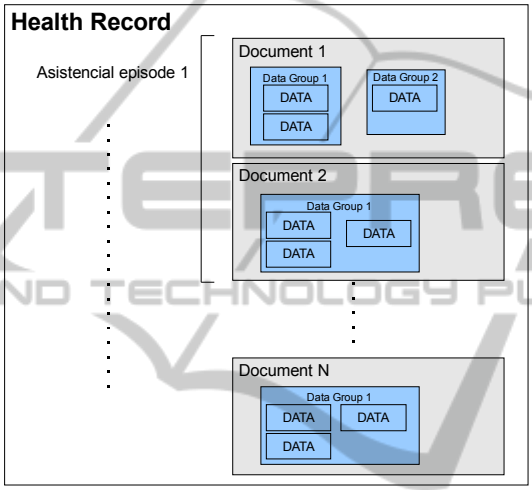

Fig. 1. Example of EHR structure.

In addition we have also made use of the "access base" that registers all the accesses to the system, information items acceded or modified and the assistance context where the user was involved.

To define the Ontology's structures, the Protégé tool has been used, allowing also the operations of validation, representation and translation to descriptive languages.

2.2 Legal Framework

As mentioned above, the ISO 13606 regulation proposes a dual model where the first model is the *reference model* and the second one is the *archetypes model.*

The *reference model* is used to represent the structure of the clinical data of a concrete model like, as an example, the model of a given hospital. It is based on a class called "*structure*" that gives rise to the following hierarchy of members:

- *Folder*: It represents the divisions at the highest level inside the extracts of the clinical history.
- *Composition*: It is the set of annotations related to a unique given clinical session or document.

- *Sections*: They are groupings in a clinical session.
- *Entry*: Each one represents a clinical observation or a set of them.
- *Cluster*: It is used when the representation of a unique observation or action requires a complex data structure, like a list, a table or a temporal series.
- *Element*: It contains a unique value that must be instance of some of the types defined by it.

The second model sets the *Archetypes* [4], [5] as a way to define the clinical concepts managed by the system. The archetypes are definitions of sets of clinical information items, that have a concrete clinical meaning; and they are created using the components defined in the ISO 13606.

However this regulation just sets the basis and general description on which everything is opened and must be concreted, which is what we do in this paper.

3 Ontology Proposed

To materialize the general models described in the previous section, we propose and describe in this section an ontology.

3.1 General Description

The EHR structure's design itself implies the existence of a categorization according to the semantic classes of the documentary organization, and also to the assistance part. As an example, the documents are classified by their types, and the data are organized regarding their clinical orientation inside the document. In addition these data items are organized according to assistance acts and medical specialities. Based on it we make the formalization through the ontology.

To choose the components of the Ontology we have used two criteria. On one hand, the documentary criteria, that gives rise to the classes that structure and define the set of documents included in the EHR. On the other hand, we approach a clinical criteria determinating the categories related to the clinical processes and concrete pathologies, and even the assistance context on which the information is used.

Nevertheless, the semantic universe must be manageable and easily formalizable, so we have avoided to define categories that are not clearly useful to reach our final targets, previously indicated.

3.2 Semantic Categories in the Ontology

We have analyzed the semantic categories to define the Ontology. The main purpose was double: on one hand, to categorize every kind of data that could be found in the EHR, on the other hand to respect the information structures defined in our EHR model. Whit it the classes defined in the Ontology are:

Structure Model (EHR-EXTRACT): This class corresponds to the structure defi-

ned in the ISO 13606, and has the members Folder, Composition, Section, Entry, Cluster and Element.

Document: A document can be considered as any grouping of data with a common purpose, nested regarding a clinical action or observation. The documents are hierarchized depending on whether they are "general", "of process", "of medical speciality", "of nursery", "surgical" or "logistical". Hence, this class can be considered as the fundamental logical grouping of the organization of the information in the EHR. With this class the EHR can be organized according to assistance acts (admissions, consultations, emergencies,…) or to pathological processes, always grouping documents. Each document may contain different sections of contents, and each section has its own entries, clusters and elements as concrete data in the document.

Assistance Process: These processes define the clinical pathology environments, previously set, on which sequences of clinical actions are pre-established. As an example, we have the "diabetes process", "cataract process",… Here we have focused on the pathologies with well defined processes, since not all the pathologies have them. The members of this class represent the different pre-established actions for each process.

Data Type: They can be considered as texts, encoded data, magnitudes that include rations, intervals, lengths, durations, graphs, images, signals, dates and so on.

Observation Type: The aim of this class is to qualify the data item according to its source: if it is a subjective observation, an objective result of an analysis, a protocolyzed observation, a related fact or a chronological action, among others.

Assistance Procedure: It contains the references to the diagnosis methods, explorations, sources of knowledge, technological support, and any other source of data. As an example, we have electromedical explorations (electrocardiogram, electroencephalogram,…), radiological explorations (RMN, TAC, conventional radiology,…), and direct observation, among others.

Clinical Context: It is related to the variety of situations or states of an assistance act, like a revision consultation, a postsurgical consultation, an admission, an emergency assistance or a ward checkup. These contexts are obviously classified according to the medical speciality and, in some cases, to sub-speciality and process.

Assistance act: It determines the origin of the assistance procedure (admission, consultation, emergency,…).

Agent: This class is used to define the kind of professional that is involved in the act, locating him/her in the corresponding service and professional category (doctor, nurse, assistant,…).

Archetype: We use the internally defined archetypes and those other defined by the different research groups working on the interoperability of the EHR [7].

Application: This class captures the variety of functional applications from different providers and the specific tools, that the clinical workstations entail and must be integrated. These applications are complimented in the system ARCHINET by means of its own and specific functionalities, with a logistical or departmental character. Some examples are the application of medicine and unidosis management, the application of analytical requests management, or the emergency monitoring. Some of these ap-

plications may derive clinical data towards the EHR.

ICD-10 Hierarchy: It reproduces the class structure in this international classification [8]. We have chosen this classification since it is the most habitually used in the Hospital for diagnosis encoding.

Data Model: It is a class of internal use for the procedures of computing agents. Its aim is to reproduce the data model starting from its logical modelling and down to reach the physical Data Base model of the EHR. This is how the tables stored in the data base are described. The instances of this class are each of the individual data (columns). The hierarchy of this class shows the typology of these structures: movement tables, primary tables, history tables, etc.

3.3 Properties in the Ontology

Regarding the properties in the Ontology, their purpose is to create sets of restrictions based on the taxonomical relation between classes, in such a way that each possible entry in a EHR has a semantic map to contextualize its use, and hence its relations to other elements in the EHR.

This way, as an example, the entry "*anaesthesia type*" belongs to the document "*anaesthesia sheet*", is a data type of restricted values, and is part of the context "*intrasurgical information*" and of the assistance procedure "*Anaesthesia*". In addition, it is characteristic of the assistance acts "*admission"*, *"emergency"* and *"surgical day hospital*". Its agent profile is "*anaesthetist doctor*" and it is considered as related to the archetype "*anaesthetic report*".

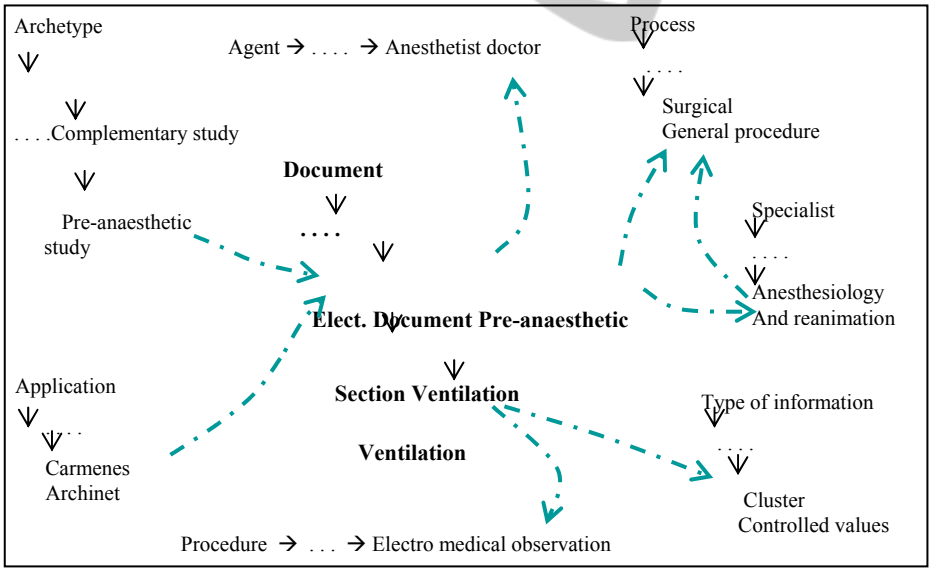

Fig. 2. OWL Based Relationships Between Classes and their Properties.

To allow the creation of these "semantic contextual maps" in the Ontology we ha-

ve defined complex relations between classes and their corresponding attributes and restrictions.

The process to create these relations is quite complex. However, it is easier using the information stored in the EHR Base and in the Access Base, and also referencing the data model itself. Doing it most of them can even be automatically generated.

In the Ontology we have also included implicit properties for concrete classes like the "*character of a document*" (confidential or open), or the "*type of document*" (gene-ral, of speciality, of process, logistical,…).

Finally, we must remark that the definition of the Ontology is not a closed topic, but a continuous process that, depending on the experiments, we widen or modify.

4 Results

The creation of the Ontology provides a Knowledge Base formalized with structures that the computing procedures can use to answer the query processes performed on the EHRs [9], and opens the possibility of using new accessibility models to the EHR. Concretely, it makes possible the conceptual accessibility to the data in the EHR, what opens the path towards the interoperability between EHR systems, since it provides the system with the capability to semantically interpretate the clinical data retrieval pro-cessess. In addition, it sets the basis for the next uses of the information and the system:

Contextual Use: to allow the doctors to have the information really needed for the assistance activity in which he/she is involved, acceding just to a determined context. This way superfluous or not pertinent information items are avoided, as well as complex accesses with the navigation systems.

Restricted Navigation: used in the cases where only some concrete information items are needed, avoiding the unuseful navigation through acts, processes and documents with no interest to the search purposes.

Limited Navigation for Mobile Devices: The navigation through the contents of the EHR is quite difficult in mobile devices, since their screens set a very limited representation capability, especially for complex menus. In this case, the information presented can be initially focused according to a given work environment, like the medical speciality, the assistance act to be performed, the process or the assistance procedure. All of them set an environment to which the system can give a response depending on the information relevant to it.

Ontology Navigability: Traditionally there have been discrepancies regarding the different ways to show the documental organization of the EHR. Some times it is necessary to organize them according to assistance acts, whereas in other cases the organization according to processes is preferred. In our case the user can choose, with the scheme of classes that the Ontology provides, allowing him/her to design of his/her own navigation model.

Interoperability: It is easier to reach with the Knowledge Base provided, making possible the understanding with other formalized models, especially with the Reference and Archetypes models defined in the ISO 13606.

Access According to the Semantic Valuation: It makes possible the direct access to elements contained in the EHR, using the terminology in the Ontology.

As a summary, the Ontology conceptualizes our model of EHR, opening the access to a great variety of opportunities to develop computing procedures to make easier the use, control and availability if the EHR.

To our best knowledge, there are some proposals of ontologies for contextualized access in others fields (e.g. e-Goverment, business context [13]) but none for EHR access so a comparison with our proposal is not possible.

5 Conclusions

In this paper we have made several proposals:

1. We have presented a semantic conceptualization model for an EHR system, that offers a number of utilities towards three purposes: the interoperatibility, the accessibility and the mobility.
2. We have proposed concrete accessibility models for the EHR, as a practical application of the design proposed.
3. The proposed design can be generally and widely applied, independently of the documentary structure, the technological support or the development degree.
4. The Ontology provides a formalized Knowledge Base that allows the development of computing procedures with several purposes, from analytical to the accessibility, opening the path to new alternatives to the traditional navigation and access procedures to the EHRs.

However, we assume that this work is just the "starting point" for future developments and for the creation of computing procedures, more or less "intelligent", to be used as user interfaces for the EHR.

At this moment the work carried out has only been limited to the design and construction of the Ontology, and must be continued with the production of the corresponding computing agents.

Regarding this research line it is not finished, since it is just in an experimental phase, and is opened to modifications in the Ontology design, depending of the results obtained. In the present phase, we are working on the development of computing interfaces procedures and in the automation of the generation of classes and properties of the Ontology from the information stored in the system.

Finally, we must indicate that the experimental results obtained up to this moment lead us to consider quite viable the implementation at a general level.

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