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Development of Universal Electronic Health Record in Cardiology

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Abstract. In the paper we discuss the vision and experiences in development of electronic health record based on universal structure of collectable data, multimedia objects, all equipped by supporting systems for data verification and medical guidelines connection. This development is based on existing European and international standards in the field of medical informatics.

1. Introduction

Health records have become an established part of clinical practice. These records contain important information for the care of an individual and are used in many different ways for diverse purposes. The trend is towards representing these records in an electronic medium so that they are processable by computer systems. The Electronic Health Record is then a technological means of documenting the care process for an individual person [3]. Development of the electronic health record architecture at the EuroMISE Center was inspired by several European projects, mostly the I4C/TripleC project. In the I4C project the "Multimedia Electronic Patient Record" named Orca (Open Record for Care) was developed. The software was based on 2-layer architecture (database and user interface level), integrated structured data entry combined with the possibility to include multimedia objects as part of patient history. The primary user interface of Orca was the structured data entry, allowing adding free-text comments to entered data. The data set of collected data was defined by hierarchically structured knowledge base, described in many European languages. Entered data were therefore easy to translate to different languages even if the other language was used during entry. The knowledge base editor allowed the administrators to modify the set of collected data.

The EuroMISE Center participated in second part of the project - TripleC project. Among the goals of this project was the adaptation of the Orca software to Czech environment and testing of usability of structured patient record in Czech hospitals by collecting patient data for research purposes [2].

The Orca system introduced many new and useful ideas and principles, however many features were missing or could be solved in a more useful way. The system of structured data entry used in Orca showed to be more time consuming than the free-text entry and therefore not preferred by some physicians. To be able to easy export the data stored in the Orca database, simple software tools were developed. The structured data entry was than much easier for further processing of collected data than free text processing.

2. Required characteristics of EHR

Our experiences in the field of medical informatics and statistics, ideas inspired by results of I4C/TripleC project and long cooperation with physicians resulted in following list of requirements the Electronic Health Record (EHR) should fulfil.

- structured way of data storage combined with free text
- tools to ease structuralisation of entered information (transfer from free-text to structured data)
- tools for evaluation and visualisation of stored data
- dynamically extensible and modifiable set of collectable features without change of database structure (knowledge base)
- system for access control to patient data and knowledge base
- module checking data for correctness and conformance to guidelines (bounds checking etc.)
- multilinguality
- pedigree information
- grouping of patient data according to cases
- logging system maintaining information about every change of patient data, knowledge base, access rights modification etc.
- minimal dependence on database and operating system used for data storage
- wide scale usability (from single workstation used by general practitioner to distributed environment in a large hospital)
- mobile terminals interface (PDAs, mobile phones)
- motivation system for physicians (routine administrative work automatization, reports for insurance companies generation, etc.)
- multimedia information as part of EHR

3. Architecture of the EHR

The preparation phase of the EHR development consists of international standards analysis, modelling of the architecture of the whole system, process and functional analysis, data model preparation, etc. As a part of the preparation phase of the software development, international standards are analysed. Several organizations producing European and international standards exist. At the European level, the technical committee 251 of the European Committee for Standardization (CEN/TC251) produced over 40 preliminary European standards in the field of health informatics.

Fundamental base for our work is the document ENV13606 "Electronic healthcare record communication". The prime purpose of this multipart prestandard is Electronic Healthcare Record communication; communication being defined as the act of imparting information. The first part describes a conceptual model of structure and content suitable for communicating the EHCR. It is a high level template, which provides a set of design decisions, which can be used by system vendors to develop specific implementations for their customers [3].

Following the requirements stated before, the modular structure of the system was defined. The main architecture of the electronic health record is developed using 3-layer architecture - database layer, the application layer and the user interface layer. This approach separates the physical data storage, the application intelligence and the user interface and minimizes the requirements to the client side software. Two versions of database and application layer are developed - the universal one, using relational database structure and the special one using object-relational database structure using Oracle 9i. The comparison of efficiency of the classical relational architecture and the new object-relational architecture will be performed.

As stated in the list of required characteristics of EHR, to be able to use universal technique for processing and visualisation of stored data we need unified way of structured data storage. The set of collectable features varies in different departments, organizations and also during time. Therefore we need dynamically extensible and modifiable structure of items allowing reorganization without change of database structure. The main idea behind our database implementation is the separation of data values and data description.

The set of features and their relations is described by graph structure that consists of vertices representing symptoms and edges representing relations among symptoms. The basic structure underneath is the oriented graph (tree) representing the hierarchy of medical knowledge stored in the patient record by edge type "subjection". Other types of edges are used to express relations such as equivalence of some terms in different parts of knowledge tree. We call this tree structure "knowledge base". Each vertex describes the represented feature by its identification, internal name, type and identifications of user who created the vertex and user who eventually deleted the vertex. Similarly are described the edges between vertices. This enables the system to log any change in the structure. If the structure is changed for any reason, the "deleted" vertices and edges are only marked as deleted and identification of the user who deletes them is stored in them. The system enables the administrator to define access rights to any part of the tree to individual users or group of them similarly as access rights to directory structure in UNIX system. The graph structure can also be used to express relations between patients in the database, e.g. pedigree information. The graph is also used for description of usable scales and classifications. An example of hierarchically structured classification system is International Classification of Diseases (ICD10) or Anatomic Therapeutic Chemical classification (ATC). Both mentioned classification systems are already included in the implemented system. The internal name of the vertex is then used for unique identification of the vertex in the hierarchy by specifying the path from the root of the tree (e.g. SCALES.MKN10.V.(F00-F99).F60-F69.F63.2). Names of features in different languages, displayed in user applications, are stored separately.

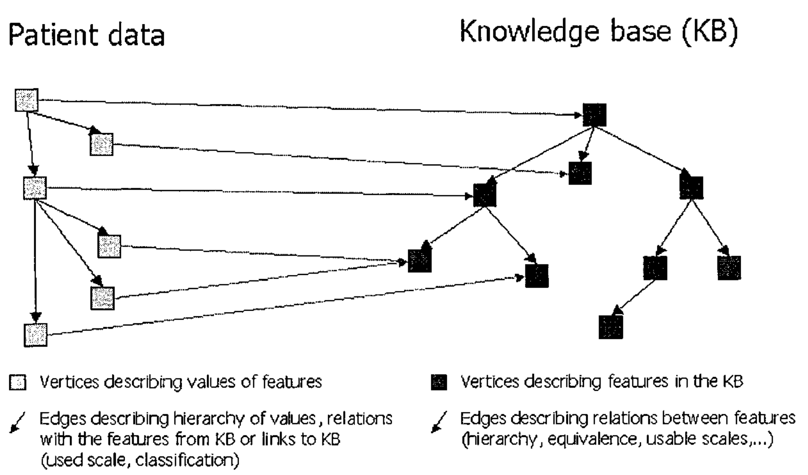

Fig. 1: Graph structure of the knowledge base and patient data

The collected data are stored using similar structure as knowledge base. Each vertex in the tree describes one instance of the feature from the knowledge base by the identification of the feature (internal name of the feature), its value (with the possibility to specify the range of values), date and time of examination, date/time range of the validity of determined data, certainty of the determined data and identification of user who entered, confirmed (doesn't have to be the same as the person who entered the data) and eventually deleted the instance. The values are physically stored in separate tables according to their types and are related to their descriptions in the tree. This simple data structure allows to store almost any type of structured information in the same way, making possible to apply generic algorithms to extract any type of information (e.g. time progress of laboratory tests, blood pressure, etc.).

The application layer implements the XML based communication protocol with the EHR system. The communication syntax between client and application layer is defined by XML Schema - recommended by W3C in May 2001. The XML documents are transported over HTTPS protocol between client application and HTTPD server using CGI scripts. The CGI scripts communicate with the main application, which translates the XML commands or queries to SQL queries and responses from SQL server to XML documents. The application logic offers basic commands for knowledge base editing, storing and recalling the patient data, modifying access rights etc. Important part of application layer is the guidelines module, which can serve as a decision support tool during the patient examination or as a compliance analysis tool.

The user interface of described system can be developed in many ways using various technologies. As stated before, the free text patient record, preferred by many physicians because of its speed and flexibility is very difficult for automated analysis. To be able to statistically process the entered data, the structured record is essential. Therefore the user interface should help users of the system to create the structured data while keeping the speed of free text entry. One of the possibilities studied was the regular analysis of the free text reports and automatic generation of records to the patient database. Another possibility is based on idea of continuous offer of features from the knowledge base related to written text during entry of free text record. User entering the report has the possibility to pick the feature from the offered list and to enter its value, range of validity and certainty. The system can then generate the sentence containing entered data and insert it into free text record. Such sentence is marked as related to specific item in the database of collected data. Manual mark-up definition of parts of entered text to items in database is also possible. The entered and marked free text report is then stored in database as XML document, giving physician the possibility to use his language to describe the examination of patient and defining links to items in the database for further processing of the data.

4. Conclusions

The pilot implementation of the proposed electronic health record structure is developed in the field of cardiology. The knowledge base is described by so called minimal data model for cardiology - the hierarchically organized list of symptoms from the field of cardiology. The minimal data model was developed by consensus of physicians and computer scientists cooperating in the EuroMISE Center - Cardio in the field of electronic health documentation.

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[3] ENV13606 Parts 1-4, CEN/TC251