Electronic Health Record in Cardiology: Pilot Application in the Czech Republic

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Abstract

The EuroMISE Centre-Cardio is focusing on new approaches to electronic health record, considering also the Czech healthcare environment. The development of new approaches is based on experience gathered in I4C and TripleC projects of the European Union. In the paper we discuss basic requirements on electronic health record and special needs of the Czech healthcare system. Finally, pilot application named MUDR implementing proposed concepts is described.

Keywords:

Electronic Health Record, Health Information System, Biomedical Informatics

1. Introduction

The European Center for Medical Informatics, Statistics and Epidemiology – Cardio (the EuroMISE Center – Cardio) is the joint workplace of five institutions. The Center associates more then 70 researchers from the Institute of Computer Science, Academy of Sciences of the Czech Republic, Charles University, University of Economics, University Hospital in Prague and Municipal Hospital in Caslav. The EuroMISE Center is focused on new approaches of designing and using of electronic health record (EHR) including telemedicine applications, intelligent systems for data mining and decision support [1], electronic medical guidelines [2] and PhD education in biomedical informatics [3]. The EuroMISE Center is running two ambulances of preventive cardiology. Further we introduced more details on MUDR (MUltimedia Distributed Record) development in the EuroMISE Center and its pilot applications in ambulances of preventive cardiology.

2. EHR development in the EuroMISE Center

The research on EHR for data acquisition, data storage and data mining has been carried in the EuroMISE Center. Different databases, storing clinical, genetic and epidemiology data, were created. It was found that data collected in cardiology had different quality and accuracy. *Minimal data model for cardiology* was proposed to assure basic cardiology data collection with high quality and accuracy over a long period of time focused on further improvement of cardiovascular diseases management [4].

Cardiology databases can serve for comparison of medical practice with medical guidelines and discover some features of diseases that can help to their management. Medical knowledge in different medical guidelines can be repeatedly evaluated using large amount of data collected by EHRs and stored in a cardiology database. The large databases in cardiology, based on appropriate data model, can further serve as a source of information for decision support systems and can be explored by data mining methods to reveal hidden associations and relationships. Moreover, EHR serving as a tool for data collection can be used for automated generation of alerts, reminders and suggestions when standards of care (e.g. based on medical guidelines) are not achieved.

Development of the EHR architecture at the EuroMISE Center was inspired by several European projects [5], mostly by the I4C and TripleC projects. In the I4C project the "Multimedia Electronic Patient Record" named ORCA (Open Record for CAre) was developed [6]. 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 the TripleC project. Among the goals of this project was the adaptation of the ORCA software to Czech environment and testing of usability of structured EHR in Czech hospitals [7]. The ORCA system introduced many new and useful ideas and principles, however many features needed for Czech healthcare environment were missing. 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 Czech physicians.

3. Required characteristics of EHR

EuroMISE centre experience in different medical informatics and statistics applications, ideas inspired by results of I4C and TripleC projects and long time cooperation with physicians resulted in the following list of requirements on EHR.

- Structured way of data storage combined with free text;
- Tools to ease structuring of entered information (transfer from free-text to structured data);
- Tools for evaluation and visualisation of stored data;
- Dynamically extensible and modifiable set of 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;
- Multilinguality;
- Pedigree information;
- Grouping of patient data according to cases;
- Logging system maintaining information on 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 systems for physicians (routine administrative work automation, reports for insurance companies generation, etc.);
- Multimedia information as the part of EHR.

4. Architecture of the MUDR

The preparation phase of the MUDR development consisted 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 were analysed. Several organizations producing European and international standards exist nowadays. 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. The main inspiration for our work is the document ENV13606 "Electronic healthcare record communication". The prime purpose of this multipart pre-standard 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 EHR [8]. Implementation of the described model in our system was considered.

Following the requirements stated before, the modular structure of the system was defined. The main architecture of MUDR 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 of 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.

5. Database representation

The set of features and their relations is described by graph structure that consists of vertices representing features edges representing relations among features. The basic structure underneath is the oriented graph (tree) representing the hierarchy of medical knowledge stored in the health 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.F60-F69.F63.2). Names of features in different languages, displayed in user applications, are stored separately.
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.

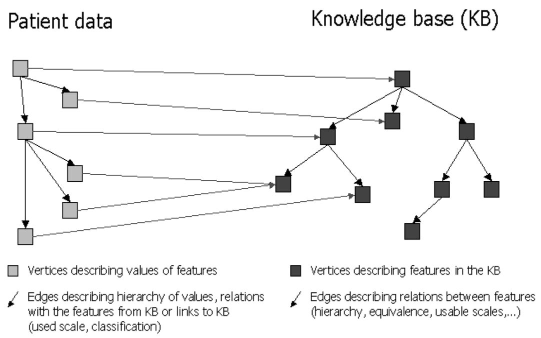

Fig. p: Graph structure of the knowledge base and patient data

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 storing 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 MUDR 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 HTTP 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. Currently developed version of application layer runs as MS Windows NT service, guidelines modules are prepared as DLL libraries, communicating with the application layer. In the future, more platform independent solution for application layer (Corba, Enterprise JavaBeans, etc.), SOAP based communication and universal guideline module is considered.

6. User interface

The user interface of described system can be developed in many ways using various technologies [9]. 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.
However, still the big problems occur with handling of EHR when the most of information is stored in the textual form. In this context we focus on the application of regular semantic analysis of the text medical reports that can lead to structured form of the information. A new system SFT (Semi Free Text) has been proposed [10]. It can store patient data in both forms, structured form and free–text at once. The SFT system implementations are based on the implementation of the knowledge base that defines the hierarchical structure of information

on patients. The data are stored in the database in a form that allows both views, free–text and structured form view. The part of the SFT system is also the module for the automatic analysis of the free text using regular grammars. It is a big advantage that this method is not bounded with a particular language. Moreover, it is not so much time consuming and there is no need of other large data sources, e.g. vocabularies. Therefore the semantic marking of medical reports is an algorithm that provides semantic analysis according to given rules and marks (e.g. using XML tags) the founded fragments of the medical report with a reference to the given knowledge base.

7. Implementation

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 in the field of electronic health documentation. A simple application for collection of data described in the minimal data model was prepared until the final form of MUDR is developed [11]. The data collected by this way will then be imported to the final form of the MUDR, compatible with the following Czech healthcare standards.

Czech unique identification number of the structure YYMMDD/XXXX, which uniquely identifies each citizen. The number is used in all health institutions, pharmacies, health insurance companies and public administration;

List of healthcare procedures with approximately 8000 health procedures accomplished not only with point values used for calculation of payments to health insurance companies, but also by time limits for running of services, that are used in special calculations (e.g. available at the server of Czech Ministry of Health - http://www.mzcr.cz).

International Classification of Diseases (ICD10) in Czech (MKN10), expressing the diagnosis as the four-digit code (see e.g. http://www.uzis.cz/).

Medication for a Czech healthcare provider allows prescribing drug from the list of produced drugs paid fully or partially by General Health Insurance Company of the Czech Republic (actualized quarterly). Therefore it is necessary to make a selection of drugs from MUDR directly.

Laboratory data are transferred according to *Data standard for transferring of data on patients among healthcare institutions.* Further Czech health providers are using *National classification of laboratory items* to communicate laboratory results.

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References

[1] Rauch, J: Mining for Statistical Association Rules. In The Fifth Pacific/Asia Conference on Knowledge Discovery and Data Mining Industrial track and Workshop Proceeding Red. Joseph Fong and Michael Ng Hong Kong 2001, 149-158

[2] Zvárová, J, Peleska, J, Hanzlícek, P, Zvára, K: Enhanced Care of Hypertensive Patients Using Internet. *Technology and Health Care* 9, 6, 2001, 487-488

[3] Zvárová, J, Svacina, S: New Czech postgraduate doctoral program in biomedical informatics. Proceeding of MIE 2002 (in print)

[4] Mannsmann, U, Taylor, W, Porter, P, Bernarding, J, Jager, HR, Lasjaunias, P, TerBrugge, K, Meisel, J. Concepts and Data Model for a Co-Operative Neurovascular Database. *Acta Neurochirurgica* 143, 2001, 783-791

[5] Iakovidis, I.: Towards personal health record: current situation, obstacles and trends in implementation of electronic healthcare record in Europe. *Int J Med Inform* 52, Nos.1-3, 1998, 105 –115

[6] Pierik, PH, van Ginneken, AM, Timmers, T, Stam, H and Weber FR, Restructuring routinely collected patient data: ORCA applied to andrology. *Methods Inf Med* 36, 1997, 184-190

[7] Zvárová, J, Hanzlíček, P and Pribik, V, Application of ORCA multimedia EPR in Czech hospitals. In: EuroREC 99, ProRec, Sadiel, Sevilla 1999, 160-165

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

[9] van Ginneken AM, Verkoien, M.J. A multi-disciplinary approach to a user interface for structured data entry. MEDINFO 2001, 693-697

[10] Semecky, J and Zvarova, J: On regular analysis of medical reports. In R. Baud and P. Ruch (eds) Natural language in biomedical applications, Nicosim Cyporsu 2002, 13-16

[11] Mares, R, Tomeckova, M, Peleska, J, Hanzlicek, P, Zvarova, J: Uzivatelska rozhrani pacientskych databazovych systemu - ukazka aplikace pro sber dat v ramci minimalniho datoveho modelu kardiologickeho pacienta, Supplementum *Cor et Vasa* 44, 4, 2002, 76

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