

User interface of MUDR Electronic Health Record

Petr Hanzlicek, Josef Spidlen, Helena Heroutova

EuroMISE Center - Cardio, Institute of Computer Science AS CR, Czech Republic

Abstract

Development of the electronic health record architecture at the EuroMISE Center was inspired by existing European standards and several European projects. The developed EHR named MUDR implements the 3-layer architecture, using XML for communication between application layer and clients. Decision support module implementing the "1999 WHO/ISH Guidelines for the Management of Hypertension" is part of an application layer. Universal graph structure is used both to represent the set of collectable items - medical concepts in the EHR and to represent the collected data. Advanced methods of interaction between EHR and its user are studied, software prototypes are developed and their effectiveness evaluated.

Keywords: *electronic health record, user interface, MUDR*

1. Introduction

An important research task of the EuroMISE Center – Cardio is applied research in the field of electronic health record (EHR). Development of the electronic health record architecture at the EuroMISE Center was inspired by existing European standards from CEN/TC251 and several European projects, mostly the I4C/TripleC project [1]. The main architecture of the electronic health record named MUDR (Multimedia Distributed Record) is developed using 3-layer architecture - database layer, the application layer and the user interface layer [6]. This approach separates the physical data storage, the application intelligence and the user interface and minimizes the requirements to the client side software. The application layer offers basic commands for manipulation with patient data and structure of stored information, modification of access rights etc. Communication between client application and application layer is done using XML based communication protocol. The XML documents are transported by HTTP protocol between client application and HTTP server. The CGI scripts on HTTP server are providing interface for application layer running as Windows NT service. Important part of an application layer is decision support module, realized as set of DLL libraries, used for conformance analysis to medical guidelines. In frame of pilot application the library based on "1999 WHO/ISH Guidelines for the Management of Hypertension" was implemented.

2. Architecture of MUDR EHR

The set of collectable features - medical concepts - 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 set of features and their relations named "knowledge base" is described by oriented graph $G = (V, E)$. Graph vertices $v \in V$ are defined by quaternions (id, name, dtype, validity), where id is unique identifier of vertex, name is internal name of vertex, dtype describes the data type of vertex and validity contains identifications of user who created the vertex and user who eventually deleted the vertex. This quaternion is also referenced as "semantic type". Edges

$e \in E$ are defined by quaternions ($v_1, v_2, \text{etype, validity}$), where v_1 is starting vertex, v_2 ending vertex, etype describes type of edge and validity contains the similar information about users entering and modifying the edge as in vertex. The physical data type can be chosen from basic data types - number, boolean, string, multimedia data types - picture, audio, video, generic binary and reference data types - data reference or knowledge base reference. The dominant edge of type "inferior" exists in the graph. This edge defines the hierarchical tree structure of the knowledge base, so that the knowledge base can be described by oriented forest with a few trees. These trees are also called "knowledge base domains". Other edge types are used mostly to describe other relations between vertices like equivalence or usable scale.

To prepare the knowledge base content for pilot project implementation in cardiology, the set of important medical concepts for diagnostics of cardiology patient was prepared by consensus of many physicians, cooperating in multidisciplinary research in EuroMISE Center - Cardio [5]. The mentioned set of medical concepts - the minimal data model for cardiology patient is being prepared for approval by Czech Society of Cardiology. Other knowledge base domains contain e.g. international classification of diseases ICD10, ATC classification, SI units or set of usable drugs.

The collected data are stored using oriented graph (oriented forest) $F=(D, E)$. Each tree in forest describes the data of one patient. Vertices are represented by quaternions (id, semantic type, value, administrative data). Each vertex in the tree describes one instance of the medical concept from the knowledge base by the identification of the concept (internal name of the vertex), 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 physical data type described by semantic data type.

3. Usage of EHR

Nowadays, the important task is to motivate the potential users of EHR - physicians to use a modern system providing structured information entry, storage and processing instead of free text based system. The functionality and good user interface is crucial for physician's acceptance. Most successful strategy is based on providing as many benefits for physicians as possible with as little effort as possible [3]. Universal access to patient data from different sources is the most often offered functionality of EHR system. When designing a system, two types of its usage should be taken into account - consultation and data entry. Consultation requires minimal search time, inspectional way of information presentation, problem oriented grouping of findings and patient visits. Data entry requires the maximal easiness and speed of process of entering the data into the system. However, the designs of EHR systems often focus too much on data entry and neglect the consultation part.

Main principles for consultation part of EHR should be an overview and predictable and clinically relevant presentation [3]. In the overview there should be presented the combination of data from different sources in one predictable view relevant to patient state, the importance of presented information should be emphasized, graphical view of time progress of important quantitative data can be very helpful. A simple link to more detailed information from parts of overview is important. The problem or organ group oriented view to patient history can help physicians to find faster the information they need. The possibility to view the historical data in different ways can improve the effectiveness of decision making by physician.

Two types of data entry exist nowadays - free text based and structured one. The structured data entry is perfect for further processing of entered data, its presentation, computations, decision support etc. The stored information can also be automatically translated into many

languages by applying very simple translation rules based on vocabularies. The main bottleneck is the navigation through the interface and selection of applicable items. The predefined information structure can also be insufficient to express all the information physician wants to store in the system, especially for broad specialities like internal medicine. On the other side, in routine care where predefined set of data is collected, fixed forms with defined structure and layout of fields are the most effective. Several EHR applications developed more dynamic ways of presenting the predefined set of collectable features - the product of I4C/TripleC Orca is an example [2]. In these systems, the structure of collectable features is often presented as hierarchy of medical concepts that can be instantiated by their values during entry. The disadvantage of such approach is time-consuming navigation in the hierarchy, especially for large set of concepts, which limits the usability of such system in broad specialities.

Free text entry is able to quickly express any information about the patient independently of predefined information structure. Physicians are not forced to change the way they think during patient examination searching for a correct term in set of medical concepts. Therefore many physicians prefer free text entry during general exploration. To be able to process the information stored in free text, some method of information extraction has to be applied. One method, studied in the EuroMISE Center, is based on regular analysis of free text medical reports [4]. The other method of structuralization of free text is based on user interface improvement, combining the possibility of free text entry with entry done by selection from structure of medical concepts. To ease the binding of structured medical concepts with parts of free text, the user interface can offer a limited selection from the whole structure of medical concepts based on last time typed words, selected part of text, etc. The user, entering the data can then easily choose the correct concept, bind it to term or sentence by simple action like clicking a button or pressing a keyboard shortcut and eventually enter the value of feature represented by the concept. The user can also choose the medical concept independently on entered free text, create an instance of the concept, enter its value and other attributes and let the system generate the free text sentence correctly bound to the selected concept automatically. Both approaches should be available together. The free text can then be stored as XML document, containing tags linking parts of text to structured medical concepts.

An important attribute of EHR improving the effectiveness and quality of physician's work during data entry is decision support capability. If we focus on decision support during data entry or consultation, the concept of so-called reminders seems to be very helpful. Reminder is a result of verification of logical rule set, defining restrictions to instances of medical concepts (real patient data). Using the above-mentioned hierarchical structure of medical concepts in MUDR, the set of rules can detect for example contraindications of a prescribed drug with other medications prescribed before, which could be omitted by examining physician. Dangerous violations of defined rules should than raise a warning - the reminder - to the physician. Less important warnings like unknown value of some medical concept possibly causing a risk can be hidden until physician asks the system for consultation. The set of rules should be based on medical guidelines for a specific medical area. These capabilities of EHR should be smoothly integrated into user interface to provide a good support to physician's work.

4. The developed user interface of MUDR EHR

The development of user interface of MUDR EHR focuses on both parts - data entry and consultation. Thanks to universal communication interface between application layer and presentation layer (the user interface), client applications implementing the user interface can be prepared for different environments and operating systems. Capabilities of these

applications can differ according to the needs of the environment where the data entry or consultation is done.

The simple pilot implementation of user interface is created as a MS Windows application, providing only structured data entry, based on above-mentioned hierarchical structure of medical concepts - knowledge base. The decision support system implements the "1999 WHO/ISH Guidelines for the Management of Hypertension" and can be used as consultation tool for checking of entered data for conformance with guidelines.

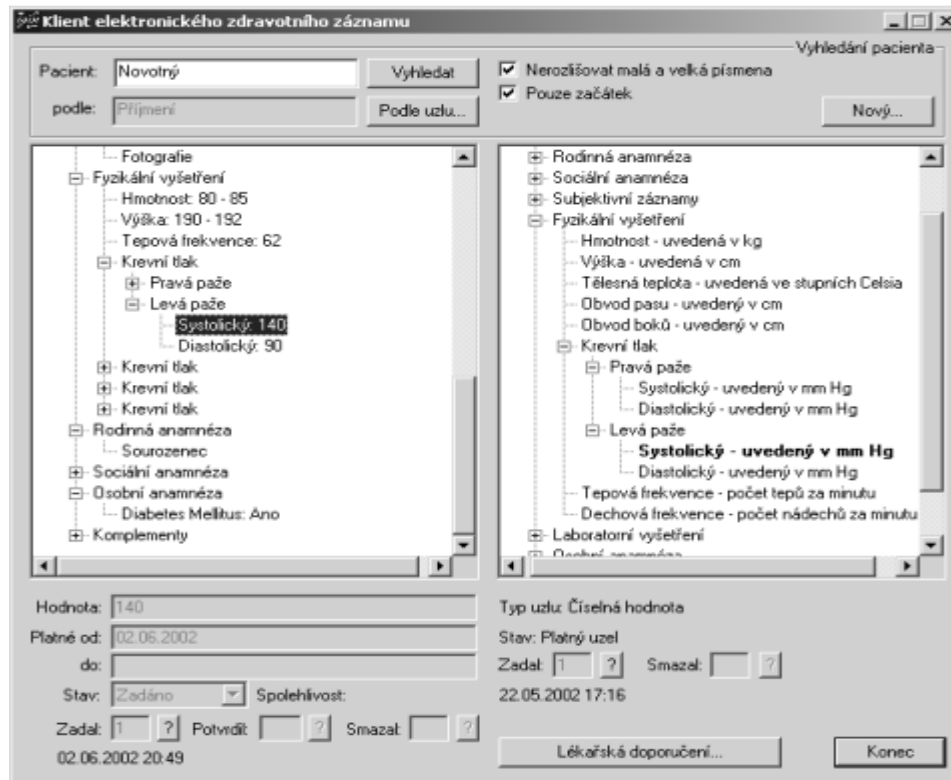


Figure 1 - First version of MUDR user interface in Czech

Analysis of physician's work during patient examination showed that physician often requires consultation with historical data even during the process of data entry. Therefore we are studying the idea of more advanced user interface, providing both historical data and possibility to enter new ones in one form. The main form is divided into several areas; each of them is used to display a specific type of information in different ways. Left part displays history of patient's examinations as timeline or as items grouped according to medical problem, type of examination etc. The requested type of view can be selected by clicking on tabs in the upper part of an area. The right part of screen is used to display the hierarchical structure of knowledge base for entering of structured data. The main part of the screen is located in the middle and is the most universal part of user interface. It can display either overview of current state of patient with highlighted important items or form for quick entry of predefined set of data or sheet containing the historical findings coupled with the above-mentioned system for combined free text and structured data entry. Main part of screen is also used to display multimedia data or graphs showing development of selected symptoms during time.

This advanced user interface is currently in development phase, so several mentioned features are still missing but will be developed in a short time. Because of platform independence requirements, Java programming language was chosen as development environment.

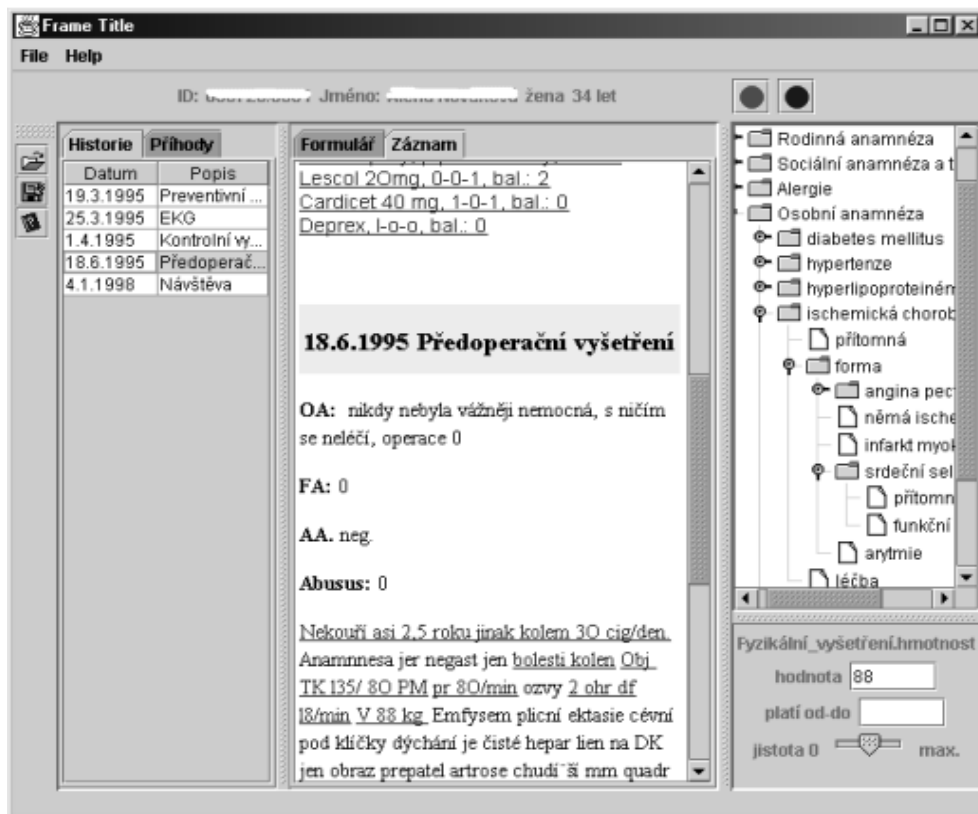


Figure 2 - Prototype of modern user interface of MUDR in Czech

5. Conclusion

The universal architecture of MUDR EHR provides a flexible platform for storage of medical data of any type. The advanced methods of interaction between user and EHR based on combination of free text entry and structured entry are studied, software prototypes are developed and evaluated.

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Address for correspondence

Petr Hanzlicek
EuroMISE Center - Cardio, Institute of Computer Science
Pod Vodarenskou vezi 2
182 07, Prague 8
Czech Republic