A web-based application to help on assessment of respiratory system

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Abstract. *We describe a Web-based application to help health care professionals on treatment of patients with chronic respiratory disease. The software addresses clinical issues and research/teaching ones. At the present the software provides an Electronic Patient Record (EPR) that allows integrating different exams used to assess respiratory conditions of a subject. It is also possible to retrieve the history of assessments, with graphic view for each kind of exam. Recent contributions of the software includes retrieving information using dynamic filters and authoring of medical knowledge, by means of XML documents that add metadata to exams. The information retrieving module helps in research issues, allowing identification of groups of patients that satisfy conditions defined by the user. The medical knowledge authoring module has contributed to improve the process of software development, increasing the integration between health care expert, knowledge engineering and software designer.*

1. Introduction

Health care professionals at university hospital must be concerned to clinical issues as well as teaching and scientific ones. Frequently, clinical data can be a rich source of study and should be structured, in such way that it can be easily retrieved. Even thought there are many alternatives of open source Electronic Patient Record (EPR), it is common that many health care units[1] have difficulties to keep integrated the clinical data and results from a lot of exams, as well as to keep a temporal record of the patient's assessments performed. At scientific and teaching issues, it is desirable for the teacher/researcher not only a fast way to retrieve information, but also to get an explanation about each exam, including: how it is performed, what variables are collected, what variables are computed, details about computation, how to interpret results, and so on. Surely, clinical and/or researchers have methods to reach their tags, but it is observed that naive procedures are commonly performed. A typical example is the generation of a lot of worksheets that can be easily updated, and do not require the definition of a structure to organize the data. This approach is a great source of human errors.

[1] Along the text, health unit means one of the following: a hospital, a clinic, a laboratory, a research group.

In our university, there is a health care unit responsible for the physical rehabilitation of chronic respiratory diseases patients Chronic diseases in general require continuous attention to control the occurrence of crisis. Aiming to help health care professionals (mainly in cardiac and respiratory rehabilitation) to accompany their patients individually as well as to study groups of patients, according to specific features, it was designed, developed and implemented the software SACAR-Web (Software for Assessment of Cardiac and Respiratory System for WEB). The assessment can be made through several kinds of exams, which have specific material and methods for both, execution techniques and analysis of results.

One of the great challenges of the proposed software is to construct a large database with shared clinical data from several health care units. The idea of sharing database of clinical data has emerged from the need to get a large set of cases of study for both issues (teaching and research). Such approach may be a fast way to reach the target, instead of considering the data of only one health care unit. It was though in a collaborative work, where each health care unit has a local administrator that is responsible for the data of his/her patients, with full access (reading/writing) on them, allowing (or no) to share his/her patients data with local administrators of other health care units (with permissions of data reading but with blinded names of patients). However, when the first prototype was ready, it was observed that some health care researches had a certain resistance on sharing all the data. An alternative approach proposed by the potential users was the creation of research groups that could share some kind of clinical data, but only for specific studies. That alternative approach is in progress, but facing this problem we decide to give priority on working hardly in adding some features to the application in such way that the health care professionals feel more trustful. Such decision has implied in review the requirements established in the software design. The details are described in section 2.

Some features of the web-based application had already presented in early paper [Camargo-Brunetto, 2005]. So, here we briefly present such features and outline the main additional modules developed at present, which includes: (i) relevant information retrieving using dynamic filters on the variables of interest of the health care professional; (ii) module of authoring medical knowledge that provides explanation about procedures, variables and calculus involved in each exam. In previous version of Sacar-Web application, information about the exams was available as static content including tables or explaining texts. In fact, such explanations are the metadata of the exams. So, it was observed the need to organize such metadata and to isolate this from the program code. The use of XML Schema was essential to attend this requirement. The remaining of the article is organized in the following sections: Section 2 presents a system overview, information retrieving by means dynamic filters is presented in section 3. Section 4 presents the methodology employed to add metadata on the exams. In section 5 are presented related works. Section 6 concluding remarks and future works.

2. System Overview

In this section we describe some design considerations and present the architecture of the system with a brief description of its modules.

2.1. Design Considerations

During the design of the application, it has been identified some user's needs, that given support to establish the software requirements:

(i) The software can be used from different locations, and should be easy to learn how to use it.

(ii) The software should attend different interests of health care professionals, including clinical and/or teaching/researching ones.

(iii) The software provides a large variety of exams, but should allow that health care professionals select only ones matching with their interests.

(iv) The software should provide information about the exams, including how the results have been reached, how the exam has been executed. It is important that health care professionals know how the software provides the results of the exams.

(v) Different health care unit databases can be shared for teaching/research issues.

(vi) The knowledge domain must be extensible (today it addresses cardiac and respiratory systems, but other systems are associated, as muscular system, nervous system, and others).

Based on these requirements, we have established the following decisions:
For the requirement (i), the simple way to provide wide access to the application is through a web-based application. We had decided to develop the software based on open source languages and standards. For the requirement (ii), to attend different issues (clinical and teaching/research), the most appropriate strategy was to define different levels of users with specific roles and permissions that are explained in the following:

The system has three kinds of users: **local administrator**, **collaborator** and **knowledge expert**. The **local administrator** is the person responsible for a health care unit (normally an experienced health care professional, including teachers and researchers) and has the following permissions: (i) to customize the system for his/her unit care which includes: to select the exams of his/her interest and to select the idiom to be used; (ii) full access to the Electronic Patient Record (EPR); (iii) to perform information retrieving using dynamical filters; (iv) to see the evaluation of a specific patient according to graphic view of different exams and (v) to register his/her collaborators that will take the role of filling the EPR. The **Collaborator user** has permission to use only the Patient Assessment module (to register patients, introduce or view exams) and must report his actions to the local administrator. The **knowledge expert** has the role to add information about each exam, including details on execution procedure, variables considered, interpretation rules of the results, bibliography and so on. Such activities are related to the requirement (iv).
For the requirement (iii), it was established a user profile, so that the web application provides an adapted interface. The requirement (iv) was established after some observations: several biomedical software systems are embedded in specific devices that deliver a large variety of graphics, table results, provides a set of standards of normal values, complex analysis, and so on; it is possible that one health care unit has different devices and each one has its own software; the user does not know how the result

provided by the software device was obtained; also it is possible that the health care unit does not have some special kind of device (for example, a gas analyzer, that is expensive), but uses exams that provides indirect measures. Such facts have been motivated to include in our software additional information about the exams, including procedures of execution, as well as possible interpretation of the results. For requirement (v), the strategy is to work with shared databases, and different visions of the union of them, according to the user profile. Confidential information, as the patient name for example is not shared. It is essential that requirement (iv) be fully reached.

The requirement (vi), domain extensibility will be attended by a work in progress, by means XML structured documents describing the different systems (cardiac, respiratory, muscular, nervous and so on), with their structure and assessment techniques possible.

2.2 Architecture of the System

Figure 1 shows the architecture of the application.

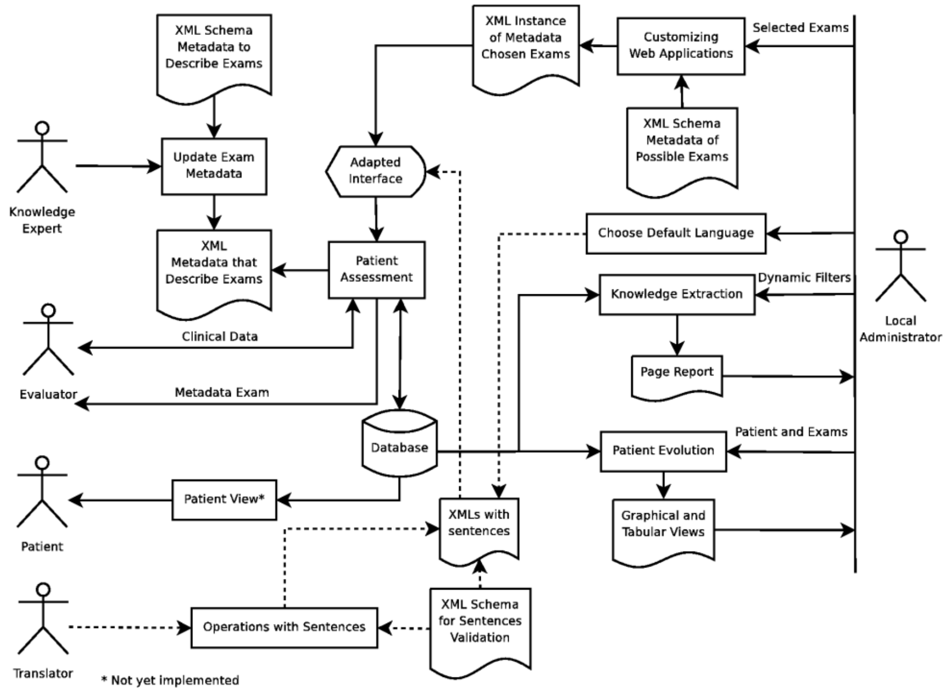


Figure 1: Sacar-Web system architecture

By means the module **Patient Assessment** it is possible to perform data collecting and analysis of patient exams. Each assessment is represented by a set of exams. The exams available are grouped by category: **Questionnaires to assess quality of life:** Chronic Respiratory Disease Questionnaire (CRQ) [Guyatt, 1987], adapted to brazilian population, and St. George's Respiratory Questionnaire Paul Jones (SGRQ) [Jones, 1991]; **Tests of pulmonary function:** The system provides the use of different equations of normal values, including Brazilian standard [SBPT, 1996], American standard due to [Knudson, 1976] and European standard by the Official Statement of the European Respiratory Society [ERS, 1993]; **Exams to test exercise capacity:** Shuttle Walk Test [Payne, 1996], the 6 Minutes Walking Test [Troosters, 1999] and Test of

Cardiac and Pulmonary Effort (TCPE) [Casaburi, 2005]. For TCPE, the system accepts the user attaches files containing graphics generated by other software developed in our laboratory that analyses physiologic signs. This software runs on client-side using Scilab (open source scientific software) and generates a set of 9 graphics grouped and aligned in a 3 x 3 matrix of graphics.

The module **customizing the web application** allows that the local administrator selects what exams he/she intends to use. The possible exams that the system provides are represented by a XML of the possible exams. When the local administrator selects his/her preferences, the system generates a XML document with an instance of exams of that health care unit.

2.3 Hardware and Software specifications

Sacar-Web is hosted on the Web-server Apache 2-2.2.4 [Apache, 2009] and has been developed using PHP language (5.2.1) with coding standard. The code documentation is made using the PHPDoc. Interfaces have been designed using CSS (Cascading Style Sheet) and Javascript for the user interaction with interface. For managing database it has been used MySQL 5.0.27 [Oracle, 2010] with tables InnoDB, that provides safe storage. XML documents were used to store the structure of an assessment that is a set of specific exams). XML [Bray, 2008] was also used do organize metadata of the exams. This approach helps to isolate content, structure and presentation, giving more flexibility, simplicity and easy reading. Furthermore such language allows include metadata that can be useful to aggregate semantic to the content of the document. To define the structure of XML documents it has been used XML Schema. In order to establish an interface between the computer program in PHP and XML documents it has been used the API (Application Programming Interface) DOM (Document Object Model).

3. Information retrieving by applying dynamic filters

An important feature of the proposed web application is the possibility to extract groups of subjects that satisfy different conditions, according to the interest of the health care professional. There are some variables that are commonly used to filter data, as gender and age range. Besides these static filters, it was introduced dynamic filters that the user (local administrator) defines at execution time. A filter consists of a set of rules. Each rule includes: to select an exam, to select a variable of this exam and to select a relational operator specifying the range of values of select variable. The user can define so many rules so desire. This procedure will help the researcher to discover interesting features about different groups of patients.

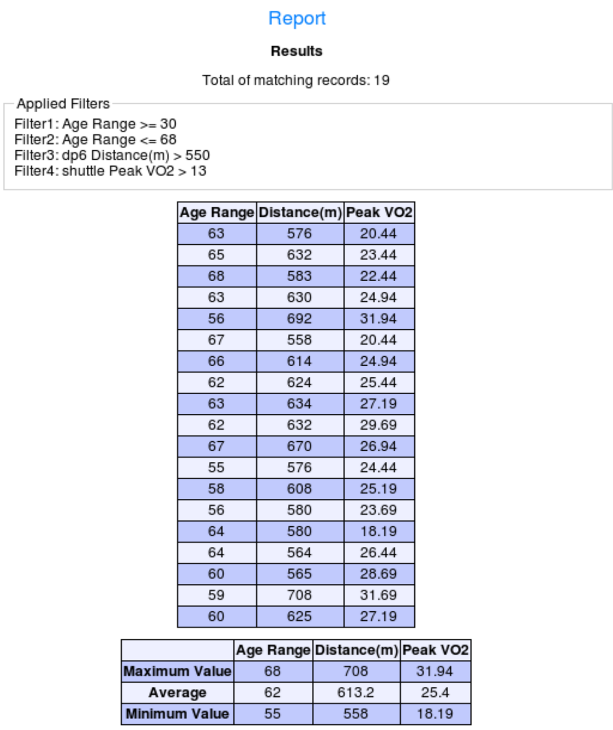
3.1 Application of dynamic filters example

Suppose the health care professional needs to identify subjects with limited capacity of exercise. A subset of subjects can be searched analyzing variables from different exams. For example, the variable distance achieved in the six-minutes walking test and the volume of used up oxygen estimated by the Shuttle-walking test.

One instance of such search could be the following: Select gender female, age between 30 and 68, total distance achieved in 6 minutes-walking test greater than 550 meters, and estimative of Volume of used up Oxygen given by the Shuttle Walk Test greater than 13. In this case we have a rule defined by two conditions that must be satisfied simultaneously (by using *and* operator). Figure 2 shows a screen shot of the example of application of dynamic filter. Each line of the filter composes a part of the SQL query that will be submitted to database server.

Figure 2: Applying dynamic filters for information retrieving

The result of applying the filter is browsed by a report page that displays the results in a tabular format, where each row is a subject and columns include the values of the variables used in the filter. Figure 3 shows the report page of the example above. In this information retrieving, the data of all health care units are searched. At the moment we are working with two health care units.



Report

Results

Total of matching records: 19

Applied Filters
Filter1: Age Range >= 30
Filter2: Age Range <= 68
Filter3: dp6 Distance(m) > 550
Filter4: shuttle Peak VO2 > 13

Age Range	Distance(m)	Peak VO2
63	576	20.44
65	632	23.44
68	583	22.44
63	630	24.94
56	692	31.94
67	558	20.44
66	614	24.94
62	624	25.44
63	634	27.19
62	632	29.69
67	670	26.94
55	576	24.44
58	608	25.19
56	580	23.69
64	580	18.19
64	564	26.44
60	565	28.69
59	708	31.69
60	625	27.19

	Age Range	Distance(m)	Peak VO2
Maximum Value	68	708	31.94
Average	62	613.2	25.4
Minimum Value	55	558	18.19

Figure 3 – Result of applying dynamic filters

Metadata of exams using XML

As argued early, it is important that the user of the system know how each exam is considered in the software. Each exam has a set of information available to the users, in order to give clarity about the main features of each exam. They include: (i) how the exam is performed (protocol), (ii) Identification of the input variables and calculated variables, including the mathematical expressions used to obtain them, (iii) Unit of measure used in each input variable, (iv) domain of valid values of input variables, (v) mathematical expression used to give the interpretation of the result, (vi) the standard of normality used (if it is the case), (vii) the bibliography that support the information and procedures given. The first idea was to delivery metadata of the exams, but in a very naive way. This idea has emerged from the need that new users (local administrators) had to be sure about the protocols of the exams. If the health care professional knows about all the conditions on what each exam is performed, he/she can be sure about the suitability of the web application for him/her. Another point to be outlined is the fact that students can take advantage, once the system presents readily the details of each exam. It is common that health care professionals use devices that normally have embedded software with a lot of results, but most of times, the user does not know how the results were obtained. Figure 4 shows a screenshot of a window with the metadata of DP6 exam. Firstly, such information was provided by means static pages. In the following, it was designed XML document, but the content was still filled by the software designer, based on the information delivered by the knowledge expert.

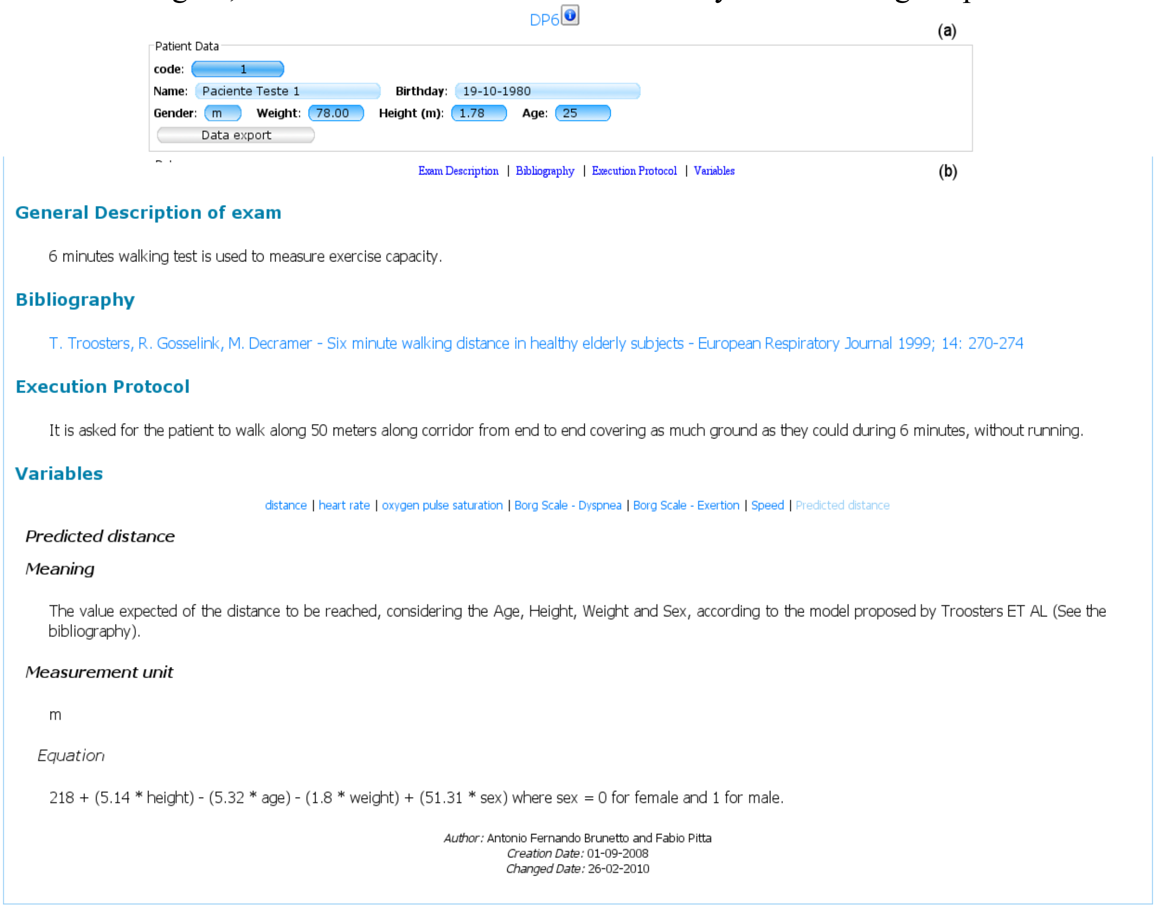


Figure 4 – Metadata of the exam DP-6 in browsing view

Considering some difficulty to get all this information from the experts on the exam, it was developed an authoring module that allows the creation and/or updating of content of metadata of the exams. In this module, the knowledge expert user should select a specific exam and fill a form with the metadata about the exam. The metadata of the exams are stored in RDF [Manola, 2004] and XML documents. Each exam has its XML-Schema [Fallside, 2004] and XML document associated. In this way, the metadata of the exams is independent of the program code, assuring more flexibility of the system and more reliability on the information.

4. Related Works

In SACAR-web we use technologies of open source Software. The set of technologies named LAMP (Linux + Apache + MySQL + PHP) has been used. McDonald (2003) has presented the advances in open source medical software that was revisited in our work. OpenEMed (1999) is a "virtual patient record" based on two CORBAmed specifications: Patient Identification Data Service (PIDS) and Clinical Observation Access Service (COAS). Open Source Clinical Applications & Resources [OSCAR, 1991] is a medical record system developed and used at McMaster University. The software provides registration, scheduling, medical record and billing services. Also, the Good Electronic Health Record (GEHR) based on openEHR [Leslie, 2008] is a model and framework for developing medical record systems. Other works address the issue of medical contents using XML. Hulse et al (2005) proposes a knowledge authoring environment to make easy the development of medical knowledge documents based on XML schema, the KAT. The key features of KAT include quick access to content for authors; flexible, generic addition of new content types; support for content reuse and rapid availability of knowledge content in clinical applications. In this context, Sacar-Web has the module of authoring the metadata of the exams, as described in section 4. PropeRWeb [van der Linden, 2005] is a multidisciplinary electronic health record (HER) system used in extramural patient care for stroke patients. The system uses open source components and is based on open standards. It is a Web application that uses servlets and Java Server Pages (JSP's) with CORBA connection to the database servers. This work, which is similar to ours, uses archetypes. Archetypes are defined by medical experts separated from the software. In Sacar-Web, we have defined a XML document storing all the possible exams and a XML document storing the exams selected by the health expert. In this way, the acceptability of the software by the medical users tends to be greater. The work of McKenna et al (2007) refers to the system PAS (Physiology analysis system), which is a resource to support efficient warehousing, management and analysis of physiologic data, particularly, continuous time-series data that may be extensive, of variable quality and distributed across many files. These works have given support to our project, once the development of software has been started based on the health care professional user needs reported by the knowledge engineer and software designer.

5. Concluding Remarks and future works

The main contributions of this work are: to provide a web-based application addressing different issues about assessment of cardiac and respiratory conditions; to propose a set of strategies to attend the main health care user needs. Among such strategies it is included: to define different roles for each user type, to establish a user profile that is used by the application to provide an adapted interface, to separate knowledge expert from coding, to include the authoring module of metadata exams, to include dynamical filters in order to retrieve relevant information. Separating knowledge expert from coding has shown to be a good practice in software development, once the maintenance is easer and the system tends to be more reliable. As future work it is being designed several improvements, mainly concerning to usability of the software.

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