Supporting in- and off-Hospital Patient Management Using a Web-based Integrated Software Platform

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Abstract. In this paper, a Web-based software platform appropriately designed to support the continuity of health care information and management for both in and out of hospital care is presented. The system has some additional features as it is the formation of continuity of care records and the transmission of referral letters with a semantically annotated web service. The platform’s Web-orientation provides significant advantages, allowing for easily accomplished remote access.

Keywords. Health Information Systems, Patient Care Management

Introduction

The tremendous rise of hospital care cost, together with the continuous and rapid evolution of information and communication technology, will eventually alter the way that healthcare is going to be delivered. Healthcare provision will soon move towards decentralized models, focusing in outpatient, community and homecare schemas, providing at the same time for the upcoming demand for patient-centered care.

Nevertheless, although the implementation of a decentralized model is nowadays technologically feasible, well documented concerns are raising about the fragmentation of patient’s information, the discontinuity in the delivered care\textsuperscript{1} and the integration of provider networks and health-care information systems\textsuperscript{2}. In this context, Web applications that allow for easily accomplished remote access and computing technologies like the Semantic Web, which allow for the comprehension of the semantics of the exchanged data, appear to be promising approaches towards the integration and interoperability problem solution\textsuperscript{3}.

1. Methods

We have developed a modular system, appropriately designed to provide for both in and out of hospital care, having also two special modules for home care management.

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and supervision. The system consists of three modules, namely the Patient Management, the Non Hospital Scheduling and the Non Hospital Supervision. All modules are designed and implemented as autonomous web applications, while at the same time they are fully integrated and communicate with each other through the Web.

Regarding the interoperability with other systems, we have experimented with two promising techniques. The first one is the creation and transmission of an ASTM (American Society for Testing and Materials) compatible Continuity of Care Record, while the second one is the implementation of Semantically Annotated Web Services for the distribution of patients’ documents over the Web.

All three applications follow classic three-tier architecture and are built with ASP.NET 4.0, using Microsoft Visual Studio 2010, Microsoft SQL Server 2008 and AJAX controls.

2. Results

2.1. The Web-based modules

The three modules that comprise our platform are going to be presented in the following paragraphs, starting with the Patient Management module. This is a web-based patient management and clinical treatment system, which provides for both In-Patient and Out-Patient care, handling patient management and clinical treatment.

An important feature of our Management module is the formation of referral letters when needed. These letters are structured and transmitted by utilizing a semantically annotated web service. Semantic Web technology appears to be a feasible solution for the interoperability problems that occur between different health-care information systems and the W3C has already started being engaged with the implementation of this technology in Health-care and Life Sciences domain.

The core of the developed module is a “Referral” ontology, whose hierarchy was defined according to the HL7 – CDA healthcare standard. The ontology was built using Protégé 4.3.8, and has the HL7 – RIM entities, the HL7 data types and vocabularies and the HL7-CDA R2 Hierarchical Description as its top-classes. These top-classes are analyzed into a number of sub-classes, which describe the concepts of these main categories. The vocabularies used were from the ICD-10, although any clinical vocabulary could be employed.

According to our implementation, the referral letters are structured as XML documents in HL7-CDA compliant format and the contents of the CDA-compliant documents are converted into ontology instances. An appropriately designed semantically annotated Web service is responsible for discovering upon demand existing Referral letters as instances of the ontology and for returning the actual contents of the documents to the calling application. Two Java applications are used as the middleware between the Web service and the Ontology itself. These applications are actually responsible for the conversion of the contents of the XML documents to Ontology Instances and vice versa.
Apart from the formation of referral letters, our module provides also for the creation of a Continuity of Care Record (CCR) when needed. This record is created on demand upon the end of an encounter or upon the discharge of a patient and it is designed in such a way as to organize and make transportable a set of basic patient information consisting of the most relevant and recently facts about the patient's condition, together with a care-plan, that is, recommendations for future care.

The CCR record is built according to the E2369 Standard Specification for Continuity of Care Record (CCR), whose later version was approved in 2012 by ASTM, an American National Standards Institute (ANSI) standard development organization. According to its official definitions, “the CCR is intended to assure at least a minimum standard of health information transportability, when a patient is discharged, referred or transferred, fostering thus and improving continuity in care”.

**Figure 1.** The basic concepts for the implementation of the Semantically Annotated Web Service.

**Figure 2.** The final form of a CCR record and a characteristic XML excerpt.
The Non Hospital Scheduling module has as its main function the creation of a homecare plan upon the transition of a patient from hospital to homecare. Our module allows for any physician to assign an appropriate set of homecare activities to specific diagnoses. These activity sets consist of diagnostic, monitoring, treatment diagnostic and nursing activities that should be employed in the post discharge period. These profiles of homecare activities are adaptable and every physician is allowed to set up his own profiles. Upon the actual discharge of a patient the physician in charge can use one of the predefined profiles, create a new one or modify an existing one in order to adapt to each patient’s specific characteristics, needs and demands.

The Non Hospital Supervision module has been developed aiming to generate personal health records from the home, allowing hospitals, health care providers and families to track and respond to critical behavioral and clinical patient data.

Our module offers a flexible platform for the surveillance and the monitoring of the homecare plan, as it was formed by the Non Hospital Scheduling module. The homecare activities that were assigned to the patient are displayed in the Supervision application in the form of instructions and reminders. Furthermore, the system allows for the manual entry of physiologic measurements and in vitro parameters that the patient should regularly monitor, according to his homecare plan. Another feature of the application is that it allows for uploading audio-visual data, for example pictures taken with the use of cameras or mobiles phones. It also allows for uploading medical images, such as ultrasound or Xray images, in DICOM format.

2.2. Security and User Control

All the applications comprising our platform utilize a role-based access model, defining the users and their permissions within each module. This ensures that only users with the proper authorization have access to patient information.

Regarding the security and authentication of the data transmitted through the internet, we have created a security web server that manages all requests that need to be secure to and from the recipient. The server is implemented using Microsoft ASP.NET Web API 2. The exposed API requires the use of HTTPS/SSL in order to allow for the execution of any action. We have created a digital certificate on our IIS Server which the user has to originally accept. After the certificate acceptance all calls that are being made are considered secured at the transmission layer.

We also use anti forgery techniques to prevent cross site request forgery (CSRF) like altering the query string on the browser. All sensitive requests contain a hash value that has to be validated on the post. As an extra level of security we have enriched our tokens with different “salt” values on each “logical domain” preventing thus an attacker that manages to get hold of a valid token to use it in another domain of the application.

After the security server has successfully received a message it strips the valid information and gives the control to an application server which knows how to process the requests. Both servers can be hosted under the same IIS or even be incorporated in a single application.

3. Discussion

We have presented in this paper the research and development approach of a multifunctional Web-based framework, appropriately designed to support the
continuity of health care information and management for both in and out of hospital care, having also two special modules for home care management and supervision.

The system has some special features as it is the formation of CCRs and the transmission of referral letters using a semantically annotated web service. The Non-Hospital Scheduling application offers a very flexible and easily adoptable module for the physician to schedule the homecare activities that are recommended for each particular patient, while the Non Hospital Supervision applications provides for both the surveillance and the monitoring of the homecare plan.

Regarding the system’s architecture, we consider that the use of web-based techniques is appropriate for such applications, since web-based models allow for easily accomplished remote access. Furthermore, Semantic Web appears to be a feasible solution for the interoperability problems that occur between different health-care information systems, while ontologies allow for accessing patient data stored in different electronic patient records (EPR), expressing their meanings and relationship clearly. Of course, such systems should take into consideration potential problems that could arise due to the internet connection, but we believe that a flexible design could overcome such problems.

It should be mentioned here that the presented system is part of an in progress project and is thus currently being tested in our laboratory with anonymised data provided to us by the physician participating in our team. Both the services and the data bases are stored in our laboratory’s server, which hosts a Windows 2008 Server System with IIS 6.0 (Internet Information Services).

Concluding, we should mention that we are convinced that the future of the healthcare industry lies in integrated systems and web-based applications, including the semantic web technology. This composite schema will eventually allow for a solution overcoming interoperability barriers, and an alternative approach to the inaccessible patient record data.

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