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The Clinical Document Architecture (CDA) Enables Electronic Medical Records to Wireless Mobile Computing

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Abstract

The Clinical Document Architecture (CDA) has proved to be a valuable and powerful standard for a structured exchange of clinical documents between heterogeneous software systems like a Hospital Information System and a Physician Office System. In this paper we want to show how the CDA can additionally be used in order to enhance the Hospital Information System's functionality: each patient related document contained in or generated from the HIS can be converted to a CDA/XML document. With the XML/XSLT-based transformation methods, those documents can be device-specifically transformed. We use this method to display HIS-content on mobile devices like Personal Digital Assistants (PDAs) by extracting the respective data fields from the HIS database, converting them to a CDA/XML document, which is transformed and sent to the mobile devices using a wireless intranet connection. Preliminary results and users' comments are promising, but further evaluation will be necessary. Our approach shows a generic model how clinical data can be displayed on different devices independently from the underlying HIS using CDA.

Keywords

Medical Records Systems, Computerized; Medical Record Linkage; Computer Communication Networks; Documentation/ standards

Introduction

Overview

This paper wants to show how the Clinical Document Architecture can be used in order to enhance any Hospital Information Systems functionality, interoperability and availability on different devices like mobile computers. In this section we introduce the Clinical Document Architecture itself and Mobile Computing as the basic principles.

The Clinical Document Architecture

The Clinical Document Architecture (CDA) [1], an ANSI approved HL7 standard, is undoubtedly a major cornerstone for transferring rich, detailed and unambiguous clinical information over the barriers of different software applications and islands. It is a document markup standard that specifies the structure and semantics of clinical documents. The CDA is part of the HL7 version 3 family of standards, which derive their semantic content from the shared HL7 Reference Information Model (RIM) and is implemented in the Extensible Markup Language (XML) [2].

A CDA document (figure 1) consists of a header containing information about the document, the encounter data, the service actors like document originators, intended recipients, health care providers involved in the service and the service targets like the patient or family members. The body represents clinical data which is represented in the current CDA Level One as structural components which can be nested, containing narrative text, multimedia objects or codes drawn from standard terminologies..

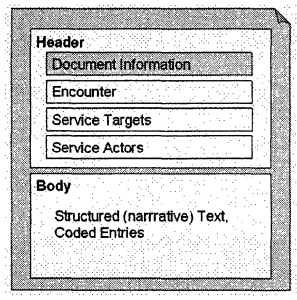

Figure 1 - Generic structure of a CDA document

For display purposes, each receiving system transforms the CDA document into a commonly used, human readable format like HTML using a specific XSLT style sheet transformation.

The CDA standard is mainly designed to exchange a number of persistent clinical documents between different software systems. The potential of CDA goes well beyond this: Actually each patient related document contained in a Hospital Information System (HIS), i.e. discharge letters, laboratory results, diagnoses or procedures list, any narrative text like radiology results and pictures etc. can be converted into a CDA document.

In different earlier projects we showed how CDA facilitates information exchange between different actors and systems in the healthcare domain:

- On users' request, CDA conformant documents are generated from discharge letters out of our hospital information system. These CDA documents are automatically

encrypted, signed and finally mailed to the general practitioner who can integrate these structured documents in the physician office system [3].

- CDA discharge letters automatically generated by the HIS can securely be uploaded and integrated in a web based personal electronic health record (EHR) owned by the patient, which we call "akteonline.de" [4]. Both discharge letters additionally contain structured information like insurance, diagnoses, medication and laboratory results, coded using the SCIPHOX-standard ("Standardization of Communication between Information Systems in Physician Offices and Hospitals using XML") [5], which provides a CDA-conformant solution of incorporating local German specifics into the CDA document. Structured information can easily be extracted by the receiving system and integrated in the respective data sets.
- Laboratory results can be sent to the electronic patient record using CDA/SCIPHOX compliant documents independently from a discharge letter.

All these applications are currently in routine use in some departments at Münster university hospital.

Mobile Computing

For physicians, mobile computers are gaining more and more popularity as point of care tools. Since the introduction of Personal Digital Assistants (PDAs) in the early 1990s, they have become increasingly popular for a large variety of medical applications [6]. In the beginning they could only be used as offline reference tools, like drug reference databases, tools for risk estimation of specific diseases, medical calculators and formulae, offline mobile patient records or diagnosis codes databases. New data entered into the PDA mostly had to be asynchronously synchronized with a network computer.

With the increasing acceptance of wireless networks in hospital two different principal scenarios and devices can be identified:

- A portable PC, i.e. a notebook is connected to a wireless network. The user has full and transparent access to the Hospital Information System, either running on the mobile device itself or on a terminal server. As the wireless PC acts like any other PC the user works in a familiar environment. Unfortunately these PC-based devices, even the recently upcoming tablet PCs, are still difficult to handle due to their size and weight and some other limitations: our experience shows that the routine use of wireless notebooks on ward rounds is not very well accepted in a clinical environment.
- A wireless network enabled PDA actually better meets the clinicians' needs because it slides smoothly in the gown pocket and is immediately available after startup, providing access to different online, mostly web-based information sources [7]. Bringing the Hospital Information System to the PDA is usually not possible due to operating system restrictions, poor PDA processor power and/or limited display size. Wireless PDAs without HIS-access have only limited use in a clinical setting. But a PDA which allows the doctor to check the latest laboratory results or to read a discharge letter may be very helpful, even if only parts of the HIS data are immediately accessible. Essentially the clinician needs fast reading access to the electronic patient record to review medical data.

We are currently introducing a wireless network on different wards in Münster university hospital. Our implementations consist of one wireless access point per ward, connected to the wired network using a virtual private network tunnel in order to meet the needs for data security. While it is actually no major technical problem to prepare PC based devices like notebooks or Tablet PCs for HIS access, the introduction of PDAs with HIS-functionality is a major challenge.

Materials and Methods

The Hospital Information System

We use a commercial HIS supplied by GWI AG [8]. It consists of a file server providing the necessary software and of a database server running an Oracle database management system. The clinical data are stored in a very complex set of tables, a generic EAV-type (Entity-Attribute-Value) [9] database schema is used for flexible storage of newly developed applications and forms [10-13]. The first step was to understand the database model and to learn how to get appropriate data from the database using SQL statements and how to convert them to appropriate CDA tags.

The CDA Server

To convert documents from the HIS to CDA and to send them to the PDA we set up a usual PC as a CDA server. This CDA server bridges the HIS to the PDA and comprises several software components:

- a CDA web server engine,
- a HIS database retrieval engine,
- a CDA conversion engine,
- an XSLT transformation engine [14],
- and a set of XSLT style sheets.

The style sheets shall manage the generation of formatted output for the browser software on the clients by converting the CDA output to HTML. We developed a style sheet for each document type (i.e. discharge letter, structured laboratory result, narrative text like radiology results, etc.) and device type (i.e. PC, Palm-based PDA, and Pocket PC-based PDA).

Figure 2 shows the CDA server's functionality:

- The user request is received by the CDA web server engine (1), cf. figure 1. Each PDA operating system (like Palm OS, Windows Pocket PC) sends characteristical information about device type, display size, browser type etc.. The web server engine checks the device type tag coming from the remote web browser for selecting the appropriate style sheet a later stage.

- The CDA web server engine passes this request to the HIS database retrieval engine which converts it to an SQL request statement (2).
- The resulting dataset (3) from the HIS is converted to a CDA string by the CDA conversion engine (4).
- The CDA conversion engine invokes the XSLT transformation engine and passes the CDA string (5).
- The XSLT transformation engine uses the respective XSLT style sheet for transformation the CDA document according to the device type and the document type to an HTML string (6).
- The resulting HTML string will be securely sent to the client via wired network, VPN tunnel and wireless network, where it is displayed to the user (7).
- The next request initiates the same cascade again

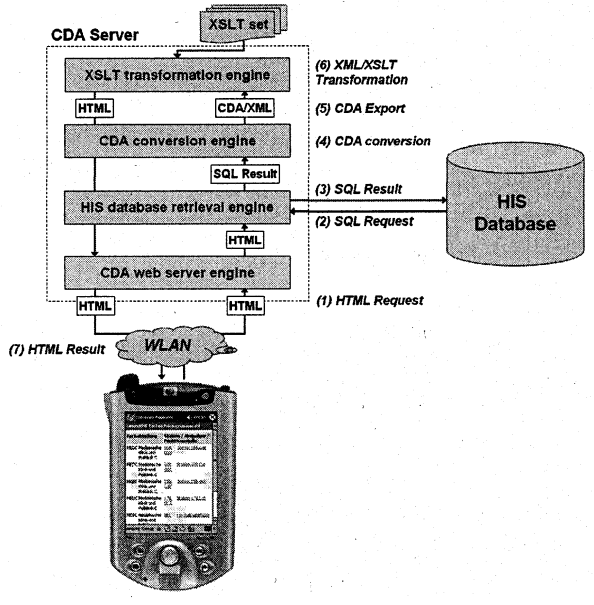

Figure 2 - Communication pathways

CDA web server engine, HIS database access engine and CDA transformation engine are written in Borland Delphi, an object oriented programming language [15]. They are linked to a single executable. The XSLT transformation engine as an external application is controlled by the CDA engine using the Component Object Model (COM) [16]. The complete cascade initiated by each request takes a few milliseconds.

Design of the XSLT Style Sheets

The XSLT style sheets control the conversion of the CDA/XML string to HTML which will be sent to the client browser. The principle design of these HTML files (figure 3) consists of

- a header, indicating the patient name, the document type an some meta data,
- a footer with some generic information about the project,
- a navigation bar which has to be adapted to currently shown document type
- and the main area, which is generated device and document type dependently, showing the actual document content.

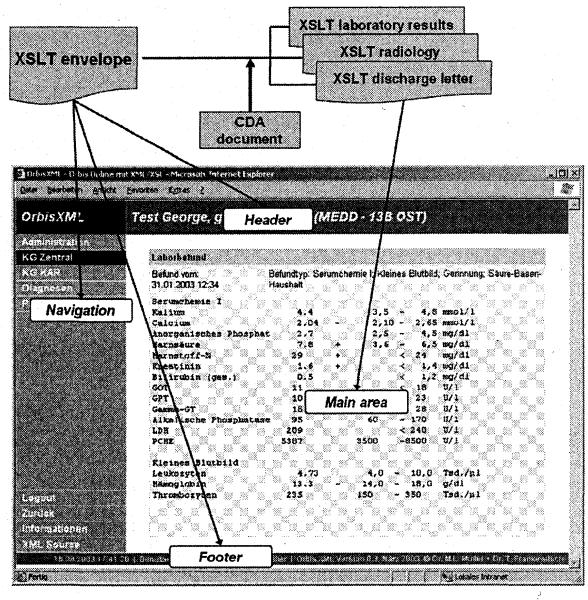

Figure 3 - HTML document (PC type)

While header, footer and navigation bar are relatively static, the main area as the core of the presentation is very dynamic. The design of the XSLT files refers to this: Since it would have been very difficult and time consuming to build completely separate style sheets for each document and device type in a homogeneous way, we nested the style sheets: The envelope style sheet covers the design of the more or less static parts of the HTML document (header, footer, navigation bar). According to the required document type, which is enclosed in the CDA document, the respective sub-style sheet for the main area will be linked and executed. So the XSLT transformation engine is always invoked with the same envelope style sheet, which covers the generic parts of the document. The CDA structure triggers the use of a specific style sheet for the main area, which handles the document type specific parts of the CDA document.

Hardware on the Client Side

On the users' side we evaluated different wireless enabled devices:

- a standard notebook,
- a standard sub-notebook,
- a tablet PC (Acer TravelMate C100) [17],
- two HP iPAQ 5450, running Windows Pocket PC [18],
- and a Palm Tungsten C running Palm OS [19].

Results

Currently, we are introducing the presented system on one ward with two physicians. They have read access to lab results, radiology reports, and discharge letters of earlier hospitalizations, administrative data, diagnoses and procedures. For the ward round we implemented a simple form which allows to upload doctors' comments and prescriptions and to integrate it into the electronic medical record. Figure 4a shows the PDA view of the laboratory results which is shown in figure 3 in the PC view. Figure 4b shows a screenshot of the selection menu of wards after logon.

Figure 4 - a/b- PDA Screenshots of a patient's lab results and selection of wards after logon

We did not experience major problems on different hardware platforms. Due to different display size and browser characteristics we had to develop different style sheets for Palm OS and Windows PC based PDAs.

Discussion

Although the HIS access has not yet become a standard application on wireless PDAs, it has a significant potential to improve medical practice – a wireless HIS brings the patient record closer to the doctor and to the patient.

A literature search identified a very small number of articles dealing with mobile wireless HIS access. Although PDA technology made rapid advances it is still not suitable for large applications like hospital information systems: a HIS would have to be at least partially recoded in a PDA conformant programming language like Java. With regard to the PDAs relatively poor processor power a web based solution seems to be the better alternative: The PDA just has to display the HTML page in the browser. There are some web based HIS on the market but often they use proprietary technology which is not supported on PDAs like Active X controls, Java Script etc.. Because the web page rendering engine in PDA browsers is by far not as performant as in PC based browsers those "heavy" web pages won't be displayed accurately.

We showed that bringing HIS to a wireless PDA is definitely possible. The CDA proved to be a valuable and flexible standard, even in this unconventional setting. Since a CDA document strictly covers one patient it is not possible to build aggregate lists of patients so we had to develop some non-CDA XML documents to represent patient and ward lists (cf. figure 4b).

Once the CDA documents are created it is of course possible to use them for additional purposes as well: we are currently developing a clinical workflow visualization tool which retrieves some clinical content through our CDA server.

Future work must focus on the further development to extend the functionality of the application, like data entry fields and embedding multimedia documents. The presented technology could as well easily being extended to other output devices like cellular phones.

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