A proposal of a digital Cephalogram Standard using DICOM

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Abstract

An important aspect of distributed data management is the structure of the managed information, which is the basis for a semantic approach of information and ensures extensibility, interoperability and adaptability in collaborative environments. This document shows a novel way to use DICOM to store and transfer digital cephalograms in collaborative orthodontic systems. Digital cephalograms are more than just plain medical radiographs of the skull. They are used to make exact measurements for craniofacial growth studies, as well as for the planning of orthodontic cases. For these applications, it is important that cephalograms be stored in a format that can hold information necessary to guarantee their accuracy. Our results find direct application to current orthodontic projects.

The Problem

Orthodontists can't easily exchange patient data because their different software don't know how to talk to each other.

Introduction

Unfortunately, the introduction of computer technology into the orthodontic office occurred before the analytic requirements of a computerized orthodontic record keeping system could be determined. To continue to communicate effectively in the information age, a standard way of storing and retrieving computerized orthodontic records needs to be established.

Valuable cephalogram film series belonging to studies performed during the first half of the 20th century, are now starting to decay. Various growth studies have been done, where patients where voluntarily x-rayed at regular intervals in order to research cranial growth and development. Today such studies would be impossible to perform, which makes the preservation of these films a high priority project for many institutions. Digitization may provide a solution to this problem since digital copies don't suffer from deterioration and are easier to distribute. Thus the need for a standardized cephalogram database of treated and untreated orthodontic cases. To date, no standards have been proposed or adopted by the orthodontic profession for storage and exchange of computerized patient data.

History

First efforts were reported to have occured in a 1991 meeting of Orthodontic Educators, where issues to be addressed before digital standards could be established were identified. In 1993 Hans organized a workshop [1] sponsored by the American Association of Orthodontics Foundation (AAOF) held at Case Western Reserve University, (Cleveland, OH, USA). This was the first attempt to discuss the technical details of creating a standard for digital orthodontic data. Interest in the project faded for ten years later when Hans et al. proved the conclusions held at the workshop to be true [2]. In 2005, Magni recovered the effort and produced a poster-board [3], an article [4], and a Master's Thesis [5]. The work provided a method for the development of a standard for the electronic orthodontic patient record, as well as a draft for a digital cephalogram standard, and a small implementation of it in JAVA.

Most of the times, even software within the same practice can't communicate with each other.

Goals

As of today, there are two major projects that could directly profit from our work: (1) Working Group 11.6 at the American Dental Association's Standards Committee for Dental Informatics which is working on a standard for the electronic orthodontic patient record [4]; (2) The AAOF project mentioned above.

The intention of this document is to apply the image resolution issues presented in [2] and the registration issues discussed in [1] into a DICOM extension for cephalograms.

The PANIO Project

PANIO

Project PANIO [6] encompasses the effort of solving interoperability problems that exists between orthodontic software. The name comes from "**PAN-I**nteroperable **O**rthodontics", i.e. all-interoperable orthodontics. Our goal is to (1) develop a public orthodontic software standard, approved by clinicians, developers and accredited institutions worldwide and (2) implement the standard in a free, open-source, platform independent software package.

Standard development

The first part of the project involves defining and getting approval for the standard. Currently, we see two ways to pursue this task: Work on top of ADA SCDI Specification No. 1000 "Standard Clinical Data Architecture for the Structure And Content of an Electronic Health Record", creating a similar documentation specific to orthodontics, or implement the orthodontic electronic data standard using other existing more implemented standards, such as HL7 and DICOM.

The first approach could be more desirable for the fact that it might help divulge ADA Spec 1000, a very well written standard, which, as of today, still remains unimplemented. On the other hand, this very fact signifies that the possibilities of it containing errors is large. Besides, it is not motivating to write a standard with the prospect of it probably not being implemented.

For this reason, the second approach might seem more appropriate: both HL7 and DICOM are very established and implemented standards: the majority of imaging devices read and write images in DICOM format, and 90% of US hospitals are currently using some variation of HL7. The available support for refining and/or implementing these standards also speak in favor: In both cases they have large active communities, much more active than the ADA SCDI, backing them up. This means a higher quality standard in less time.

A plan for the development of the standard has been published in [4] and [5] and consists of first developing and agreeing on a clinical process model. Secondly, the model will provide enough information to produce a gap analysis between what HL7 and DICOM currently have and what we require them to provide. Collaboration with the two committees is then necessary to work out the details involved in adding or modifying the standard to accomodate for orthodontic needs. Finally, the standard can be drafted, as an ADA SCDI standard that makes use of, at a lower level, HL7 for non-imaging and DICOM for imaging data.

Currently we have formed an active working group within the ADA SCDI and are defining the clinical process model for it. We have also investigated the possibilites of collaborating with HL7 and DICOM, both very interested in the project.

A standard for the orthodontic electronic patient record would solve these problems. Collaboration with DICOM, HL7 and ADA SCDI is fundamental, because they are all leading and well accepted standard developing institutions.
An open source, cross-platform, distributed software that implements this standard could be used as sringboard for its success.

Software development

Once a preliminary version of the standard has been approved, we plan to write an open-source implementation of it. This will serve various purposes:

1. Help divulge the standard by proving that it is functional.

2. Build a test application that will aid the testing and debugging of the standard. Every implementer and standard developer could use this application as a reference for functionality testing.

3. Provide the orthodontic community with a free package that will allow for basic patient database management operations.

The structure will be based on a middle-ware web framework, which will allow various software vendors to easily adapt their own software to work within the framework, offering a single web portal for all orthodontic software needs. Such novel approach will not compete on the market and will allow smaller vendors to develop custom portals (interfaces) to suite the specific orthodontists needs.

The actual first implementation of the framework will be in a platform independent language, such as JAVA and most likely hosted on an open source repository site. It shall provide only very basic functionality, needed for testing and emergency situations.

Digital Cephalograms

Digital Cephalograms

While DICOM can handle all necessities required by digital cephalograms, cephalograms are nowhere explicitly mentioned in the normative DICOM documentation. The summary of the results of our research is presented below as a list of information elements which necessarily need to accompany all digital cephalograms.

Cephalograms are more than a simple radiograph of the skull. They are used for craniofacial growth studies as well as for orthodontic treatment planning.

Cephalogram pair A cephalogram pair is considered to be a set of a lateral and PA cephalogram which are part of the same study. Lateral and postero-anterior cephalograms are related by making use of the Referenced Image Sequence (0008,1140), which is part of the Image SOP Instance Reference Macro.

Patient demographics The cephalogram is part of the patient record, and should therefore contain information for its proper identification. Such information should be patient name, ID, gender, date of birth, date/time when exposure was taken. Demographics should be stored in the patient information entity modules as defined by DICOM in C.7.1.1, C.7.1.2 and C.7.1.3 [7].

Radiographic magnification Radiographic magnification is an essential element that allows the correct interpretation of the distances within a cephalogram. It is defined as the magnification that occurs on the film due to the point-like nature of the x-ray source, and depends therefore on the distances between detector, patient and source.

This can be encoded within a DICOM DX IOD making use of the DX Positioning Module [7]. The module contains three useful attributes: Estimated Radiographic Magnification Factor (0018,1114), Distance Source to Patient (0018,1111) and Distance Source to Detector (0018,1110). By making use of either the first, or a combination of the last two attributes, magnification information can be accurately preserved along with the image.

Head orientation The orientation of the head with respect to the x-ray beam must be known in order to be able to accurately relate the x-ray distances with the subjects measurements. Normally this is done with the cephalostat by keeping the subject in a locked position, and by orienting the central x-ray beam exactly through the transmeatal axis. The cephalostat, which secures the subject by the ears, only allows movement about the transmeatal axis. In lateral cephalograms, this kind of rotation is of little importance, since it can be easily corrected by physically rotating the x-ray film after it has been developed (no distortion inserted). Yet for PA (posteroanterior) cephalograms such rotation causes a distorted projection of the skull. Correlation between cephalogram and patient measurements is not possible if the angle of rotation is unknown.

For this reason it has been decided to define, within the PA cephalogram, the angle about the transmeatal axis with respect to the Frankfort plane (The Frankfort plane is defined by the left orbitale (the lowest point on the lower edge of the orbit) and the right and left tragions (upper edge of the tragus). This plane is usually held horizontal, i.e. parallel to the ground.) as a mandatory field. This has two advantages: (1) The distances on the cephalogram can be accurately related to measurements on the subject and (2) the technician is forced to pay particular attention to the orientation of the head.

DICOM provides a way to store the angles at which the patient is oriented with respect to the detector and beam in the DX Positioning Module (C.8.11.5) defined in [7, PS 3.3, C.8.11.5]. This field already accounts for standard beam directions. Arbitrary angles should be stored using the Positioner Primary Angle (0018,1510) and Positioner Secondary Angle (0018,1511) attributes.

Image distortion It is not within DICOM's scope to directly address the distortion caused by digitization [8]. Nonetheless DICOM does allow for associating fiducials to an image, which, in turn, can be used to verify image distortion by making use of the Spatial Fiducials IOD. The details of the usage of these elements should be part of an ADA SCDI technical report. Resolution This information can be correctly stored using the Image Pixel Module (C.7.6.3). Minimum resolution requirements should be mandatory for cephalograms to be used for clinical purposes, yet not be necessary for presentation purposes. Conformance specifications Digital cephalogram can conform to the specifications in two ways: by simply guaranteeing that the image is properly encoded, or by guaranteeing the clinical usefulness of the image. In DICOM terms, these would be named ``FOR PRESENTATION'' and ``FOR PROCESSING'' respectively.

Currently, valuable cephalogram film series belonging to studies performed during the first half of the 20th century, are starting to decay. The American Association of Orthodontics Foundation (AAOF) aims to digitize and store them into a database, which must be compatible with various computer software programs, possibly in a standard format. To date, no informatics standards have been proposed or adopted by the orthodontic profession.

Providing results with `dcm4ceph`

An open source software package "dcm4ceph" was developed to produce digital cephalograms stored in DICOM according to the suggestions presented in this paper. It is based on the "dcm4che" 2.0.7 [9] open source project. "dcm4ceph" is a wrapper for various "dcm4che" classes and methods to represent the appropriate DICOM objects and attributes. It even provides classes to take care of image distortion issues discussed above. The software comes with a utility program, called "dcm2ceph", which reads a cephalogram image, its metadata and a configuration file and outputs a DICOM cephalogram object. More information can be found on the internet at http://dcm4ceph.antoniomagni.org.

Cephalogram metadata is:
- Cephalogram pair
- Patient demographics
- Radiographic magnification
- Head orientation
- Image distortion
- Resolution

Conclusions

In order to successfully address distributed data management and interoperability between orthodontic software, the full electronic orthodontic patient record must be standardized such that software vendors will be able to, by simply implementing such standard, easily import and export patient record. Digital cephalograms are an important part of the patient record, yet no standards exists for their storage. This paper discusses the necessities of digital cephalograms, and how they could be satisfied by making use of DICOM.The collaboration with various U.S. institutions for the preservation project funded by the AAOF guarantees that, in the near future, this work will be implemented and validated by experimental results.

Our research shows that DICOM is a suitable standard for cephalograms by providing details on how to store them using the DICOM vocabulary: it already defines all the necessary fields. Its just a matter of determining which ones to use in a normative documentation, such as those produced by the ADA SCDI.

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