A proposal of a digital cephalogram standard in DICOM

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Abstract

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. This document specifies how to use DICOM to store such information along with the cephalograms themselves.

This document describes how to use DICOM to store and transfer digital cephalograms. It is divided in six parts:

1. In the introduction the reader is presented with a brief history of the issues concerning the development of a standard for the electronic orthodontic patient record.

2. A discussion of the requirements for digital cephalograms, and how current DICOM resources could handle them.

3. The gap analysis to produce a list for what needs to be addressed.

4. The proposed DICOM standard for digital cephalograms.

5. Conclusion and discussion of further work.

6. Appendixes with tables and other complementary material.

1 Introduction

It was only in 1991, during the annual meeting of the American Association of Orthodontics (AAO), that the belief of the new information age reaching into the orthodontic world was accepted. 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.

Currently, the profession is being challenged to provide more information on the efficacy of various treatment methods. In addition, 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 in the past century, where patients where voluntarily x-rayed periodically (sometimes even with implanted artificial landmarks) 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. These challenges has increased the need for a standardized cephalogram database of treated and untreated orthodontic cases. The personal computer may provide a solution to this problem because it is easy to make and access copies of computerized information and because digital copies don't suffer from deterioration. However, for the copies to be useful, they must be compatible among various computers and computer software programs.

To date, no standards have been proposed or adopted by the orthodontic profession for storage and exchange of computerized cephalograms and other patient information. During a 1991 meeting of Orthodontic Educators, three issues were identified that need to be addressed before standards can be established:

1. Lexicon issues: what terms will be used to describe orthodontic conditions.
2. Resolution issues: what is the resolution (spatial and grey-scale) necessary for orthodontists to use digital representations of x-ray and models instead of the originals.
3. Registration issues: how should digitized records be registered and scaled.

Two years after the 1991 educators meeting, Hans organized a workshop sponsored by the American Association of Orthodontics Foundation (AAOF) which was held at the Bolton-Brush Growth Study Center (Case Western Reserve University, Cleveland, OH, USA) in March 1993. It was entitled *Standards for Digital Storage, Retrieval and Analysis of Orthodontic Records* [1] and was the first attempt to discuss the technical details of creating a standard for digital orthodontic data. The workshop only focused on digital x-rays and delivered a rather broad set of minimum requirements necessary for digital cephalograms to be of orthodontic use. After the workshop, interest in the project faded. It was only ten years later that Hans et al. proved the conclusions held at the workshop to be true [2]. Two years later, Magni recovered the effort and produced a posterboard [5], an article [4], and a Master's Thesis[3]. 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[1].

Cephalograms are more than a simple radiograph of the skull. They are used for craniofacial growth studies as well as for orthodontic treatment planning. It is therefore important to store, along with the radiograph itself, further information, which can guarantee the accuracy of the image itself. For this purpose, the DICOM standard is highly developed and contains enough definitions to unambigously store all metadata that should accompany all cephalograms.

[1]Further information can be found on the internet at `http://panio.antoniomagni.org`.

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. Lexicon issues are not addressed, as they are believed not to be necessary for the storage and retrieval of digital cephalograms.

2 Requirements for digital cephalograms

The need for the development of a standard for digital cephalograms has existed for about fifteen years. Over all these years, the details of its requirements have been drafted, yet have never been applied. The following list represents the six basic issues that need to be addressed in order to represent cephalograms in a digital format:

1. Patient demographics
2. Radiographic magnification
3. Head orientation
4. Image distortion
5. Resolution

2.1 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.

All required patient information can be store making use of the existing *Patient Module* (C.7.1.1).

2.2 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.

Radiographic magnification can be stored in various forms: distance between mid-sagittal plane and film associated with the distance between source and film; ratio between these two distances; ratio between 1 mm on cephalogram and 1 mm on the subject (as in, for example, the scale of a geographical map); percentage; inclusion of a 10 cm x-ray visible scale in each and every exposure. Of all the above, percentage is the preferred unit for magnification, as it directly represents the desired information. The percentage of magnification allows the conversion between the two coordinate systems (real world to cephalogram) through a simple relationship:

$$d\left(1+\frac{p}{100}\right)=d' \tag{1}$$

where d is a distance on the subject (a real world distance), d' the distance as measured on the cephalogram and p magnification of the cephalogram in percentage.

DICOM accounts for two ways to store the geometric magnification along with the x-ray image. The first method stores the ratio between the source to patient and the patient to film distances; the second stores the distance between two pixel centers in the real world.

Using SID/SOD Radiographic magnification can be encoded within a DICOM DX IOD making use of the *DX Positioning Module* [6, PS 3.3 - Page 631]. The module contains three useful attributes: *Estimated Radiographic Magnification Factor* (0018,1114) which is defined to be the "Ratio of Source Image Receptor Distance (SID) over Source Object Distance (SOD)."; *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.

In most cases, the SOD and SID distances are kept constant for all cephalograms. Utilizing these attributes is therefore relatively practical and suggested.

Using pixel spacing Alternatively, radiographic magnification can be encoded within a DICOM DX IOD making use of the *DX Detector Module:* the module contains the *Basic Pixel Spacing Calibration Macro* where the *Pixel Spacing* (0028,0030) attribute can be used to store what one pixel to the left and/or one pixel down corresponds to on the patient. From the DICOM documentation [6, PS 3.3 - Page 80], the official definition is:

> "The Pixel Spacing (0028,0030) attribute specifies the physical distance in the patient between the center of each pixel."

The macro even allows for specifying how the calibration was performed, if through the use of fiducials, or if it was just known. This can be specified through the optional attribute *Pixel Spacing Calibration Type* (0028,0402):

> "The type of correction for the effect of geometric magnification or calibration against an object of known size, if any. Enumerated Values:
>
> GEOMETRY: the Pixel Spacing (0028,0030) values account for assumed or known geometric magnification effects and correspond to some unspecified depth within in the patient; the Pixel Spacing (0028,0030) values may thus be used for measurements of objects located close to the central ray and at the same depth.
>
> FIDUCIAL: the Pixel Spacing (0028,0030) values have been calibrated by the operator or image processing software by measurement of an object (fiducial) that is visible in the pixel data and is of known size and is located close to the central ray; the Pixel Spacing (0028,0030) values may thus be used for measurements of objects located close to the central ray and located at the same depth within the patient as the fiducial." [6, PS 3.3 - Page 81]

Similarly, the attribute *Object Pixel Spacing in Center of Beam* (0018,9404) could be used: it defines the pixel spacing at the center of the beam.

Although this method would also solve the problem of knowing what the distance of the digital image corresponds to in real life, it is less practical, because it needs to be calculated from the resolution, the *Imager Pixel Spacing* (0018,1164) and the actual SID/SOD ratio.

2.3 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[2] 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.

Assuming the distortion caused by the point-like x-ray source to be negligible, distortion in the PA caused by rotation about the transmeatal axis can be corrected with the following relation:

$$d' = \frac{d''}{\cos\alpha} \tag{2}$$

where d'' is an anatomical measurement performed on the cephalogram, α the angle of rotation with respect to the Frankfort plane and d' what the anatomical measurement would be, were there no rotation (no transmeatal distortion). Eq. 2 can complement Eq. 1 by forming the following more complete magnification correction relation:

$$d = \frac{d''}{\cos\alpha\left(1 + \frac{p}{100}\right)} \tag{3}$$

Eq. 3 can substitute Eq. 1 in any situations: the cosine term disappears when the angle is zero degrees, reducing to Eq. 1.

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 [6, PS 3.3, C.8.11.5]. *View Code Sequence* (0054,0220) allows for storing which kind of cephalogram it is (postero-anterior, antero-posterior, right-lateral,...). This field already defines which side the beam hits the patient first. For example postero-anterior specifies the beam direction: from posterior to anterior. In addition, this field also allows oblique sequences (see 2 on page 10).

However, this attribute does not account for non-standard angles. Such angles can easily be stored using the *Positioner Primary Angle* (0018,1510) and

[2]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.

Positioner Secondary Angle (0018,1511) attributes. The *Positioner Primary Angle* definition is like longitude (in the equatorial plan). This is the angle that defines whether the accompanying image is a lateral or PA cephalogram. The *Positioner Secondary Angle* definition is like latitude (in the sagittal plane). This is the angle that defines the rotation about the transmeatal axis. For example, a patient facing the x-ray source for an antero-posterior image would be encoded with Primary Angle 0 degrees and Secondary Angle 0 degrees, whereas a patient oriented for a lateral Cephalogram, with the beam coming from the right side of the face, with Primary Angle -90 and Secondary Angle 0.

2.4 Image distortion

Analog cephalograms, which are exposed on film, usually don't add any additional distortion, unless the film inside the cassette holder is misplaced or somehow not completely flat. Yet, the digitization process is complicated and could introduce additional error, as has been shown by Schnepper [7]. Scanners, if not properly tested and calibrated, could produce images with slightly different vertical and horizontal pixel sizes, variation in pixel size throughout the image. Some institutions make use of fiducials for digitized analog cephalograms to guarantee that the digitalization process has not added any distortion. This method also provides an additional way to compute the scale of the digital image (hence the size of each pixel).

At the Bolton Bruch Growth Study Center four pinholes, called SB fiducials, are punched at the corners of the cephalogram making use of a template. The distance between these points is well known and should be preseverd throughout the digitization process. This can be accomplished either by storing each fiducial as a point (in x,y coordinates) or by storing the distances of the four fiducials from each other. The latter method provides two advantages: (1) there are only 6 numbers to store, instead of 8 (each point is composed of an x and a y coordinate value) and (2) there is no need to account for possible coordinate shifts introduced by the scanning or the pinhole-punching process. We therefore decided that SB Fiducials should be stored with the cephalogram making use of six fields representing the six distances of the points with each other. Only if all six distances are known, can the relation between all points be guaranteed.

A cephalogram must contain all six distances if it is digitized from film. In the case when a cephalogram originates directly from a digital x-ray sensor, making use of alternate fiducials is still suggested. By placing four or more fiducials at known distances close to the patient inside the field of view of the cephalometer, this distortion can easily be detected.

DICOM does not directly address the image of distortion caused by digitization. Yet it does allow for associating fiducials to an image, which, in turn, can be used to verify image distortion (see 2.4). Such fiducials can be represented with an IOD called *Spatial Fiducials*[3]. Although it is not possible to store the distance between each fiducial, the IOD has attributes for the coordinates of each SB corner fiducial. With a little math, it is possible to convert from distances to coordinates, and vice versa. Refer to Appendix B on page 20 for a more detailed mathematical explanation.

[3]This IOD is primarily intended to be used to correctly reference and overlap two separate images.

When the fiducials are placed in the imaging field, they are held at fixed known distances with a frame or a template. These distances can be stored in coordinate form in *Graphic Data* (0070,0022), an attribute of the *Spatial Fiducials* module. The first fiducial can start at the origin (0,0) and the others relative to that one. Once the relationship between fiducials are correctly stored in DICOM format, they must be related to the specific scanned image. This can be accomplished in two ways: (a) by storing it along with each and every image or (b) by storing it in a separate dummy patient study and series.

Storing the fiducial relationships along with the image is possible making use of the coordinate system and pixel size of the image. The implementing system would then be responsible for knowing that the fiducial pixel coordinates are not absolute to the referenced image (i.e. the first pixel is not at coordinate (0,0) of the actual image), but they should be considered as relative.

In the second approach, the fiducials can be associated to a dummy patient image of known pixel size. The distances between each fiducial can easily be computed making use of the pixel location of each fiducial in conjunction with the pixel size of the dummy image. Any scans that were performed with this set of fiducials can then be associated to this DICOM representation of the fiducials making use of the *Referenced Image Sequence* (0008,1140) attribute.

The second approach has the advantage of not having to repeat information throughout a large set of images. In addition, various fiducial sets can easily be organized and stored for future use. On the other hand, this method could be more prone to errors during the transportation of images. When an image is copied to a different system, one must pay attention that the receiving system has the fiducial set already. This consideration should be carefully evaluated and discussed with the members of the DICOM community.

2.5 Resolution

The main purpose of cephalograms is to measure angles and distances between anatomical landmarks. It is therefore essential to be able to accurately identify anatomical landmarks. Based on a research held at Case Western Reserve University [2], the minimum resolution needed for a cephalogram to be useful for orthodontic treatment or research is of 4096 shades of grey and 1536x1024 pixels on an 8"x12" film, which translates into a resolution of 128dpi x 12 bits of grey. This means that a pixel must have a vertical or a horizontal size of 0.19mm (1/128th of an inch) or less.

The standard should therefore require the pixel size to be smaller than 0.19mm both horizontally and vertically and have a depth of 12 bits.

Information on resolution can be correctly stored using the *Image Pixel Module* (C.7.6.3).

3 Gap analysis

This section highlights the gap between what is required for cephalograms and what DICOM can provide. It serves as background for the formulation of the standard presented in the next section.

As presented above, DICOM provides all necessary resources to be able to correctly encode cephalograms. Nonetheless, its documentation does not directly address cephalograms (neither as normative, nor as informative). Some minor refinements need to be made, most of which could be part of a separate implementation manual. Ideally they could be included within the official DICOM documentation.

The gap analysis can be resumed in three basic points:

1. DICOM does not specify minimum requirements for resolution. The specific resolution requirements for cephalograms need to be specified.

2. The DICOM normative documentation considers some fields as *Optional Data Elements*, while, for cephalograms, they should be mandatory. (eg. *Positioner Primary and Secondary Angles* (0018,1111) and (0018,1110), *Estimated Radiographic Magnification Factor* (0018,1508)).

3. DICOM does not specify a way for verifying the accuracy of the digitalization process (discussed in SB Corner Fiducials on page 6).

Section 4 provides a solution to the above mentioned gaps.

4 Using DICOM for digital cephalograms

DICOM (Digital Imaging and Communications in Medicine) is a well established standard maintained by the National Electric Manufacturing Association (NEMA). It defines how to store and transfer images related to the medical field. Currently, most medical equipment which deal with images, can interpret the DICOM format. DICOM was chosen as the framework to implement the standard because of its popularity and its advanced stage of development. In fact, the widespread use of DICOM in the medical field will greatly facilitate the integration of the cephalometric images with existing software. Integration and implementation are a keystone of standards development, since a well developed standard that remains unimplemented is of little use.

This section contains the standard for storage and transfer of digital cephalograms. It is based on the DICOM documentation, and requires previous knowledge of DICOM basics and IODs. All tables in this section are similar but not identical to the tables found in the DICOM documentation: here the reader will find only the attributes which require special attention. It is therefore necessary to accompany this document with the DICOM standard [6, PS 3.3, A and C].

4.1 Overview

The standard proposes a way to encode and relate a single cephalogram or a cephalogram pair with a set of fiducials using DICOM objects. It deals with DICOM Image Object Definitions (IODs)only, and not with the commands to be performed upon these objects (i.e. Service Classes, [6, PS 3.4]) nor with its operations and notifications (i.e. Message Exchange, [6, PS 3.7]). The two IODs used in this document are:

DX Image IOD for demographic information (patient name, sex, age, ID, health care institution, physician,. . .), image information (pixel size, color depth, resolution, . . .), radiographic information (detector size, distance between patient source and detector, radiographic magnification, direction of beam, . . .)

Spatial Fiducials IOD to represent the information which is required to verify distortion caused by digitization.

This section is organized in tasks, each subsection addressing a specific requirement for digital cephalograms.

4.2 Patient Demographics

Information on the patient should be stored in the patient information entity modules as defined by DICOM. Refer to C.7.1.1, C.7.1.2 and C.7.1.3 [6, PS 3.3].

4.3 Radiographic magnification

The radiographic magnification factor is to be stored within the DX Positioning Module (C.8.11.5) making use of the *Distance Source to Patient* (0018,1111) the *Distance Source to Detector* (0018,1110) and the *Estimated Radiographic Magnification Factor* (0018,1114) attributes.

These three attributes present the user with a choice: either make use of the first two, or of the third, which, according to DICOM, is simply the ratio of the first two attributes.

4.3.1 ***Estimated Radiographic Magnification Factor*** (0018,1114)

The *Estimated Radiographic Magnification Factor* (0018,1114) is the preferred way of storing radiographic magnification, as it stores the value as suggested in section 2.2.

4.4 Head orientation

Patient head orientation with respect to the x-ray beam should be stored in the attributes of the *DX Positioning Module* (C.8.11.5). Refer to table 3.

4.4.1 ***View Code Sequence*** (0054,0220)

View Code Sequence (0054,0220) describes the projection of the anatomic region or orientation. It includes a Code Sequence Macro, in which one of the codes listed in Table 1 on the next page shall be specified.

These values should be conistent with *Positioner Primary Angle* (0018,1510) and *Positioner Secondary Angle* (0018,1511) especially when they are not one of the four described in Table 2 on the following page.

4.4.2 Positioner Angles (0018,1510) and (0018,1511)

Positioner Primary Angle (0018,1510) and *Positioner Secondary Angle* (0018,1511) are used to describe the patient orientation. Since the patient orientation defines the projection, these values are very important for the correct determination of the distances on the x-ray image.

Most cephalograms are performed at fixed and standardized positions, such as the ones described in 2 on the next page. However, the standard leaves room for oblique cephalograms as well, as long as their angle of obliqueness is known.

Table 1: SNM3 Codes available for the *View Code Sequence* (0054,0220).

Prefix	**Code**	**Code name**
SNM3	R-10206	antero-posterior
SNM3	R-10208	antero-posterior oblique
SNM3	R-10210	right posterior oblique
SNM3	R-10212	left posterior oblique
SNM3	R-10214	postero-anterior
SNM3	R-10216	postero-anterior oblique
SNM3	R-10218	right anterior oblique
SNM3	R-10220	left anterior oblique
SNM3	R-10232	right lateral
SNM3	R-10234	right oblique
SNM3	R-10236	left lateral
SNM3	R-10238	left oblique

Table 2: Primary and secondary positioner angles for standard positions.

SNM3 code	**Prim. Angle**	**Sec. Angle**	**Comments**
R-10206	0	0	antero-posterior
R-10214	+/-180	0	postero-anterior
R-10232	-90	0	right lateral
R-10236	+90	0	left lateral

With such angle it is in fact possible to compute the distortion introduced by the rotation.

The cephalostat only allows for rotation about the transmeatal axis. Hence, the axis of rotation can only be the axis that passes through the ears (transmeatal). Therefore it shall be defined as zero degrees the direction parallel to the Frankfort plane: 180 degrees if the patient has its back towards the x-ray source and 0 degress when the patient is facing the x-ray beam. Positive angles indicate a rotation such that the patient is looking downward, negative angles indicate a rotation such that the patient is looking upward.

In DICOM, the secondary Angle is defined as follows:

> "The Secondary Axis is in the Patient Plane and is perpendicular to the Primary Axis at the isocenter. The Positioner Secondary Angle is defined in the Sagittal Plane at the isocenter with zero degrees in the direction perpendicular to the patient's chest. +90 degrees corresponds to the cranial direction. The Secondary Positioner Angle range is -90 to + 90 degrees."[6, PS 3.3, p. 439]

The cephalostat only allows for rotation about the transmeatal axis. Therefore the angle of 0 degrees shall be defined as zero degrees in the direction parallel to the Frankfort plane, instead of being defined as perpendicular to the chest (which is not a region of interest for cephalograms), 180 degrees if the patient has its back towards the x-ray source and 0 degrees when the patient is facing it. Positive angles indicate a rotation such that the patient is looking downward, negative angles indicate a rotation such that the patient is looking upward (see 2 on the preceding page).

For standard cephalograms, the *Positioner Secondary Angle* should conventionally always be 0 degrees. Nonetheless, there could be some applications when it may be convenient to image the patient at different angles. As long as these angles are recorded, the images can be considered useful cephalograms. However, for the cephalostat positioner type, it is not reasonable to have a secondary angle greater than 80 degrees or smaller than -80 degrees: 90 degrees would mean that the whole body is being imaged from head to feet, which would provide an image that could not be considered a cephalogram any longer; a 180 degrees angle signifies that the patient is being imaged upside down (head down, feet up), which creates an unlikely scenario.

4.5 Image distortion

Image distortion can be evaluated making use of SB Corner Fiducials (see section 2.4 on page 6), i.e. four or more markers located within the imaging area and digitized along with the subject. They are used to verify that the digitization process did not introduce any distortion. Their exact absolute position on the image is unknown, but the distances between each and every point is well known. It is the responsibility of the implementing software to verify that the known fixed distances correspond to the fiducial appearance on the scanned image.

Usually, SB Corner Fiducials are placed in the imaging field making use of templates. The information on the set or template of SB Corner Fiducials should be stored making use of the *Spatial Fiducials* IOD [6, PS 3.3, A.40]. The implementation details can be found in Table 9 on page 19.

DICOM has a well defined structure for the storage of each fiducial: each fiducial module contains a *Fiducial Set Sequence* (0070,031C). Each fiducial set contains a *Fiducial Sequence* (0070,031E), which in turn contains the actual fiducial points stored within the *Graphic Coordinates Data Sequence* (0070,0318). This structure permits the co-existance of different sets of fiducials, a useful feature, considering that fiducials for this purpose have not been standardized yet.

4.5.1 *SOP Class UID* (0008,0016)

Each image that makes use of a specific fiducial set, should reference the set making use of the *Referenced Instance Sequence* (0008,114A) within the General Image Module. The *SOP Class UID* (0008,0016) should therefore be set to

```
1.2.840.10008.5.1.4.1.1.66.2 Spatial Fiducials Storage
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As no ideal code for this purpose was found, the most appropriate that should be used is the DCM version 01 112171 “Fiducial mark” code.

4.5.2 *Contour Data* (3006,0050)

The *Contour Data* (3006,0050) is used to specify the shape of the fiducials, if they are not a single point. The standard even offers a way to store the *Uncertainty Radius* (0070,0312) if necessary. In the case of SB Corner Fiducials punched on films before scanning, this feature should not be necessary, as the fiducials are point like and should appear only as a few pixels on the image itself.

4.5.3 Spatial Fiducials Series Module (C.21.1)

No modifications necessary. Refer to DICOM documentation. Note, however, that this is a mandatory module, and has only one *Modality* (0008,0060) Attribute, which must be set to "FID", according to DICOM.

4.6 Resolution

Minimum resolution requirements are mandatory for cephalograms to be used for clinical purposes, yet are not necessary for full DICOM conformance. The level of conformance is to be specified using the *Presentation Intent Type* (0008,0068) as specified in section 4.7.

Cephalograms for clinical use must be stored with a resolution of 128dpi or higher and at least 4096 shades of grey. Resolution is to be stored in the *Image Pixel Module* (C.7.6.3) as defined by DICOM (see table 4).

4.7 Conformance specifications

Digital cephalogram can conform to the specifications in two ways: the first simply guarantees that the image is properly formatted, while the second adds resolution requirements (discussed in 4.6), which makes the image clinically useful. Conformance type is stored making use of the *Presentation Intent Type* (0008,0068) attribute. Permitted values are "FOR PRESENTATION" e "FOR PROCESSING" (see 7).

FOR PRESENTATION is used when the encapsulated image *does not* comply with the resolution requirements specified by this standard. Nonetheless, this image is properly formatted, and can be assumed to contain all required cephalometric attributes defined by DICOM and this standard.

FOR PROCESSING is used when the encapsulated image *does* comply with the resolution requirements specified by this standard, as well as its formatting requirements. This is the highest level of conformance.

According to DICOM, this attribute must agree with *SOP Class UID* (0008,0016) (see 6).

4.8 Cephalogram pairs

A cephalogram pair is considered to be a set of a lateral and PA cephalogram which are part of the same study. In such situation, the lateral cephalogram is related to the PA by making use of the *Referenced Image Sequence* (0008,1140), which is part of the *Image SOP Instance Reference Macro.*

Image Type (0008,0008) is an attribute which could very well be suited to define a cephalogram pair. Yet, it is part of the *X-Ray Image Module* (C.8.7.1), which is not included in the DX Image IOD.

4.9 Derivation

Cephalograms are not derived images. According to DICOM, derived images are images that have been processed in a way that the information contained within the image has changed. The digitization process is not considered to produce derived images. Therefore the derivation attriubtes (such as *Derivation Description* (0008,2111) or *Derivation Code Sequence* (0008,9215)) should be omitted, unless the digital image has undergone some processing, which has modified it in a non-revertable way (such as normalizing, resizing or cropping).

4.10 SOP Common Module

The *SOP Common Module* (C.12.1) must containt the code that describes the correct Digital X-Ray Storage object, according to whether its for presentation or for processing:

Digital X-Ray Storage – For Processing

`1.2.840.10008.5.1.4.1.1.1.1.1`

Digital X-Ray Storage – For Presentation

`1.2.840.10008.5.1.4.1.1.1.1`

5 Conclusions

Further work should be performed to analyze and complement the DICOM Service Classes, [6, PS 3.4] and DICOM Message Exchange, [6, PS 3.7], in order to complete the standard.

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A Module Tables

Table 3: DX Positioning Module (C.8.11.5)

Attribute Name	***Tag***	**Type**	**Notes**
Patient Position	(0018,5100)	3	Omit in favour of (0054,0222).
View Position	(0018,5101)	3	Omit in favour of (0054,0222).
View Code Sequence	(0054,0222)	3	Refer to section 4.4.1.
Patient Orientation Code Sequence	(0054,0410)	3	If used, shall be SNM3 code number F-10440 "ERECT".
Patient Orientation Modifier Code Sequence	(0054,0412)	3	If used, shall be SNM3 code number F-10320 "STANDING".
Distance Source to Patient	(0018,1111)	1C	Necessary when *Estimated Radiographic Magnification Factor* (0018,1114) is missing.
Distance Source to Detector	(0018,1110)	1C	Necessary when *Estimated Radiographic Magnification Factor* (0018,1114) is missing.
Estimated Radiographic Magnification Factor	(0018,1114)	1C	Necessary when *Distance Source to Detector* (0018,1110) and *Distance Source to Patient* (0018,1111) are missing.
Positioner Type	(0018,1508)	1	Must be "CEPHALOGRAM".
Positioner Primary Angle	(0018,1510)	1	X-Ray beam relative to patient. Refer to section 4.4.2.
Positioner Secondary Angle	(0018,1511)	1	X-ray beam relative to patient. Refer to section 4.4.2.
Column Angulation	(0018,1450)	3	To be omitted.
Table Type	(0018,113A)	3	If used, shall be "FIXED".
Table Angle	(0018,1138)	3	To be omitted.
Body Part Thickness	(0018,11A0)	3	To be omitted.
Compression Force	(0018,11A2)	3	To be omitted.

Table 4: Image Pixel Module (C.7.6.3)

Attribute Name	***Tag***	**Type**	**Notes**
Samples per Pixel	(0028,0002)	1	Must be ”1”.
Rows	(0028,0010)	1	This value divided by *Imager Pixel Spacing* (0018,1164) must be greater than or equal to 128dpi (see 5).
Columns	(0028,0011)	1	This value divided by *Imager Pixel Spacing* (0018,1164) must be greater than or equal to 128dpi (see 5).
Bits Allocated	(0028,0100)	1	Must be 16 or more.
Bits Stored	(0028,0100)	1	Must be 12 or more.
Planar Configuration	(0028,0006)	1C	Must be omitted.
Pixel Aspect Ratio	(0028,0100)	1C	Must be omitted.
RGB Palette Color Lookup Table Descriptor	(0028,1101), (0028,1102), (0028,1103)	1C	Must be omitted.
RGB Palette Color Lookup Table Data	(0028,1201), (0028,1202), (0028,1203)	1C	Must be omitted.

Table 5: DX Detector Module (C.8.11.4)

Attribute Name	***Tag***	**Type**	**Notes**
Imager Pixel Spacing	(0018,1164)	1	The value of *Rows* (0028,0010) or *Columns* (0028,0011) divided by this value must be greater than or equals to 128dpi (ver 4).
Bits Allocated	(0028,0100)	1	Must be 16 or more.
Bits Stored	(0028,0100)	1	Must be 12 or more.

Table 6: SOP Common Module (C.12.1)

Attribute Name	***Tag***	**Type**	**Notes**
SOP Class UID	(0008,0016)	1	The SOP class differs for *FOR PRESENTATION* and *FOR PROCESSING* cephalograms. Detailed description in 4.1 and 7.

Table 7: DX Series Module (C.8.11.1)

Attribute Name	***Tag***	**Type**	**Notes**
Modality	(0008,0060)	1	Deve ser “DX”.
Presentation Intent Type	(0008,0068)	1	Must be “FOR PROCESSING” or “FOR PRESESNTATION”. This option must agree with 6.

Table 8: General Image Module (C.7.6.1)

Attribute Name	***Tag***	**Type**	**Notes**
Referenced Image Sequence	(0008,1140)	1C	This image sequence is to represent the accompanying cephalogram, lateral if this is a PA or PA if this is a lateral. Additional fields of this sequence remain unchanged. Only necessary if the study is made of two cephalograms.
Derivation Description	(0008,2111)	3	Must be omitted. Refer to 4.1.
Derivation Code Sequence	(0008,9215)	3	Must be omitted. Refer to 4.1.
Burned in Annotations	(0028,0301)	1	Whether cephalogram has enough burned in annotaions to identify the patient and the date of the study. Must be “YES” or “NO”.

Table 9: Spatial Fiducials Module (C.21.2)

Attribute Name	***Tag***	**Type**	**Notes**
>Referenced Image Sequence	(0008,1140)	1	Sequence of images which physically contain the fiducials represented by this IOD. The sequence is supposed to be composed of only two images: one for the lateral, and one for the PA cephalogram.
>>Fiducial Identifier	(0070,0310)	1C	A descritption to identify this fiducial. This attribute is neccessary when (0070,0311) is not defined.
>>Fiducial Identifier Code Sequence	(0070,0311)	1C	A code to identify this fiducial. This attribute is necessary when (0070,0310) is not defined.
>>Shape Type	(0070,0306)	1	For SB fiducials, this attribute should be set to "POINT". Nevertheless, the standard does not limit the use of this type of fiducials. Refer to the DICOM documentation for further fiducial possibilities.
>>Number of Contour Points	(3006,0046)	1C	Useful when (0070,0306) is not "POINT".
>>Contour Data	(3006,0050)	3	Useful when (0070,0306) is not "POINT".
>>Graphic Coordinates Data Sequence	(0070,0318)	1	This sequence should contain a single item.
>>>Graphic Data	(0070,0022)	1	This attribute contains the fiducial coordinates.
>>>Referenced Image Sequence	(0008,1140)	1	Must be one and only one of the images referenced in the *Referenced Image Sequence* of the *Fiducial Set Sequence* (0020,0052).

B Distance to coordinate conversion

The Spatial Fiducials IOD is only capable of storing coordinates, while the SB Corner Fiducial set is stored as a set of distances. It is therefore necessary to perform a basic conversion between distanaces and coordinates.

Consider the setup of 1 on the following page: four fiducials and six distances. Points $A1$ and $A2$ are set initially to be:

$$\begin{aligned} A_{1x} &= 0 \\ A_{1y} &= 0 \end{aligned}$$

and we arbitrarily choose the x-axis to be superimposed on d_1 such that

$$\begin{aligned} A_{2x} &= d_1 \\ A_{2y} &= 0 \end{aligned}$$

Then A_{3x}can be found making use of d_1,$d_2$and d_3:

$$A_{3x} = \frac{d_1^2 + d_2^2 - {d_3}^2}{2d_1}$$

and by using the pythagorean theorem we can find $A3_y$:

$$A_{3y} = \sqrt{d_2^2 - A_{3x}^2}$$

In a very similar fashion, A_4can be found making use of d_1,$d_4$and d_5:

$$\begin{aligned} A_{4x} &= \pm \frac{d_1^2 + d_4^2 - d_5^2}{2d_1} \\ A_{4y} &= \pm \sqrt{d_4^2 - A_{4x}^2} \end{aligned}$$

It is now necessary to make use of d_6 to find the signs of A_4.

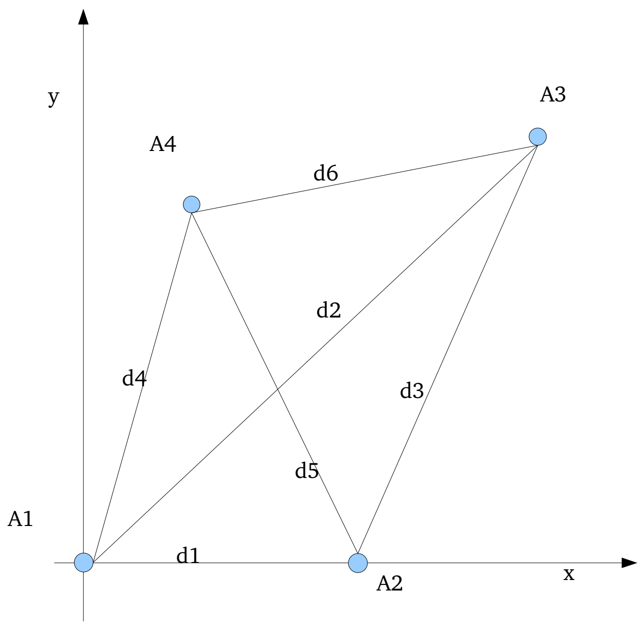

Figure 1: Fiducials and their distances