Medical Image Processing

PACS and DICOM

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Why bother?

• Almost ALL medical images are stored in DICOM format.
• All hospitals use PACS (Picture Archive and Communication Systems)
• If you ever will work with medical images in real life you need to understand basics of the DICOM standard.
• Reading DICOM images is part of the fourth hand-in assignment…
Knowledge expectations

• Being able to write minimalistic DICOM reader (part of assignment 4)

• Understand the basics of the DICOM standard and PACS systems

• Understand the basics on how to display medical images
Basics

- **Digital Imaging and Communication in Medicine**

- Both an image format & network protocol

- Huge standard (20 volumes, ~8000 pages)

- Bad standard...
Supported Imaging Modalities

- Magnetic Resonance Imaging
- Nuclear Medicine
- Computed Tomography
- Positron Emission Tomography
- Ultrasound
- Digital X-Ray & X-Ray Angiography
- Electron Microscope
- Digital Microscopy
- ...

DICOM file format

- Header and image data stored together
- Stores data about the patient, machine, and data acquisition
- Implemented by the manufacturers
- Generally one slice per file
DICOM encoding

| Header | Data element | Data element | Data element | Data element | … | … | … |

Unique tag ID defined in dictionary ex (0028,1041) = SliceLocation

OPTIONAL!!! (Explicit vs implicit) Value representation (VR) dependent on transfer syntax
Value representations

- **AS AgeString** (4 bytes fixed)
- **DA Date** (8 bytes fixed)
- **DS DecimalString** (16 bytes maximum)
- **DT DateTime** (26 bytes maximum)
- **FL FloatingPoint** (4 bytes fixed)
- **IS IntegerString** (12 bytes maximum)
- **UN Unknown** (Unlimited)
- **UT UnlimitedText** (Unlimited)
## Transfer syntax (examples)

<table>
<thead>
<tr>
<th>Transfer Syntax UID</th>
<th>Transfer Syntax name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2.840.10008.1.2</td>
<td>Implicit VR Endian: Default Transfer Syntax for DICOM</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.1</td>
<td>Explicit VR Little Endian</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.1.99</td>
<td>Deflated Explicit VR Big Endian</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.2</td>
<td>Explicit VR Big Endian</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.50</td>
<td>JPEG Baseline (Process 1):</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.51</td>
<td>JPEG Baseline (Processes 2 &amp; 4):</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.52</td>
<td>JPEG Extended (Processes 3 &amp; 5) Retired</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.53</td>
<td>.....</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.66</td>
<td>JPEG Lossless, Nonhierarchical (Process 29) Retired</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.70</td>
<td>JPEG Lossless, Nonhierarchical, First-Order Prediction</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.80</td>
<td>JPEG-LS Lossless Image Compression</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.81</td>
<td>JPEG-LS Lossy (Near-Lossless) Image Compression</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.90</td>
<td>JPEG 2000 Image Compression (Lossless Only)</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.91</td>
<td>JPEG 2000 Image Compression</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.92</td>
<td>JPEG 2000 Part 2 Multicomponent Image Compression (Lossless Only)</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.93</td>
<td>JPEG 2000 Part 2 Multicomponent Image Compression</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.94</td>
<td>JPIP Referenced</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.95</td>
<td>JPIP Referenced Deflate</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.5</td>
<td>RLE Lossless</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.6.1</td>
<td>RFC 2557 MIME Encapsulation</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.100</td>
<td>MPEG2 Main Profile Main Level</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.102</td>
<td>MPEG-4 AVC/H.264 High Profile / Level 4.1</td>
</tr>
<tr>
<td>1.2.840.10008.1.2.4.103</td>
<td>MPEG-4 AVC/H.264 BD-compatible High Profile / Level 4.1</td>
</tr>
</tbody>
</table>
Surprises

- Tags are of variable length
- Fields are generally optional
- You never know what fields will be there
- Headers have to be read sequentially
- Coding DICOM support is full of surprises

General advice: Trust nobody! Most of the answers are found in discussion forums, not plowing the standard.
Important tags

• “Image information”
  – (0018, 0050) **Slice Thickness**
  – (0018, 0088) **Spacing Between Slices**
  – (0018, 1060) **Trigger Time**
  – (0020, 1041) **Slice Location**
  – (0020, 0032) **Image Position**
  – (0020, 0037) **Image Orientation**

Red = extra important for the assignment…
Important tags

• How & where the image data is stored
  – (0028, 0010) Rows
  – (0028, 0011) Columns
  – (0028, 0030) Pixel Spacing
  – (0028, 0100) Bits Allocated
  – (0028, 0101) Bits Stored
  – (0028, 0102) High Bit
  – (0028,1052) Rescale Intercept
  – (0028,1053) Rescale Slope
  – (7ef0, 0010) Pixel Data
Pixel storage

Example 1: CT Pixel Cell

Bits Allocated = 16
Bits Stored = 12
High Bit = 11

Example 2: Hypothetical Pixel Cell

Bits Allocated = 24
Bits Stored = 18
High Bit = 19
Less important tags…

- Birth time (0010, 0032)
- Patient Insurance Plane Seq (0010, 0050)
- Mother’s Birth Name (0010, 1060)
- Military Rank (0010, 1080)
- Smoking Status (0010, 21A0)
- Patient Sex Neutered (0010, 2203)
- Religious Preference (0010, 21F0)
- Breed Description (0010, 2292)
- …
Picture Archive and Communication System (PACS)

• All image storage in hospitals today are done in PACS systems.
• In one hospital several PACS systems may be used to store images from different departments.
• In Sweden there is growing possibilities to send images between hospitals (and Counties).
Image Information Model

- Patient level information
- Study level information
- Series information
- Image information

Diagram shows a hierarchical structure with various modules:
- Patient Module
  - General Study Module
  - Frame of Reference Module
  - General Equipment Module
- Image Module
  - General Image Module
  - Image Plane Module
  - LUT Module
  - SOP Common Module
  - Contrast Bolus Module
  - Overlay Plane Module
  - Image Pixel Module

Image on the right side of the diagram.
Storage communication

Source

Association Establishment
Services offered (SOP Classes UID)
Associated coding (Transfer Syntax UID)

C-Store Request
Sending image according accepted transfer syntax

C-Store Response
Success / failed

C-Store Request
C-Store Response

Server
Response

• The response contains type of the data that server can accept. It can be an acknowledge or a reject. If the request is not understood or can not be properly answered, it’s rejected.
Query / Retrieve communication

- **DICOM workstation**
  - Association Establishment
    - Services offered (SOP Classes UID)
    - Associated coding (Transfer Syntax UID)
  - Query Request
    - (Patient information, Request level)
  - Query Response
    - (list of matching DICOM objects)

- **Server**
Query / Retrieve communication

DICOM workstation

Association Establishment
Services offered (SOP Classes UID)
Associated coding (Transfer Syntax UID)

Retrieve Request (unique identifiers)

Retrieve Response
DICOM object(s)

Retrieve Request (unique identifiers)

Retrieve Response
DICOM object(s)

......
What is needed to set up communication?

• "Client" (scanner/workstation) needs to know server: AETitle, IP address, port

• "Server" (PACS system) generally needs to know AETitle (of client)

• Permission to Query / Retrieve images may be set on IP address
Challenges

• Large complex format -> difficult to implement support
• Each implementation has a different level of completeness -> difficult to predict which tags and services will be available
• Most scanners add custom proprietary tags to the header
• One slice per file is lame
DICOM conformance statement

- Details what transfer syntaxes that are supported
- Required DICOM attributes
- For some tags vendor make own decisions on interpretation
Presentation of medical images

- It is key to not mix right / left in images
- Take physical pixel size into account
- Standardized views
  - Transversal
    as seen from the feet
  - Coronal
    as seen from the nose
  - Sagittal
    nose to the left
Scaling displaying pixels

- The scanner (CT, MRI, PET…) may output "arbitrary" pixel values that needs to be interpreted in order to be displayed.
- For CT the unit is usually in Hounsfield units.
- For MR the unit is arbitrary or in some case quantitative in cm/s or ms etc.
- For PET/SPECT the unit is often in counts.
Scaling displaying pixels

- Prior to displaying the pixel value it needs to be rescaled (using the tags RescaleIntercept and RescaleSlope)
- After rescaled the developer needs to figure out which greyscale should be connected to which value.
Knowledge review

http://m.voto.se/FMNA30-DICOM