Medical Image Processing

PACS and DICOM

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Who am I?

- Master of Science in computer engineering
- PhD medical image analysis and modelling
- Worked in hospital environment for 20 years
- Senior member of Lund Cardiac MR Group
- Founder of Medviso AB
- CTO for Imacor AB

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

- Unique tag ID defined in dictionary ex (0028,1041) = SliceLocation
- Tag VR Length Data
- 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>1.2.840.1008.1.2</td>
<td>Implicit VR Endian: Default Transfer Syntax for DICOM</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.1</td>
<td>Explicit VR Little Endian</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.1.199</td>
<td>Defaced Explicit VR Big Endian</td>
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<tr>
<td>1.2.840.1008.1.2.2</td>
<td>Explicit VR Big Endian</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.4.50</td>
<td>JPEG Baseline (Process 1):</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.4.51</td>
<td>JPEG Baseline (Processes 2 &amp; 4):</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.4.52</td>
<td>JPEG Extended (Processes 3 &amp; 5) Retired</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.4.53</td>
<td>JPEG Lossless Non-Hierarchical (Process 29) Retired</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.4.66</td>
<td>JPEG Lossless Non-Hierarchical, First Order Prediction</td>
</tr>
<tr>
<td>1.2.840.1008.1.2.4.80</td>
<td>JPEG LS Lossless Image Compression</td>
</tr>
<tr>
<td>1.2.840.1.2.4.81</td>
<td>JPEG LS Lossy (Lossless) Image Compression</td>
</tr>
<tr>
<td>1.2.840.1.2.4.90</td>
<td>JPEG 2000 Image Compression (Lossless Only)</td>
</tr>
<tr>
<td>1.2.840.1.2.4.91</td>
<td>JPEG 2000 Image Compression (Lossless Only)</td>
</tr>
<tr>
<td>1.2.840.1.2.4.92</td>
<td>JPEG 2000 (Process 2) Multicomponent Image Compression (Lossless Only)</td>
</tr>
<tr>
<td>1.2.840.1.2.4.93</td>
<td>JPEG 2000 (Process 2) Multicomponent Image Compression (Lossless Only)</td>
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<tr>
<td>1.2.840.1.2.4.94</td>
<td>JPEG Referenced</td>
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<tr>
<td>1.2.840.1.2.4.95</td>
<td>JPEG Referenced Deflate</td>
</tr>
<tr>
<td>1.2.840.1.2.5</td>
<td>RLE Lossless</td>
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<tr>
<td>1.2.840.1.2.6.1</td>
<td>RFC 2057 MIME Encapsulation</td>
</tr>
<tr>
<td>1.2.840.1.2.4.100</td>
<td>MPEG2 Main Profile Main Level</td>
</tr>
<tr>
<td>1.2.840.1.2.4.102</td>
<td>MPEG4 AVCH 264 High Profile / Level 4.1</td>
</tr>
<tr>
<td>1.2.840.1.2.4.103</td>
<td>MPEG4 AVCH 264 S3-completable 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

Example 2: Hypothetical Pixel Cell

Compare with how Matlab stores images!

Less important tags…

• Birth time (0010, 0032)
• Patient Insurance Plane Seq (0010, 0050)
• Mother’s Birth Name (0010, 0160)
• Military Rank (0010, 1080)
• Smoking Status (0010, 21A0)
• Patient Sex Neutered (0010, 2200)
• 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

[Diagram of image information model with various modules and information flow]
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)
- Query Request
- Query Response

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)

Server

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