DICOM- an overview with an emphasis on Therapy

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Outline

a. What is DICOM?
   i. Standard
   ii. Applications
b. Making the connection
   i. TCP/IP + DICOM
   ii. Configuring Clients and Servers (IP, port, AET, services)
   iii. Associations
c. File Format
   i. Data Elements
   ii. Data Dictionary
   iii. Dicom Part 10 file
d. Information Object Definitions
   i. Object Model
   ii. Modules
   iii. Sequences
   iv. References

Outline-II

e. DICOM-RT
   i. Modules
   ii. RT-Plan Attributes
   iii. IEC 1217 overview
f. Clinical issues in Radiation Oncology
   i. Freeware/Shareware
   ii. Anonymization
   iii. Troubleshooting/using File contents – DICOM readers
   iv. Troubleshooting Connections- DICOM ConquestServer

What is DICOM

- Digital Imaging and Communications in Medicine
- A standard defining digital data formats
- A standard defining communication protocols
- Covers data transfer, storage and display
- Includes coordinate conventions
- The **standard defines the representation of Information**

Information vs Data

- Information Object Definition (IOD)
- Data are associated with attributes
- There should be enough attributes to be unambiguous

Value	attribute	information
99	?	?
	age	A very old person
	Code number	Maxwell Smart's sidekick?
	Weight	May be light or heavy. Lbs or Kg?

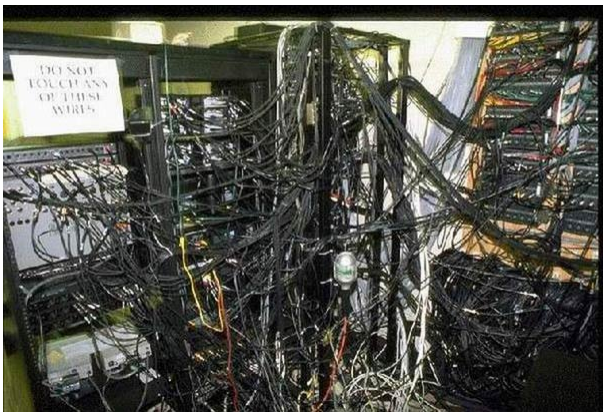
Applications

- Picture Archiving and Communications System (PACS)
- DICOM-RT capable treatment planning systems, for export to R&V and IGRT systems
- DICOM from imaging systems to treatment planning systems

Making the Connection

http://worldrec.info/2006/10/26/the-worlds-messiest-network-cable-arrangements

I hope your DICOM "physical layer" looks better than this!

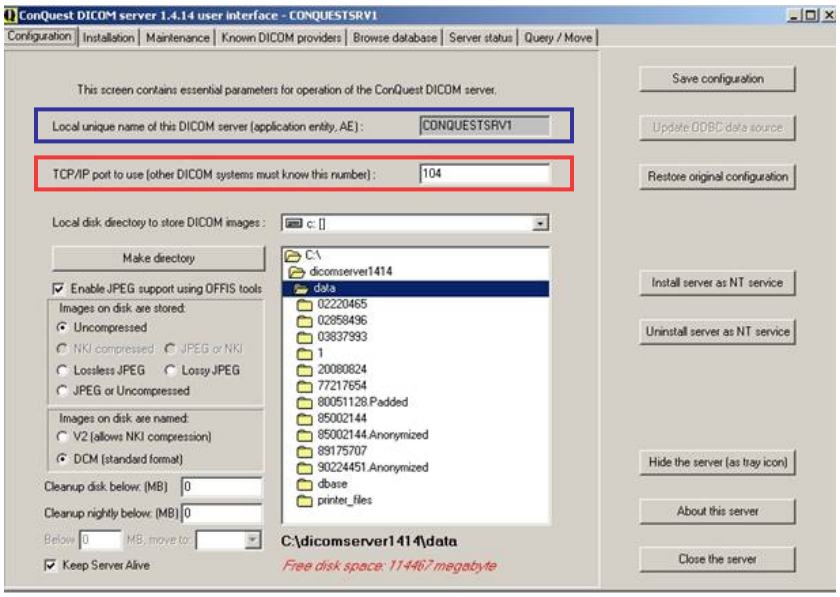


A DICOM network uses the underlying TCP/IP infrastructure.

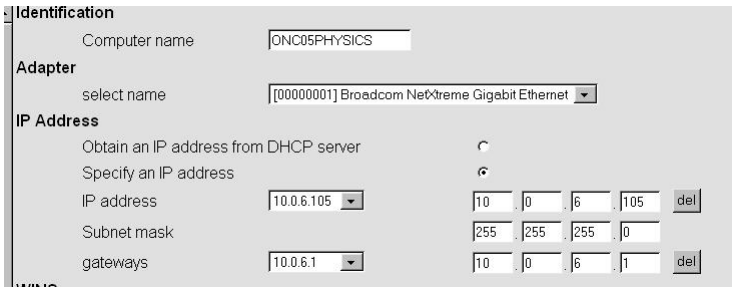
Application Entities (AEs)

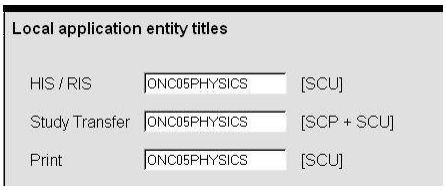
- Software application residing on a computer with a static IP address
- Default port 104
- or any unused port as long as receivers and senders use the same one
- Other configurations possible but more complex

http://www.xs4all.nl/~ingenium/dicom.html

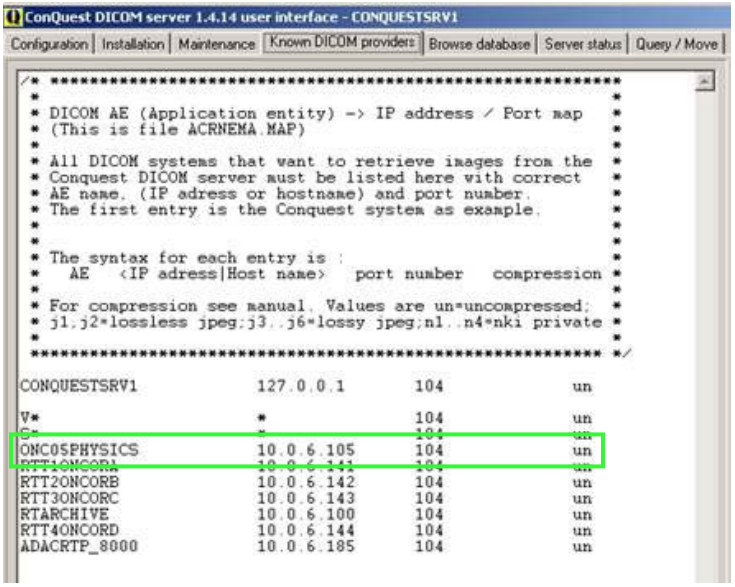


On the quad core. AET of the ConQuest DICOM server = CONQUESTSRV1

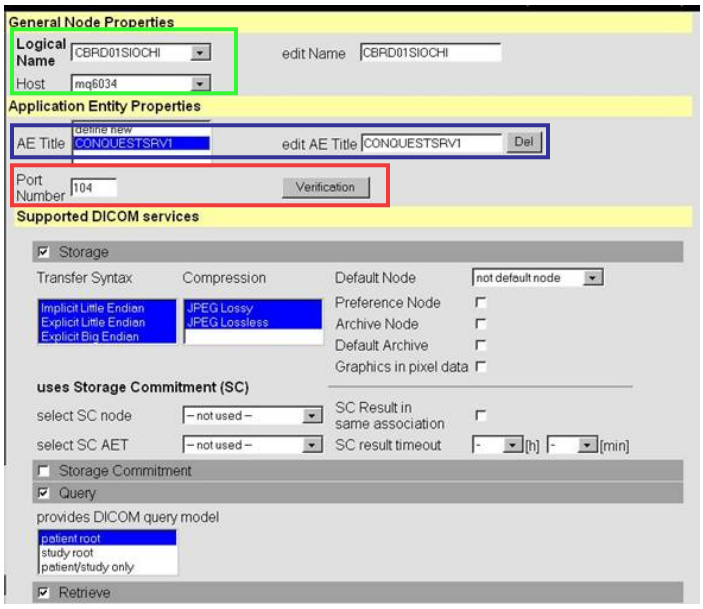




Local IP and AE settings on the Coherence Workstation



The quad core AE knows about the Coherence workstation ONC05PHYSICS



Coherence knows about the quad core AE and its supported Dicom Services

ASSOCIATIONS

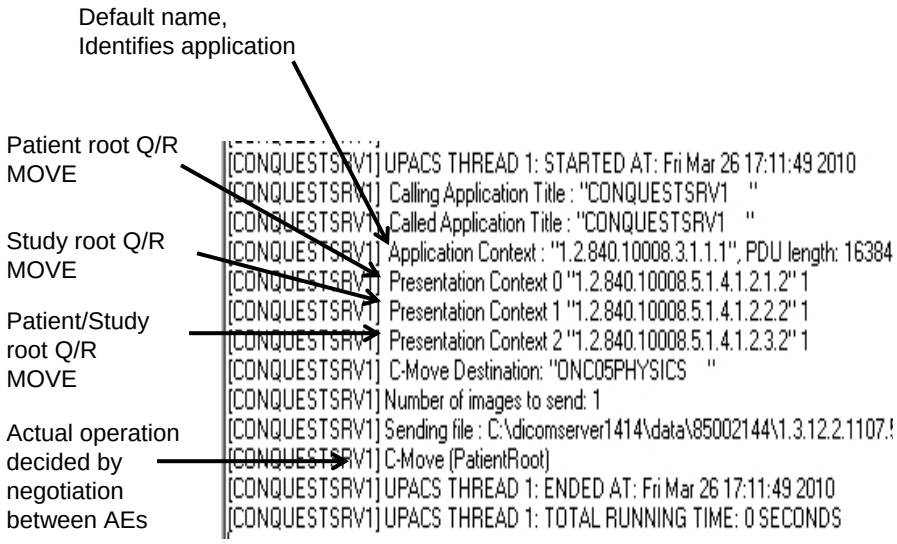
- A handshake, a dialogue to make a contract
- Check that AEs are compatible
  - Able to perform requested service
- Ensure AEs agree on data transfer
  - Have at least one common transfer syntax

Services

- An AE can be a
  - Service Class Provider (SCP)
  - Service Class User (SCU)
- SCP responds to request of SCU to provide a service:
  - Service Object Pair (SOP = command + IOD)
    - CT image Storage = C-Store (push) + CT image
    - Commands (DICOM Message Service Elements, DIMSE): C-Find, C-Echo (ping), C-Move or C-Get (pull)

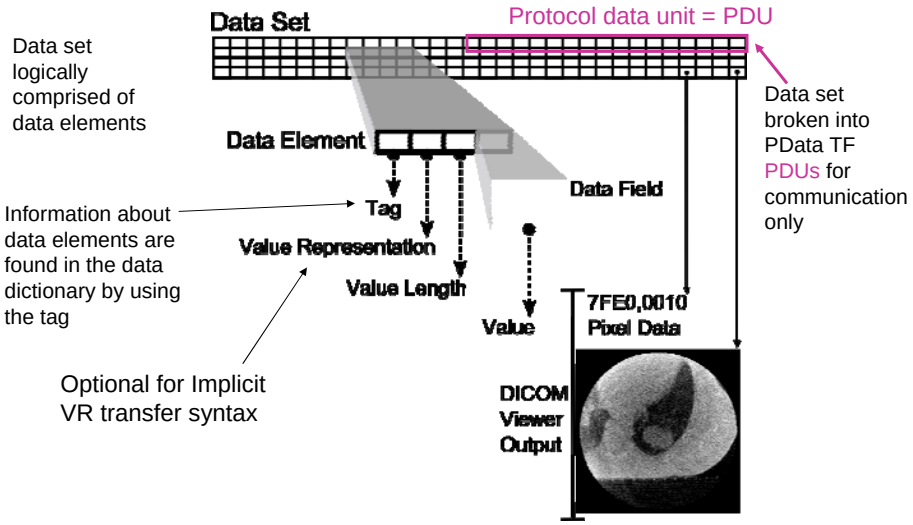
Transfer Syntax

- How are the data transmitted?
- “unambiguous representation of data”
  - Byte Order: Little vs Big Endian
  - Value Representation: Implicit or Explicit
    - Implicit VR, Little Endian (Default – all must support)
    - Explicit VR, Little Endian
    - Explicit VR, Big Endian



Transcript of Dicom Association between CONQUESTSRV1 and ONC05PHYSICS

What gets transferred?



From "Informatics in Radiation Oncology", eds. Curran and Starkschall, – Ch. 11, Information Resources for Radiation Oncology by R.A.C. Siochi- In Press.

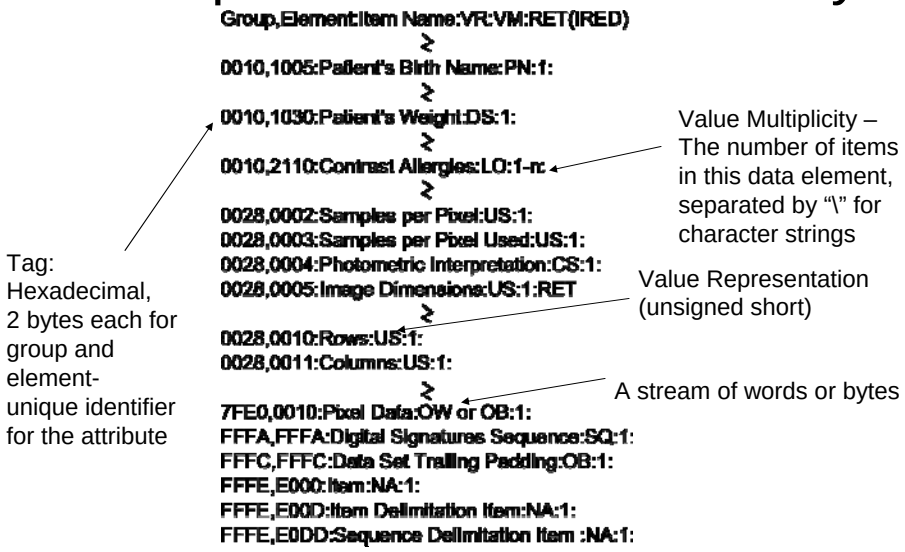
What happens after the transfer ? Depends on your AE:

- Bytes stored in proprietary format in a proprietary database known only to the AE
- Bytes stored in DICOM part 10 format as a dicom file in a proprietary database.
  - Essentially a "transcript" of the dicom transfer
  - Includes a metafile to handle transfer syntax
- Part 10 format file stored in a folder
- DICOM file service is used to store part 10 format files (becomes abstract to media storage)
- *.dcm, *.ima – let's take a closer look…

Data Elements

- Tag: Group Bytes + Element Bytes
- Value Representation (VR) (optional field)
  - How is the value represented?
  - Strings of specific lengths or Text or Strings following a set of rules (e.g. Person Name, “PN”)
  - Floating Points?
  - Integers? Long, short, unsigned?
- Value Length
  - how many bytes long- always padded to an even number of bytes
- Value (the actual data itself)
- Meaning of the data element? Look in the data dictionary for the Item Name.

Excerpt from a Data Dictionary



From “Informatics in Radiation Oncology”, eds. Curran and Starkschall, – Ch. 11, Information Resources for Radiation Oncology by R.A.C. Siochi- In Press.

Using the Data Dictionary

- IF your application can't read a Dicom file, it might have encountered a data element whose tag is not listed in the application's dictionary
- Implicit VR: VR must be determined from a Dictionary
- Converting the data into human readable form requires getting the Item name from the Dictionary (to serve as a label)

PS 3.10 File format

- Binary file
- Extension: .dcm or .ima
- Metafile + data set
- Data set = Stream of data elements
- Increasing tag order
- Data elements are from the Information Object Definiton of the object in the dataset

Information Object Definitions

- A dataset represents an Object
- An object can be made of several attributes
- An Image IOD includes many data elements:
  - Number of rows
  - Number of columns
  - Pixel dimensions and positions
  - The intensities in the image (pixel data)
  - Subject of the image (patient name)
  - Unique identifiers
  - Etc.
- DICOM transfers include not just the image but also the attributes of the image
- IODs are “modularized”

Modules

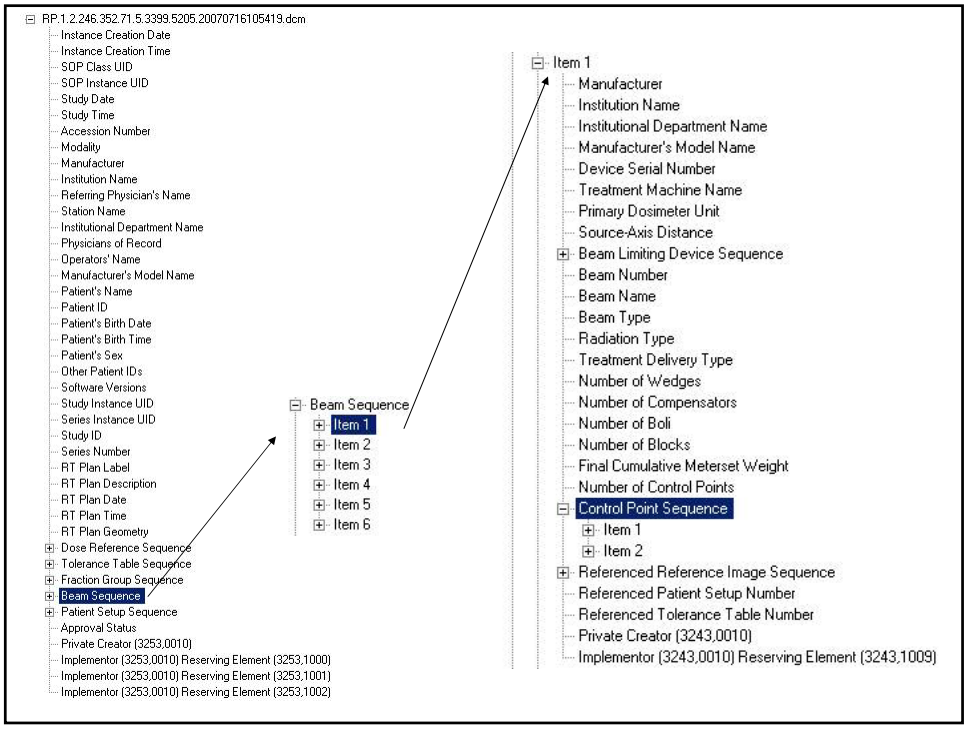
- Set of attributes that are logically related
- A dataset contains many modules
- Example modules in a CT IOD:
  - Patient
  - General Series
  - General Study
  - General Image
  - Image Pixel

Patient Module

- Made up of the following data elements
  - Patient's Name
  - Patient ID
  - Patient's Birth Date
  - Patient's Sex
  - Responsible Person
  - Etc.
  - (There are even fields for a veterinarian's patients, e.g. Breed)

Sequences

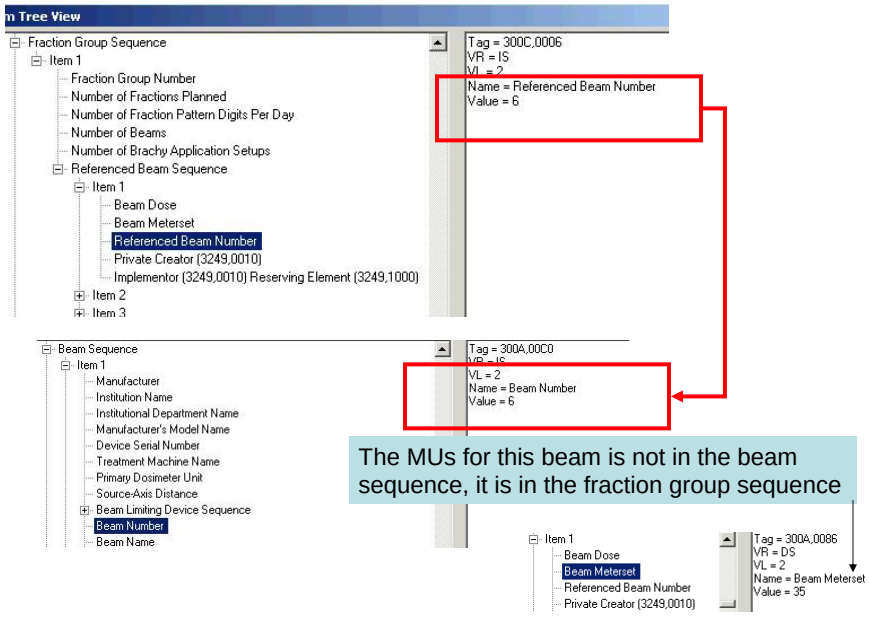
- Related attributes
- Contains several items of the same kind
- Can contain other sequences (nesting)
- E.g. DICOM-RT Beam sequence
  - Attributes that define a linac treatment beam
  - Has as many items as there are beams
  - Contains a control point sequence for all techniques, not just IMRT



References

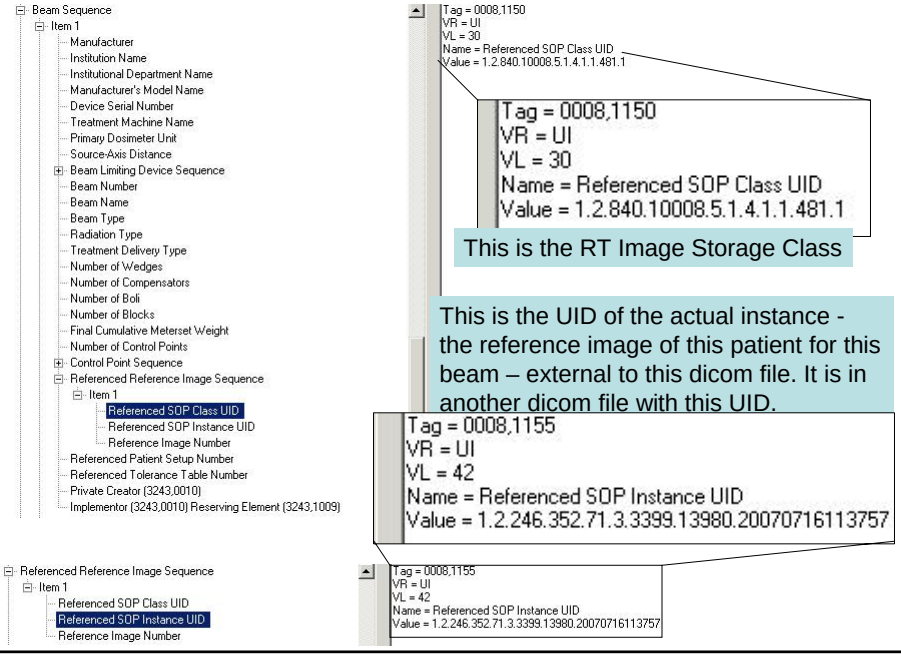
- Some attributes are a reference to another attribute
- They may be external and are identified by a UID (unique identifier), NEVER by filename
- They may be internal to the data set and are identified by another attribute

Internal reference



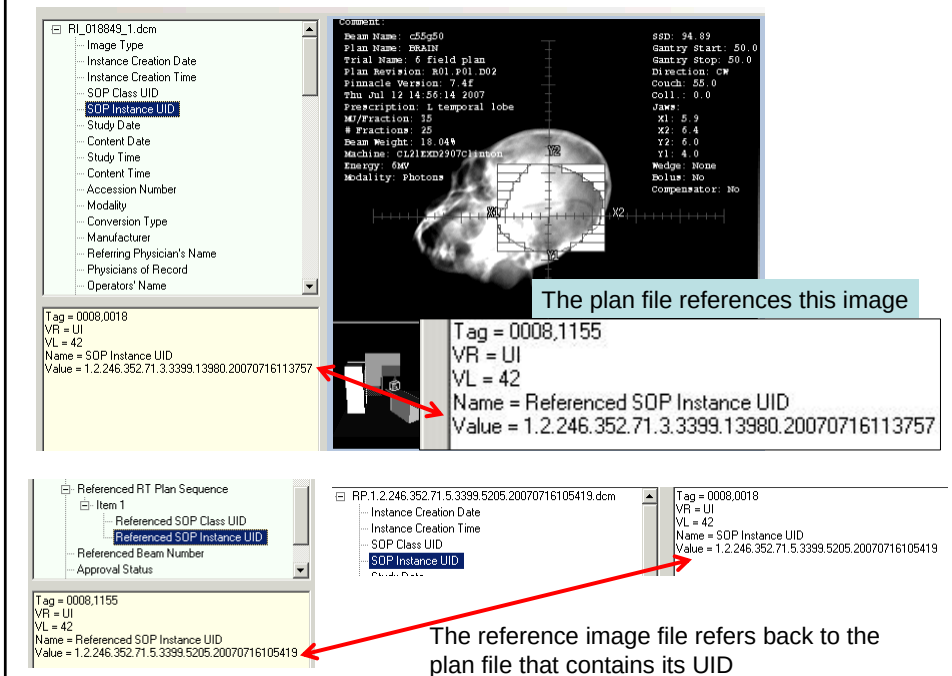
The MUs for this beam is not in the beam sequence, it is in the fraction group sequence

External reference



This is the RT Image Storage Class

This is the UID of the actual instance - the reference image of this patient for this beam – external to this dicom file. It is in another dicom file with this UID.



The Binary file

- The actual file is binary – a stream of bytes (sometimes you do recognize character strings)
- You need DICOM applications (previous slides show two in-house applications, one for the plan, the other for images) to make them readable!

DICOM-RT

- Uses the same paradigm for data elements, file structure and communication
- Several Modules
  - RT Series
  - RT Image (conical imaging geometry)
  - RT Dose
  - RT DVH
  - Structure Set
  - ROI Contour
  - RT Dose ROI
  - RT General Plan*
  - RT Prescription*
  - RT Tolerance Tables*
  - RT Patient Setup*
  - RT Fraction Scheme*
  - RT Beams*

  ← RT-Plan Modules for external beam treatments
  - RT Brachy Application Setups
  - Approval
  - RT General Treatment Record
  - RT Treatment Machine Record
  - Measured Dose Reference Record
  - Calculated Dose Reference Record
  - RT Beams Session Record
  - RT Brachy Session Record
  - RT Treatment Summary record

  ← RT-Record Modules

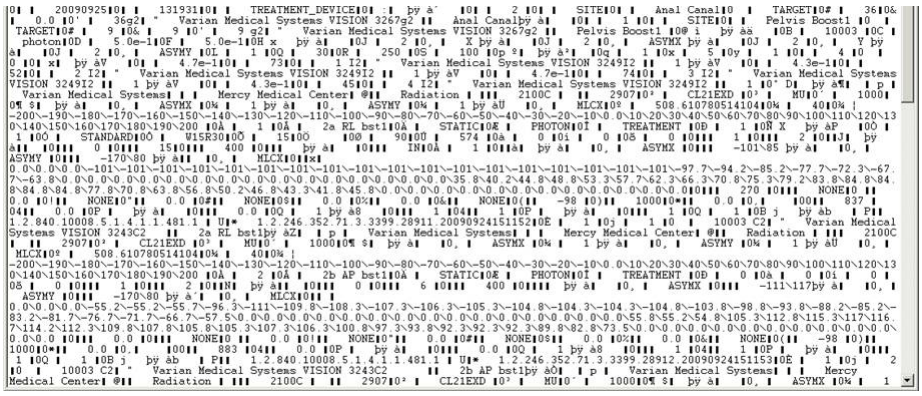
DICOM-RT Modules

- Designed to completely describe
  - Treatment Plan
  - Delivered Treatments
- References associated Images
- Some images may be the planning images (CT, MR) that were used for contouring
- Others may be RT Images (DRRs, portal images, CBCT).

RT-Plan

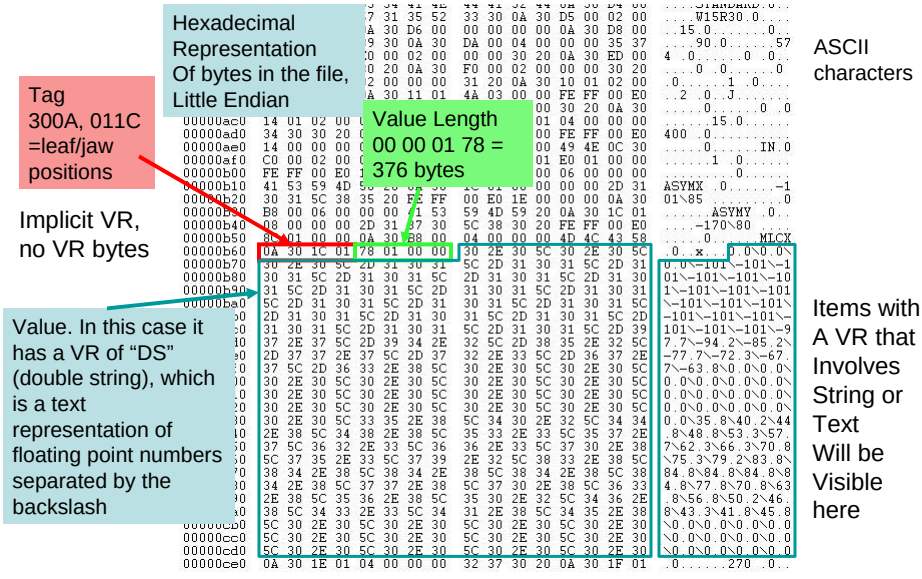
- Probably most important DICOM RT IOD to know
- Used by some systems for export/import to/from Record & Verify
- Not easy to read even when put in “human-readable” form
  - Too many references
  - Doesn’t easily fit our pre-conceived treatment beam model
  - IEC 61217 coordinate conventions
- Need applications to convert it into something that we are used to seeing (e.g. MUs belong with the field, native coordinates)

DICOM RT file in Notepad

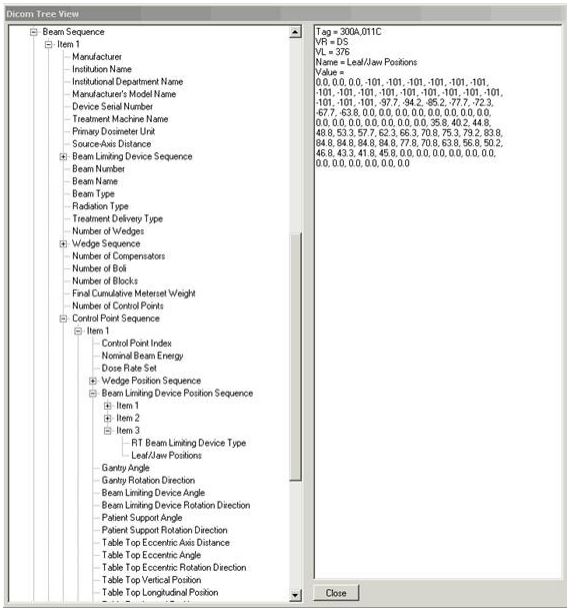


Can only recognize ASCII characters. All other bytes outside of that range appear as spaces or control characters in this figure.

DICOM RT file in Visual Studio



In an in-house Dicom File Content Browser



The file structure and bytes have been converted into ASCII and tree view representations. However, this is still in the IEC 61217 coordinate convention, and you have to look for referenced attributes.

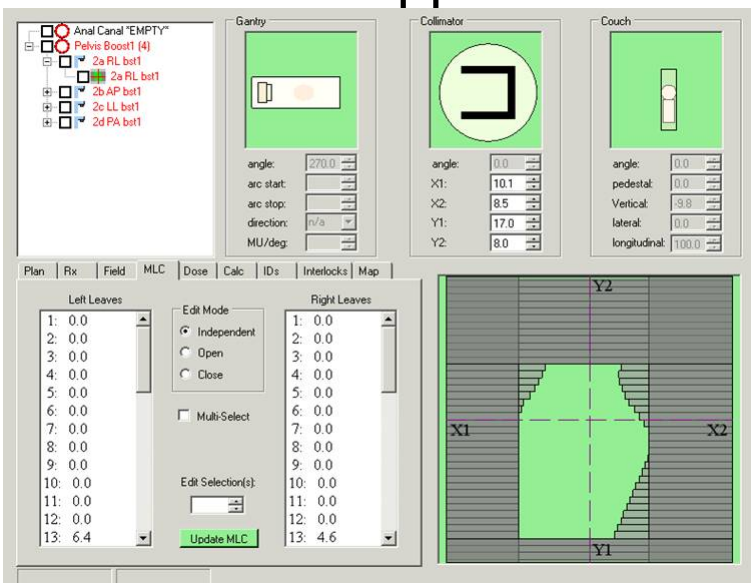
In an in-house Application

1. Import Dicom-RT file

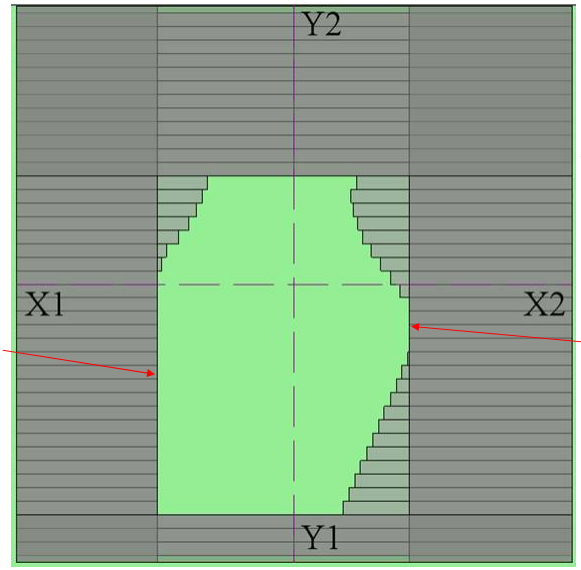
2. Convert to native data structures

3.Convert to application coordinate system

4. Display in application

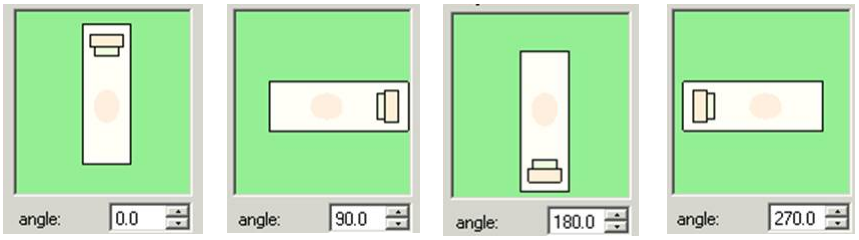


IEC 61217: MLC- coordinate axis fixed to collimator

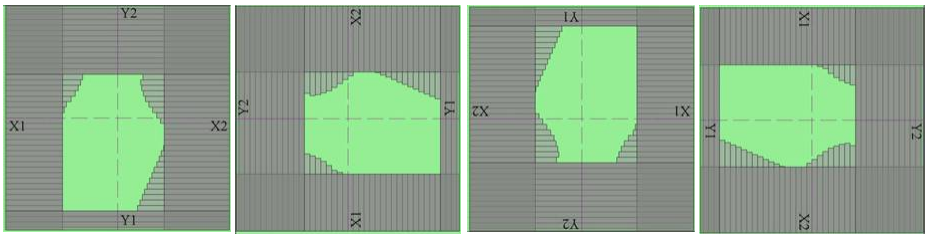


IEC 61217: Gantry

Angle increases clockwise with the source at the top (zero) as the viewer faces the gantry



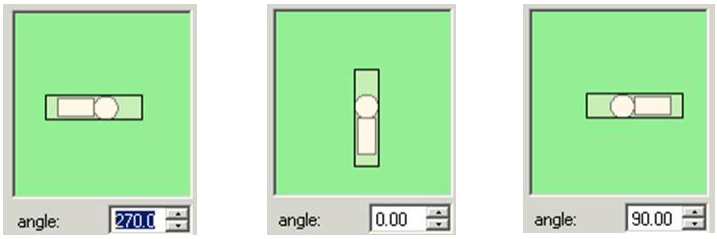
IEC 61217: Collimator



0 90 180 270

From Beam's Eye view, collimator angles increase counter-clockwise, with an angle of zero degrees when X1 is on the viewer's left.

IEC 61217: Couch



Viewed from above, the couch angle increases counter-clockwise. The couch angle is zero when the couch is parallel to the gantry rotation axis.

Clinical Issues in RT

- DICOM is used to transfer plan information from the TPS to the R&V and IGRT systems
- If there is a problem with the transfer, how do you troubleshoot it?
- If you need to extract other information, what do you do?
- Need DICOM aware applications
- DICOM readers, viewers, editors
- DICOM servers

DICOM software

- Do a Google search
- DICOM +
  - Viewer
  - Reader
  - Server
  - Anonymizer
  - Editor
- They may not do all that you want nor how you want it done
- Shop around, test drive them
- Or write your own!

DICOM anonymization

- Removing patient related information, HIPAA
- Be careful when dealing with UIDs and external references
- Share/ free ware
  - Dicom Anonymizer: http://eng.neologica.it/download/downloadDICOMAnonymizer.html
  - Dicom Editor: http://mircwiki.rsna.org/index.php?title=DicomEditor

DICOM share/free ware -Some servers/viewers

- Conquest DICOM Server
  - http://www.xs4all.nl/~ingenium/dicom.html
- K-PACS
  - http://www.k-pacs.de
- Clear Canvas
  - http://www.clearcanvas.ca/
  - Also has a .net SDK (Visual C#)
- Central Test Node Software
  - http://erl.wustl.edu/research/dicom/ctn.html

DICOM share/free ware - viewers

- DICOM Works
  - http://www.dicomworks.com/
- ImageJ
  - http://rsb.info.nih.gov/ij/
- IrfanView
  - http://www.irfanview.com/
- Many, many others
- Note: some viewers will only work with images and will not decode RTPlan files – get a "dump" using DICOMDumper: http://eng.neologica.it/download/downloadDICOMDumper.html

Example 1: Pixel value for SUV 2.5

- ImageJ
- Or Matlab
- Or In-house scripts
- All involve reading the header of a PET image
  - decaySecs = dicomTimeStrToSeconds(pScanTime) - dicomTimeStrToSeconds(pInjectTime);
  - imageBq = activity*((float)Math.pow(0.5,(decaySecs/halfLife)));
  - suv1PixValue = Math.round(imageBq/pWeightGrams);
  - (SUV 2.5 pixel value = 2.5* SUV 1 pixel value)

Example 2: Export of IGRT related items

- For MVision CBCT, Adaptive Targeting on Coherence Workstation
- Export plan isocenter, contours, plan CT from Pinnacle to Coherence
- Coherence sometimes has problems importing or reading the DICOM file – generic error message (non-planar contour)
- Try re-sending smaller files with only essential elements
- Problem usually is the contour (structure set, ROIs)
- Read the DICOM header. Correct files sent to ensure external references are okay? Check UIDs.

Get example images of the process ?

Example 3: Connectivity

- System A cannot send to System B
- Try using an intermediate server (e.g. Conquest), System C
  - Does System A to System C work? Vice versa?
  - Does System B to System C work? Vice versa?
- Or use editors, or dumpers to view the problematic data
- Example: Satellite clinic in Burlington, IA
- Old CT system – incompatible files once sent to CMS workstation – workaround was to send files to Conquest Server.

Example 4: Connectivity

- Archive A was retired and Data was transferred to Archive B.
- Archive B would not accept a particular study containing CT Images
- Archive A sent the study to CONQUESTSRV1
- CONQUESTSRV1 sent the study to other stations where it was needed (could not be pushed to or pulled by Archive B, however.)