

# DICOM- an overview with an emphasis on Therapy

R. Alfredo C. Siochi, PhD

## 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?

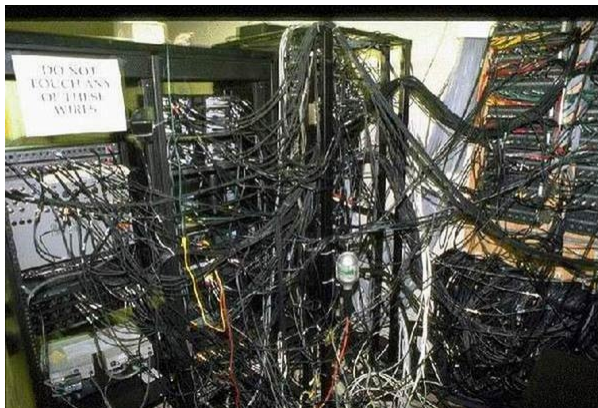
## Applications

- 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!

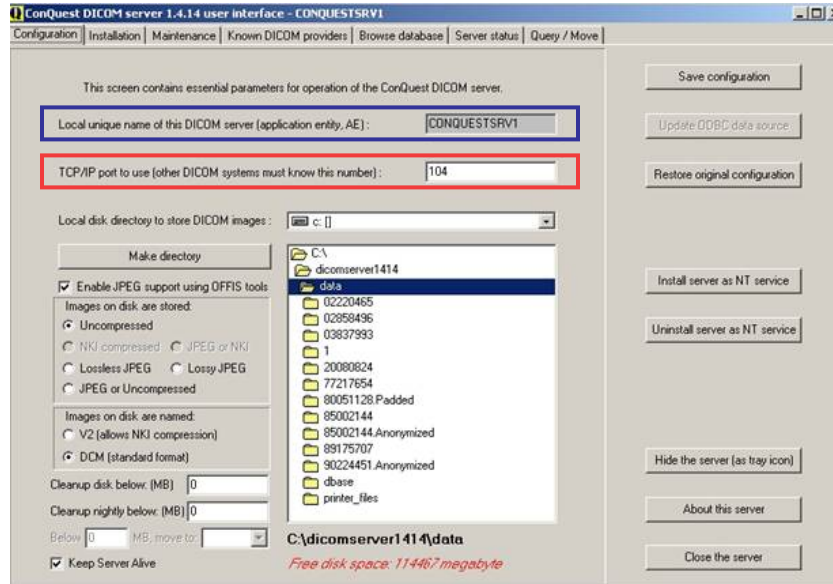


A DICOM network uses the underlying TCP/IP infrastructure.

## 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

**Identification**

Computer name: [ONC05PHYSICS]

**Adapter**

select name: [00000001] Broadcom NetXtreme Gigabit Ethernet

**IP Address**

Obtain an IP address from DHCP server:

Specify an IP address:

IP address: [10.0.6.105] [10] [0] [6] [105] [del]

Subnet mask: [255.255.255.0] [255] [255] [255] [0]

gateways: [10.0.6.1] [10] [0] [6] [1] [del]

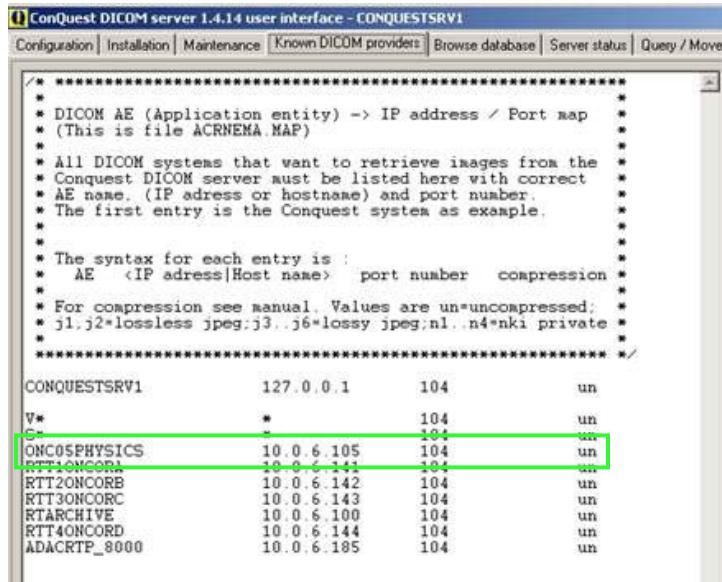
**Local application entity titles**

HIS / RIS: [ONC05PHYSICS] [SCU]

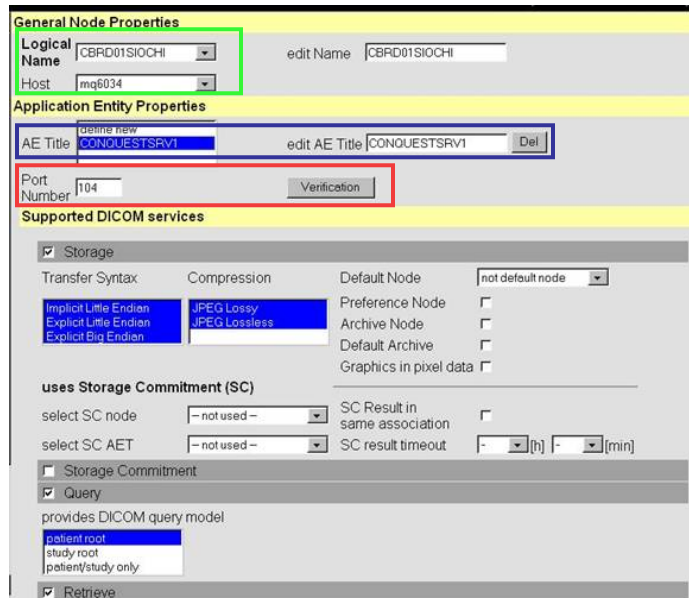
Study Transfer: [ONC05PHYSICS] [SCP + SCU]

Print: [ONC05PHYSICS] [SCU]

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

Default name,  
Identifies application

Patient root Q/R  
MOVE

Study root Q/R  
MOVE

Patient/Study  
root Q/R  
MOVE

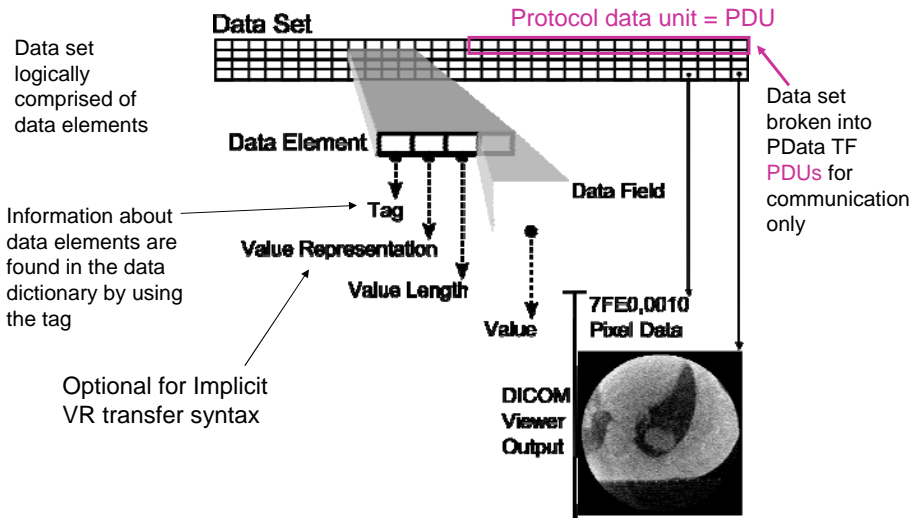
Actual operation  
decided by  
negotiation  
between AEs

```
[CONQUESTSRV1] UPACS THREAD 1: STARTED AT: Fri Mar 26 17:11:49 2010
[CONQUESTSRV1] Calling Application Title: "CONQUESTSRV1  "
[CONQUESTSRV1] Called Application Title: "CONQUESTSRV1  "
[CONQUESTSRV1] Application Context: "1.2.840.10008.3.1.1.1", PDU length: 16384
[CONQUESTSRV1] Presentation Context 0 "1.2.840.10008.5.1.4.1.2.1.2" 1
[CONQUESTSRV1] Presentation Context 1 "1.2.840.10008.5.1.4.1.2.2.2" 1
[CONQUESTSRV1] Presentation Context 2 "1.2.840.10008.5.1.4.1.2.3.2" 1
[CONQUESTSRV1] C-Move Destination: "ONC05PHYSICS  "
[CONQUESTSRV1] Number of images to send: 1
[CONQUESTSRV1] Sending file : C:\dicomserver1414\data\85002144\1.3.12.2.1107.1
[CONQUESTSRV1] C-Move (PatientRoot)
[CONQUESTSRV1] UPACS THREAD 1: ENDED AT: Fri Mar 26 17:11:49 2010
[CONQUESTSRV1] UPACS THREAD 1: TOTAL RUNNING TIME: 0 SECONDS
```

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

```

Group,Element,Item Name:VR:VM:RET(I,RED)
>
0010,1005:Patient's Birth Name:PN:1:
>
0010,1030:Patient's Weight:DS:1:
>
0010,2110:Contrast Allergies:LO:1-rc
>
0028,0002:Samples per Pixel:US:1:
0028,0003:Samples per Pixel Used:US:1:
0028,0004:Photometric Interpretation:CS:1:
0028,0005:Image Dimensions:US:1:RET
>
0028,0010:Rows:US:1:
0028,0011:Columns:US:1:
>
7FE0,0010:Pixel Data:OW or OB:1:
FFFA,FFFA:Digital Signatures Sequence:SQ:1:
FFFC,FFFC:Data Set Trailing Padding:OB:1:
FFFE,E000:Item:NA:1:
FFFE,E00D:Item Delimitation Item:NA:1:
FFFE,E0DD:Sequence Delimitation Item:NA:1:

```

Tag:  
Hexadecimal,  
2 bytes each for  
group and  
element-  
unique identifier  
for the attribute

Value Multiplicity –  
The number of items  
in this data element,  
separated by “\” for  
character strings

Value Representation  
(unsigned short)

A stream of words or bytes

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 Definition 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

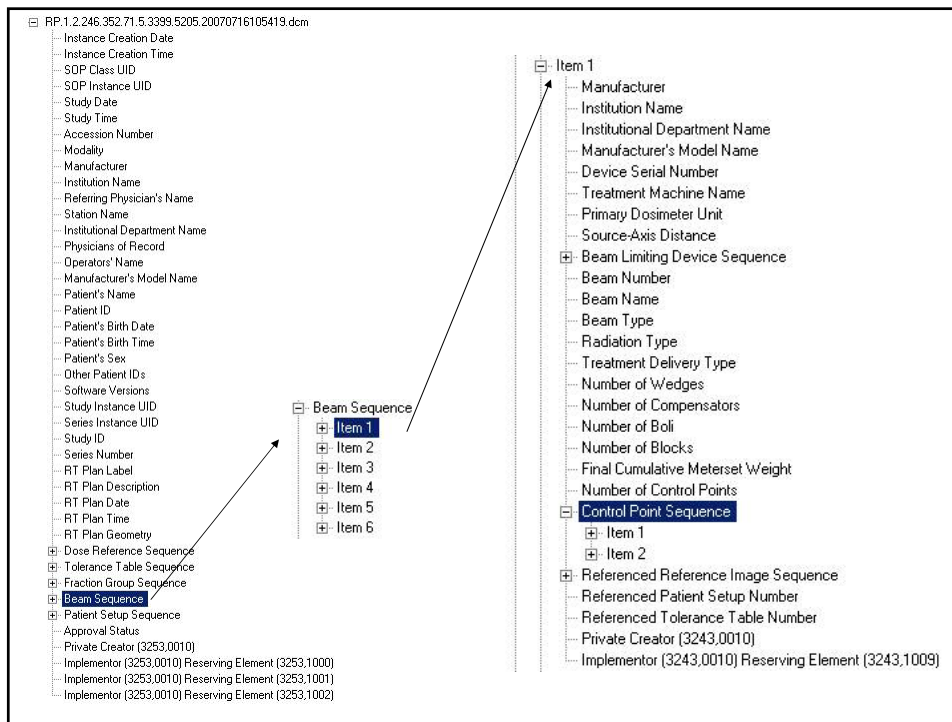
- Set of attributes that are logically related
- A dataset contains many modules
- Example modules in a CT IOD:
  - Patient
  - General Series
  - General Study
  - General Image
  - Image Pixel

## 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 screenshot shows a DICOM Tree View with the following structure:

- Fraction Group Sequence
  - Item 1
    - Fraction Group Number
    - Number of Fractions Planned
    - Number of Fraction Pattern Digits Per Day
    - Number of Beams
    - Number of Brachy Application Setups
    - Referenced Beam Sequence
      - Item 1
        - Beam Dose
        - Beam Meterset
        - Referenced Beam Number
        - Private Creator (3249,0010)
        - Implementor (3249,0010) Reserving Element (3249,1000)
      - Item 2
      - Item 3
- Beam Sequence
  - Item 1
    - Manufacturer
    - Institution Name
    - Institutional Department Name
    - Manufacturer's Model Name
    - Device Serial Number
    - Treatment Machine Name
    - Primary Dosimeter Unit
    - Source-Axis Distance
    - Beam Limiting Device Sequence
      - Beam Number
      - Beam Name

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

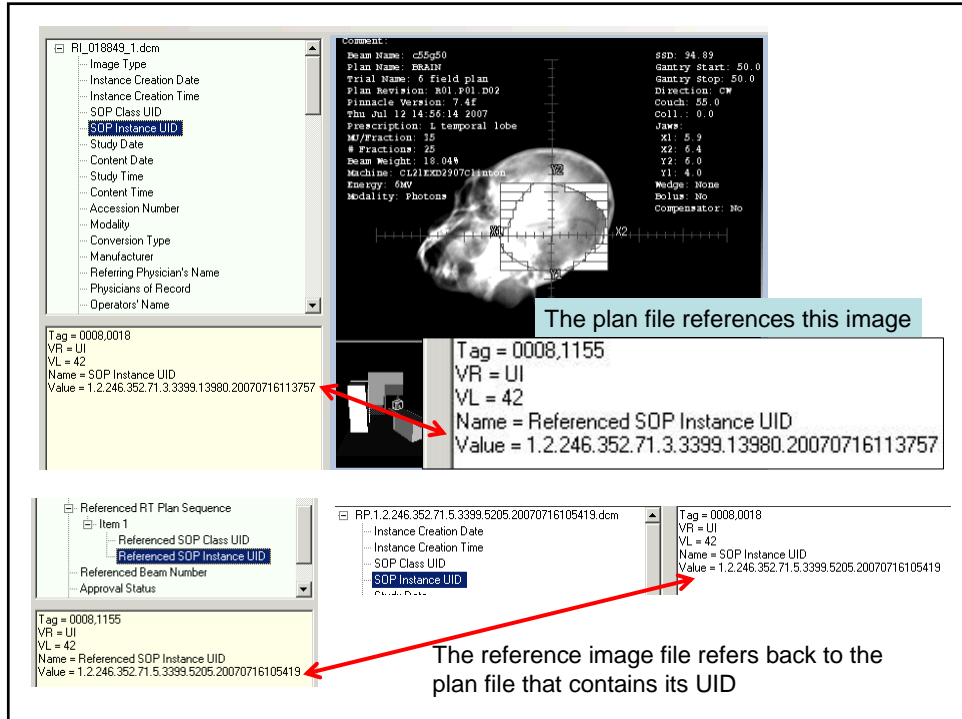
# External reference

The screenshot shows a DICOM Tree View with the following structure:

- Beam Sequence
  - Item 1
    - Manufacturer
    - Institution Name
    - Institutional Department Name
    - Manufacturer's Model Name
    - Device Serial Number
    - Treatment Machine Name
    - Primary Dosimeter Unit
    - Source-Axis Distance
    - Beam Limiting Device Sequence
      - Beam Number
      - Beam Name
      - Beam Type
      - Radiation Type
      - Treatment Delivery Type
      - Number of Wedges
      - Number of Compensators
      - Number of Bolus
      - Number of Blocks
      - Final Cumulative Meterset Weight
      - Number of Control Points
      - Control Point Sequence
        - Referenced Reference Image Sequence
          - Item 1
            - Referenced SOP Class UID
            - Referenced SOP Instance UID
            - Reference Image Number
        - Referenced Patient Setup Number
        - Referenced Tolerance Table Number
        - Private Creator (3243,0010)
        - Implementor (3243,0010) Reserving Element (3243,1009)

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!

```

center: @|| Radiation || || 2100C | || 290/00' | CL21EAD 10' | MU10 |
100010% $ | by à | 10. | ASYMX 10% | 1 by à | 10. | ASYMY 10% | 1 by
àU | 0. | MLCK10% | 508 61078051410410% | 4010% |
-200\ -190\ -180\ -170\ -160\ -150\ -140\ -130\ -120\ -110\ -100\ -90\ -80\ -70\ -60\ -50\ -40\ -30\ -2
0\ -10\ 0\ 10\ 20\ 30\ 40\ 50\ 60\ 70\ 80\ 90\ 100\ 110\ 120\ 130\ 140\ 150\ 160\ 170\ 180\ 190\ 200 | 0A
| 6 | 0A | 1a c55g50 | 0A | STATIC10% | PHOTON10 | TREATMENT 10 | 0 | 0a |
0 | 0i | 0 | 0% | 0 | 0|| 1 | 0|| 2 | 0|| by à | 0 || 0 | 0 || 6 | 0 ||
400 | 0 || by à | 10. | ASYMX 10 || -59\ 64 by à | 10. | ASYMY 10 ||
-40\ 60 by à | 10. | MLCK10 ||
0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ -14. 8\ -27. 8\ -45. 6\ -55. 6\
58. 7\ -55. 1\ -47. 8\ -44. 1\ -40. 7\ -33. 3\ -24\ -16. 7\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\
0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 12. 3\ 24. 7\ 38.
9\ 49. 8\ 58. 7\ 60. 2\ 61. 5\ 58. 4\ 50. 6\ 38. 4\ 14. 6\ -9. 8\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0. 0\ 0.
0\ 0. 0\ 0. 0\ 0 | 0 || 50 | 0 || NONE | 0 || 0. 0 | 0 || NONE | 0 || 305 | 0% ||
NONE | 0% || 0. 0 | 0% || 0. 0 | 0% || NONE | 0 ( | -139 | 0 ) || 1000 | 0 * || -39 |
0. | 100 || 949 | 104 || 0. 0 | 10P | by à | 10 || 1 | 10Q | 1 | 10B | by à | P ||
1 | 04 || 1 | 10P | by à | 10 || 1 | 10Q | 1 | 10B | by à | P ||
1.2. 840. 10008. 5. 1. 4. 1. 1. 481. 1. | U | * | 1.2. 246. 352. 71. 3. 3399. 13980. 20070716113757 | 10E |
| 1 | 0j | 6 | 10 | 10003 C2 | " | Varian Medical Systems VISION 3243C2 |  ||

```



# 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-Plan Modules for external beam treatments
  - RT Patient Setup\*
  - RT Fraction Scheme\*
  - RT Beams\*
  - 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).



# DICOM RT file in Visual Studio

Hexadecimal Representation Of bytes in the file, Little Endian	Value Length	ASCII characters
00000a00	14 01 02 00 1	W15R30 0
00000a00	34 30 30 20 0	15 0
00000a00	14 00 00 00 0	90 0 57
00000a00	C0 00 02 00 0	4 0 0 0
00000b00	FE FF 00 E0 1	0 0 0 0
00000b10	41 53 59 4D 50	0 0 0 1
00000b20	30 31 5C 38 35 20	0 0 0 0
00000b30	B8 00 06 00 00 0	0 0 0 0
00000b40	08 00 00 00 2D 31	0 0 0 0
00000b50	0A 30 1C 01 78 01 00 00	0 0 0 0
00000b60	30 2E 30 5C 30 2E 30 5C	0 0 0 0
00000b70	30 31 5C 2D 31 30 31 5C	0 0 0 0
00000b80	31 5C 2D 31 30 31 5C 2D	0 0 0 0
00000b90	5C 2D 31 30 31 5C 2D 31	0 0 0 0
00000ba0	2D 31 30 31 5C 2D 31 30	0 0 0 0
00000bb0	31 30 31 5C 2D 31 30 31	0 0 0 0
00000bc0	30 2E 30 5C 30 2E 30 5C	0 0 0 0
00000bd0	30 2E 30 5C 30 2E 30 5C	0 0 0 0
00000be0	30 2E 30 5C 30 2E 30 5C	0 0 0 0
00000bf0	30 2E 30 5C 30 2E 30 5C	0 0 0 0
00000c00	2E 38 5C 34 38 2E 38 5C	0 0 0 0
00000c10	37 5C 35 32 2E 33 5C 36	0 0 0 0
00000c20	5C 37 35 2E 33 5C 37 39	0 0 0 0
00000c30	38 34 2E 38 5C 38 34 2E	0 0 0 0
00000c40	34 2E 38 5C 37 37 2E 38	0 0 0 0
00000c50	2E 38 5C 35 36 2E 38 5C	0 0 0 0
00000c60	38 5C 34 33 2E 33 5C 34	0 0 0 0
00000c70	5C 30 2E 30 5C 30 2E 30	0 0 0 0
00000c80	5C 30 2E 30 5C 30 2E 30	0 0 0 0
00000c90	5C 30 2E 30 5C 30 2E 30	0 0 0 0
00000ca0	0A 30 1E 01 04 00 00 00	0 0 0 0

**Tag 300A, 011C =leaf/jaw positions**

**Implicit VR, no VR bytes**

**Value. In this case it has a VR of "DS" (double string), which is a text representation of floating point numbers separated by the backslash**

**Items with A VR that Involves String or Text Will be Visible here**

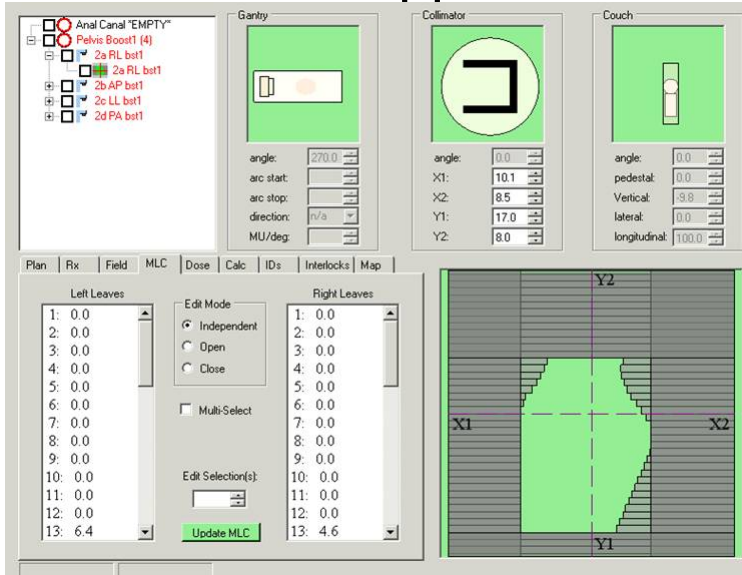
# In an in-house Dicom File Content Browser

Tag = 300A,011C  
 VR = DS  
 VL = 376  
 Name = Leaf/Jaw Positions  
 Value =  
 0.0, 0.0, -101, -101, -101, -101, -101, -101,  
 -101, -101, -101, -101, -101, -101, -101, -101,  
 -101, -101, -101, -101, -101, -101, -101, -101,  
 -101, -101, -101, -101, -101, -101, -101, -101,  
 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 48.8, 53.3, 57.7, 62.3, 66.3, 70.8, 75.3, 79.2, 83.8,  
 84.8, 84.8, 84.8, 84.8, 77.8, 70.8, 63.8, 56.2,  
 46.8, 43.3, 41.8, 45.8, 0.0, 0.0, 0.0, 0.0, 0.0,  
 0.0, 0.0, 0.0, 0.0, 0.0

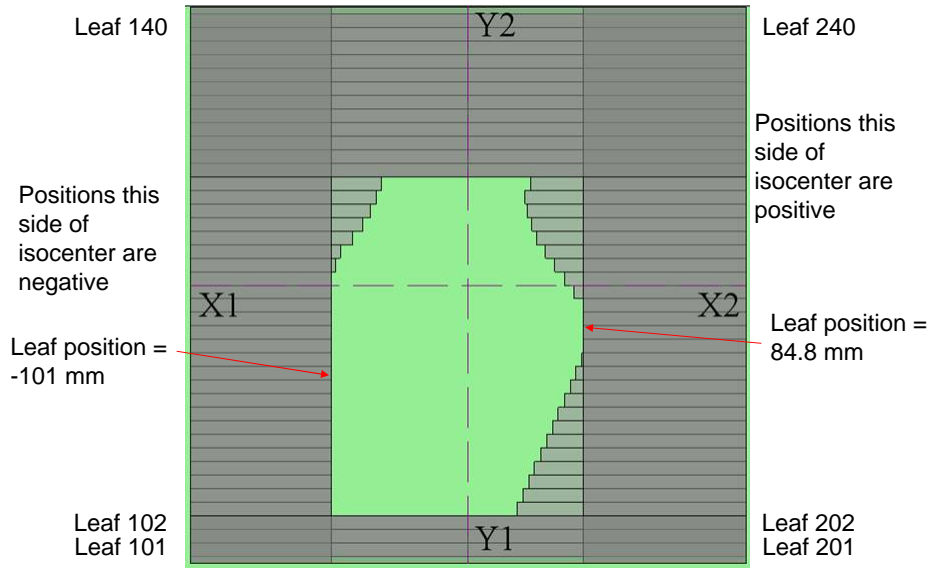
The file structure and bytes have been converted into ASCII and tree view representations. However, this is still in the IEC 61217 coordinate convention, and you have to look for referenced attributes.

# In an in-house Application

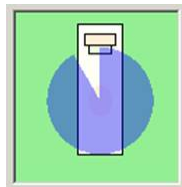
1. Import Dicom-RT file
2. Convert to native data structures
3. Convert to application coordinate system
4. Display in application



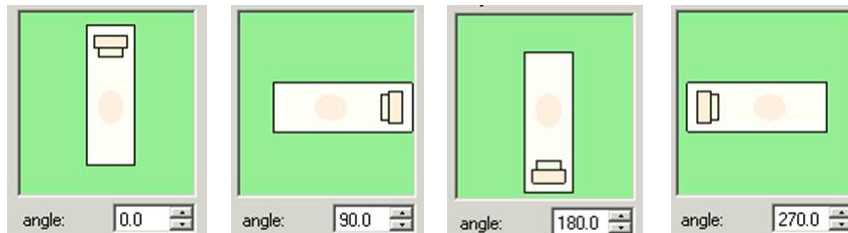
## IEC 61217: MLC- coordinate axis fixed to collimator



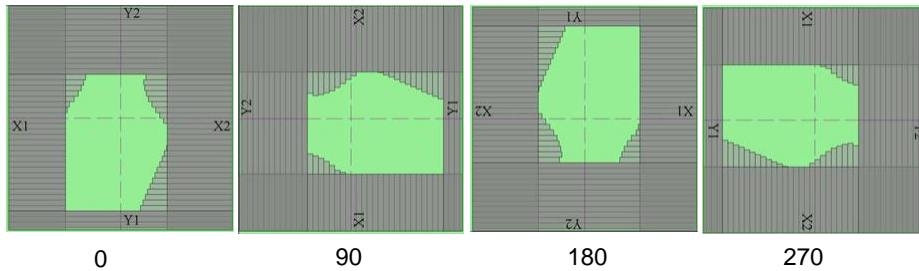
# IEC 61217: Gantry



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

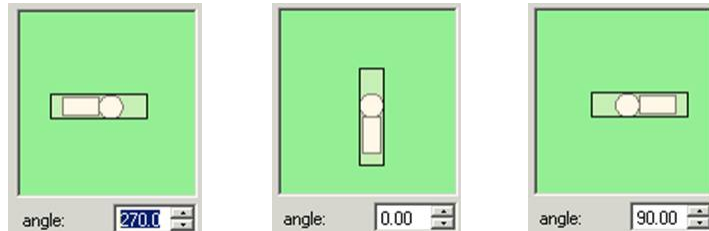


# IEC 61217: Collimator



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.)