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DICOM
Digital Imaging and Communications in Medicine

Tools for DICOM Implementation

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Outline

- **Tools for DICOM implementation**
- **Toolkits and sample/reference code**
- **Validators, test tools and sample data**
- **IHE as implementation guide and testing venue**

Categories of tools

- **Purpose**
  - viewers
  - servers (PACS)
  - toolkits for implementers
  - reference for implementers
  - testing and validation tools
- **Availability and support**
  - freeware
  - open source
  - commercial

Viewers

- **Simple and primitive**
  - load single image & display
- **Media (CD) viewers**
  - view entire patients
  - various modalities (CT, MR, etc.)
  - from CD or local hard drive
  - +/- advanced visualization (3D, etc.)
- **Network capable**
  - DICOM store/query/retrieve

Servers

- **Applications**
  - testing
  - research PACS
  - clinical PACS
- **Capabilities**
  - store/query/retrieve
  - management functions (exceptions/edit/reconcile)
  - workflow enabled (HL7 RIS interface)
  - web server (WADO)
  - security (authentication/access control/audit trail)

Toolkits

- **Functionality**
  - read/write DICOM “files” and messages
  - access to lists of DICOM attributes
  - hide details of encoding from programmer
  - convenient access to bulk (pixel) data
  - memory management for large images
  - compressed image support
  - simplify creating/writing “correct” objects
  - implement network services
  - read/write DICOM media (DICOMDIR)

Toolkits

- **Abstraction Level**
  - network
    - send/receive sets of files
    - open associations, send individual commands
  - data
    - lists of attributes (data elements)
    - create/extract entire objects, modules, macros
    - create/extract structure (e.g., trees for sequences)
    - create/extract abstract models (e.g., in 3D space)
    - support for enhanced multi-frame descriptors

Toolkits

- **Choice**
  - free, open source, commercial
  - level of support – help desk, public forum
  - platform – single (windows) or cross-platform
  - language/framework – C, C++, Java, .NET
  - robustness – exceptions, logging
  - performance – input/output/network
  - comprehensiveness of support for DICOM standard
  - still under active development
  - support the evolving DICOM standard

Reference implementations

- **Value**
  - source code educates implementers
  - resolves ambiguities in standard
  - indicates of what parts of DICOM standard are used
  - may be well documented and/or designed
  - may have well-defined API
  - often multi-platform
  - if open source, reusable in products
  - faster time to market with lower risk
  - test target in the absence of other products

Standard API

- **Application Hosting**
  - DICOM PS 3.19 WG 23 Sup 118
  - web service between “Host” & “Application”
  - WS end-points on same machine
  - language neutral (C++, C#, Java, etc.)
  - file, native XML model, abstract XML model
  - bi-directional and symmetric
  - future common API for toolkits ?

Testing & validation tools

- **Types of tests**
  - development – unit/system/integration
  - deployment – user acceptance/cross-vendor
  - service & support – diagnostic tools
- **Types of tools**
  - testing utilities & frameworks
  - debugging tools
  - test objects
  - test servers
  - object and message validators

Testing utilities

- **Interface to utilities**
  - command line or graphical user interface
  - usable from scripts and batch files
- **Typical functions**
  - dump DICOM file contents in readable form
  - extract attributes from files
  - create test files from script or template
  - edit attributes (add/remove/change values)
  - send/receive on network

Debugging tools

- **Usage**
  - site support staff
  - field service and support staff
  - during inter-vendor testing
- **Types of tools**
  - simulate device behavior
  - capture messages between devices
  - analyze captured messages

Test Objects

- **Image and other composite objects**
  - synthetic – generated *de novo*
  - real – from modalities (de-identified)
  - combination – modified real images
- **Test messages**
  - to use to test DICOM network services
  - e.g., test queries and responses
  - scripts & templates to use with toolkits
- **Test Media**
  - physical media or ISO image files

Test Servers

- **Public**
  - receive/query/retrieve
  - avoiding configuration issues
    - C-GET
    - C-MOVE assume same port as retrieve command
  - www.dicomserver.co.uk
- **Local**
  - within company or hospital or lab
  - tunnel in firewall to DICOM port

Validators

- **Validate for compliance with DICOM**
  - images and other composite objects in files
  - from media or received/captured from network
  - captured network messages (queries, etc.)
- **What to validate**
  - compliance with IOD (defined by SOP Class)
  - compliance with template (Structured Reports)
  - correct encoding of attributes
  - compliance with “profiles” (media, IHE)
  - warn of “undesirable” characteristics

Validators - example

% dciodvfy op.dcm

Ophthalmic Photography 16 Bit Image

Error - Value invalid for this VR
- (0x0010,0x0030) DA Patient's Birth Date DA [0] = <9999/99/99>
- Character invalid for this VR = '9' (0x39)

Warning - Value is zero for attribute <Emmetropic Magnification>

Error - Attribute present when condition unsatisfied
(which may not be present otherwise)
Type 2C Conditional Element=<Mydriatic Agent Code Sequence>
Module=<Ophthalmic Acquisition Parameters Macro>

Validators - example

% dciodvfy cr.dcm

CR Image

Error - Missing attribute Type 2 Required Element=<Study ID>
Module=<General Study>

Error - Lookup Table Data bad - VOI LUT - LUT Descriptor number of bits = 16
but maximum LUT Data value is 0xfd3

Warning - Retired attribute - (0x0032,0x1030) LO Reason for Study

Warning - Unrecognized defined term <LOG_E REL> for attribute <Rescale Type>

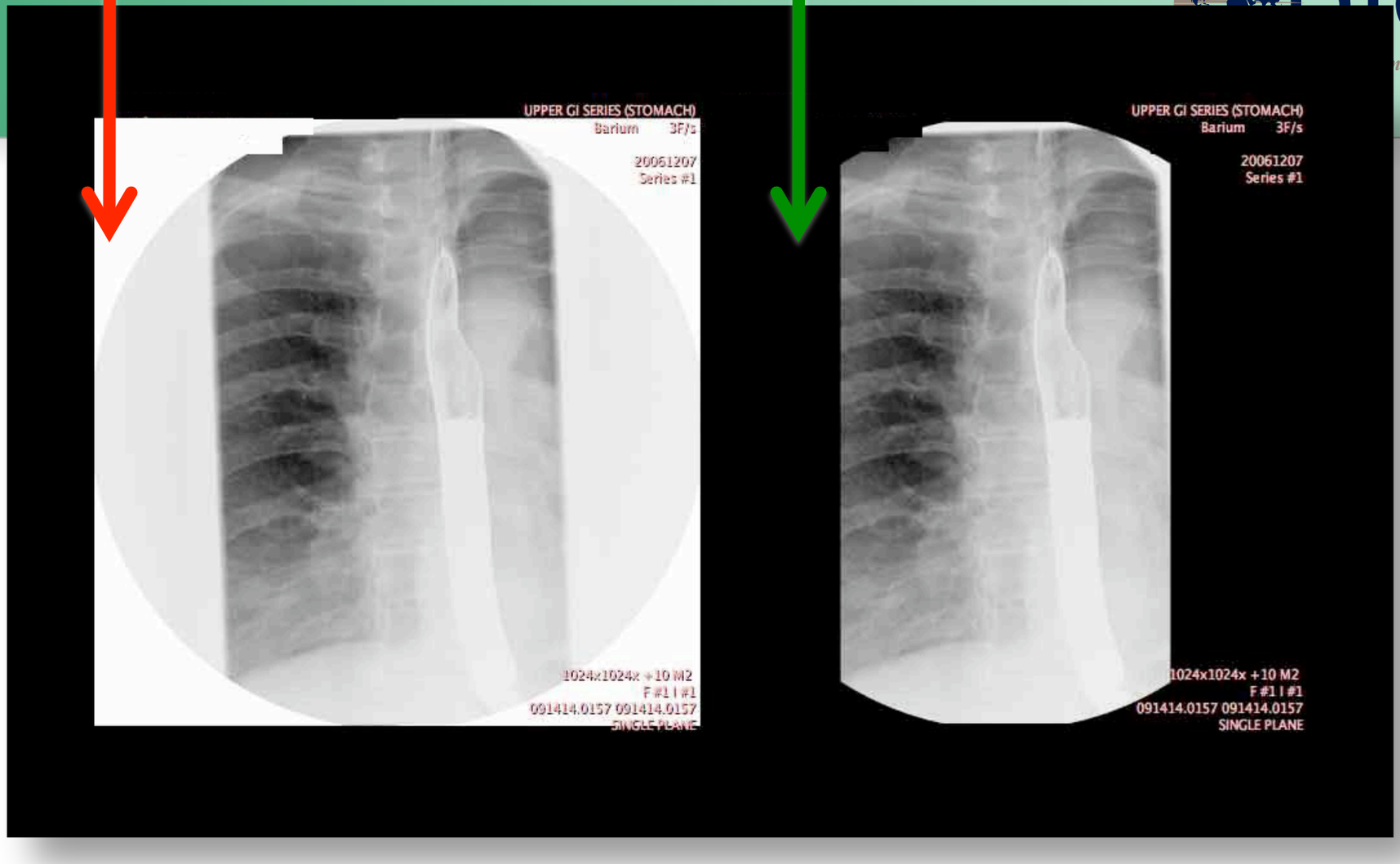
Warning - Attribute is not present in standard DICOM IOD
- (0x0032,0x1032) PN Requesting Physician

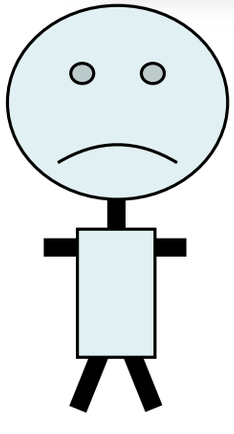
What standard to test against

- **What needs to be tested**
  - does it “work” ?
  - is it “correct” ?
- **Compliance with DICOM standard**
  - does NOT mean that it will “work”
  - may not be necessary for it to “work”
- **For example**
  - device may “interoperate” by ignoring non-compliance
  - a compliant device may fail by ignoring a “feature”

White Background - BAD

Black Background - GOOD





Failure to apply Display Shutter to inverted DICOM image
Modality vendor is compliant – sends Display Shutter
PACS vendor is “compliant” – allowed to ignore Display Shutter
PACS vendor promises this “feature” in new version only
– requires complete PACS server hardware replacement !@#$

Customer “unsatisfied”

What to test

- **Standalone**
  - devices produce compliant objects
  - devices use compliant objects correctly
  - implement the features user requires
  - gracefully handle “bad” but usable objects
- **As pairs of devices**
  - that they successfully communicate
  - that they “work” to the user’s satisfaction
- **As sequence of multiple devices**
  - e.g., workflow from order/acquire/store/check/display

IHE and testing

DICOM℠
Digital Imaging and Communications in Medicine

- **Original RSNA DICOM testing initiative**
  - central test node(s), test tools and plans
- **IHE developed "integration profiles"**
- **IHE "connectathons"**
  - standalone testing with tools
  - test scenarios between "actors"
  - tests against reference implementations
  - tests between actual implementations
  - check logs to be sure "work" for right reasons

IHE®

- **Free and open source**

Finding tools

- **Google**
  - “dicom toolkit”
- **Some useful web sites with links**
  - http://www.dclunie.com
  - http://www.idoimaging.com
- **Forum for dicom discussion**
  - news:comp.protocols.dicom
  - http://groups.google.com/group/comp.protocols.dicom/

Finding test images

- **Not quite as easy as finding tools**
- **Google**
  - "dicom samples", "dicom images"
- **Some useful web sites with links**
  - http://www.dclunie.com
  - http://barre.nom.fr/medical/samples/
  - http://gdcm.sourceforge.net/wiki/index.php/Sample_DataSet
  - http://www.nibib.nih.gov/Research/Resources/ImageClinData
- **There is no "official" test library**
  - ftp://medical.nema.org/MEDICAL/Dicom/DataSets
  - Is a non-public NEMA members-only test library ? status

Conclusions

- **Plethora of implementations and tools**
  - many are free and open source
  - many are well supported
  - so, do not fear DICOM's "complexity"
- **Testing is important**
  - failure to test is inexcusable
  - good testing leads to happy customers
- **IHE can help**
  - use the profiles, use the tools, participate