Evaluation of AutoQA Lite™ Image Quality Measurement Software

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Overview

- Overview of AutoQA Lite™ software
- Our context and requirements
- Evaluation criteria
- Evaluation results
- Example applications
- Conclusions

Overview of AutoQA Lite™

- Written by The Institute for Radiological Image Sciences (IRIS) Inc (http://www.theiris.com)
- UK Distributor: Southern-Scientific
- Approx cost: £1350 + VAT (exchange rate dependent)
- Features
  - Fully automatic analysis of axial images from Catphan 410, 412, 424, 440, 500, InnerVision (Toshiba) and Siemens CT phantoms. Plans for GE and ACR phantoms in future.
  - On-screen / printable report of results
  - Results stored in accessible database
  - Trend analysis facility
- Version 1.5 evaluated over 18 month period

Context: Edinburgh Cancer Centre

- GE HiSpeed FX/i single slice, helical scanner
- Primarily for radiotherapy treatment planning
  - Frequent QA
    - daily, fortnightly, monthly…
  - Strict, tight tolerances
    - ±10 HU on CT number calibration, ± 1 mm on geometry
  - Unusual set-up
    - external lasers, flat couch-top, etc.
- Catphan 500
- Possibility of future use with Sim-CT system


HiSpeed

Our Ideal Analysis Software

- Quick and easy to use for routine QA
  - Fully automatic in as many different set-up configurations as possible
- Accurate, reliable, robust
- Knowledge of implemented algorithms
  - Understand limitations and caveats
- Ability to access results for further analysis outside software

- BUT able to deal with unusual situations
  - Manual methods when automatic algorithms fail

Evaluation Criteria

1. Software installation
2. Import of CT image files
3. Quality, accuracy and robustness of image analysis and result reporting
4. Retrospective trend analysis
5. Overall impressions (user interface, stability, documentation etc)

1. Software Installation

- Tested on Windows NT and 2000 machines
- Installation fully automatic and generally smooth
- Utilises Hardlock USB or Parallel port dongle, requiring installation of additional drivers
- Merge DICOM server
  - NOT automatically installed
  - Installation not described in manual but is relatively straightforward
  - Automatically starts on login
- Uninstall program does not remove all icons and files

2. Import of CT Image Files

- Supports DICOM 3.0 files
  - Implicit VR Little Endian format ONLY
- Two import methods
  - Copy files into appropriate directory for automatic detection by software
  - Send files across network to supplied DICOM server
- Exhaustively tested both of these

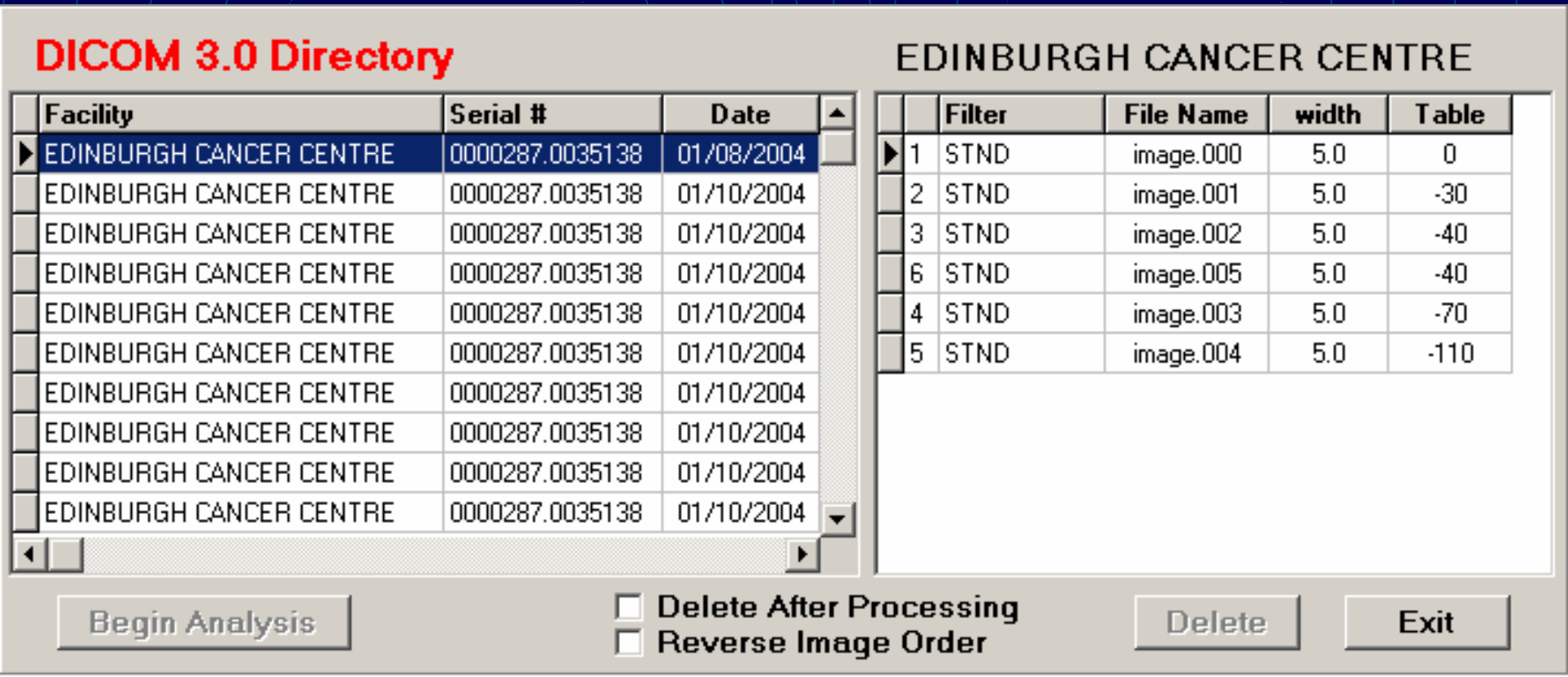
Import via Copying Files

- Images must be placed in c:\images\ct
- Strict naming convention
  - No additional periods, dashes, etc in file names
  - i.e. standard DICOM UID names not permitted
- Tested various DICOM formats
  - Import of implicit VR LE images worked correctly
  - All other DICOM formats failed
- Attempted import directly from CD-ROM written by GE Advantage Workstation
  - FAILED! Images are stored as **explicit** VR LE
  - Therefore, must be converted to correct format before importing into AutoQA software

Import via Network Transfer

- Fiddly to set-up but once correct worked very smoothly
- Practical end-user implementation
  - EITHER, requires direct access to network configuration options of CT scanner or workstation
  - OR, copy DICOM files from scanner to CD-ROM / optical disk and send to AutoQA server via local DICOM link in physics
- Tested both of above and both worked well

AutoQA Lite™ Browser



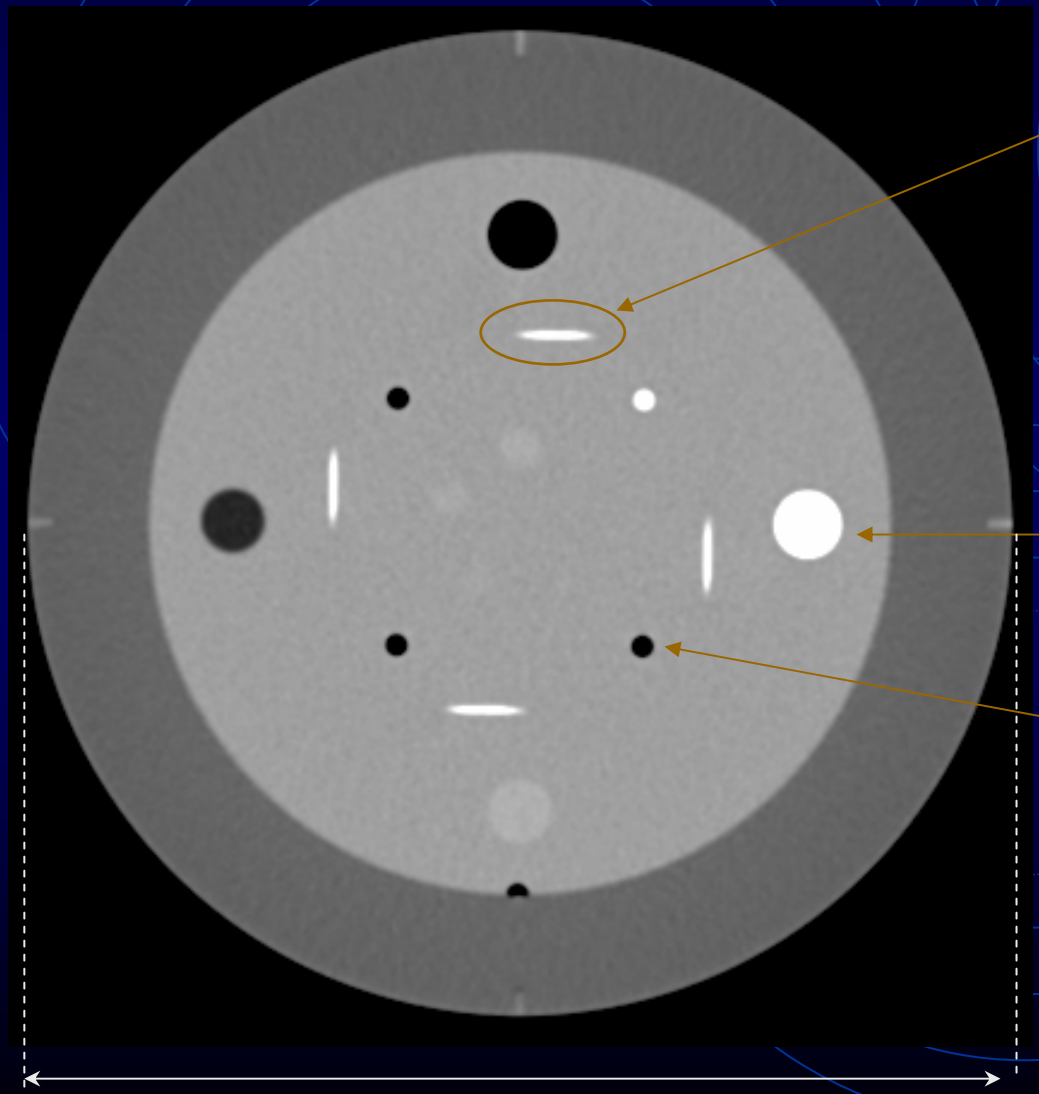
AutoQA Lite™ Browser

- Merges all image series under a particular study into one series
  - Can be difficult to identify image required
- Image selection is a bit unstable
  - Possible to start analysis without selecting an image!
  - Causes software to crash
- Images which software cannot interpret appear in the browser as odd entries
- Delete option does not always work properly

3. Evaluation of Analysis Features

- Scanned all Catphan 500 slices using standard protocol
  - Patient head-first, supine
  - 120 kV, 200 mA, 1.5 s rotation, 5 mm slice width
  - 25 cm diameter scan and reconstruction FOVs
  - Standard reconstruction and processing filters
- Analysed alignment, MTF and uniformity slices using software
- Compared results against manual analysis and Dundee / ImPACT measurement software

Analysis Summary: Alignment Slice

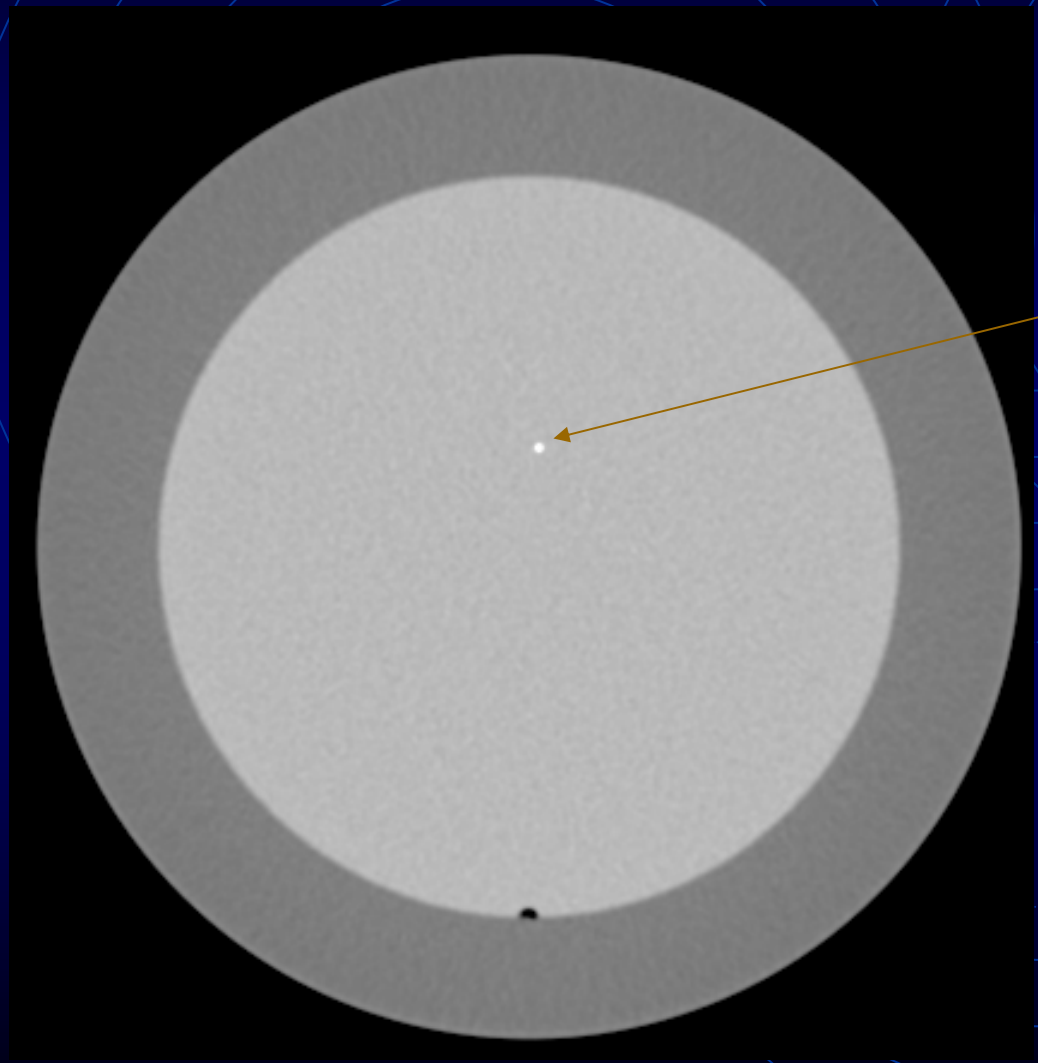


Bars:
- Centres give z alignment and rotation
- FWHM above background gives slice width

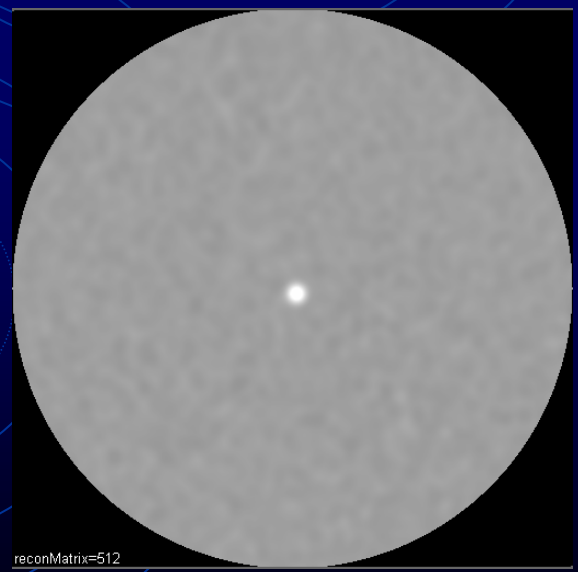
CT Number linearity inserts

Holes + phantom edges
- Pixel size calculation
- x and y alignment

Analysis Summary: MTF Slice

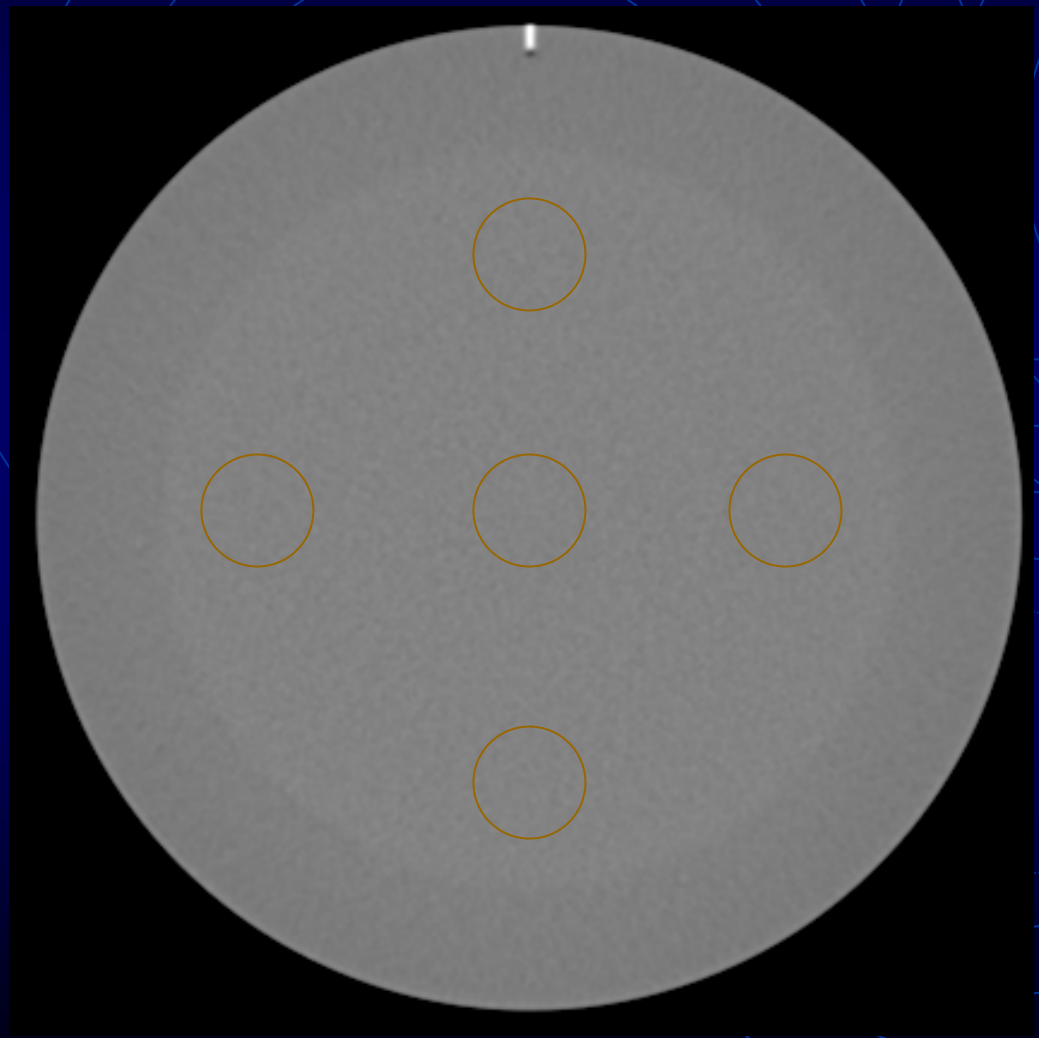


Fourier transform of point spread function gives modulation transfer function (MTF)
(Various methods exist)



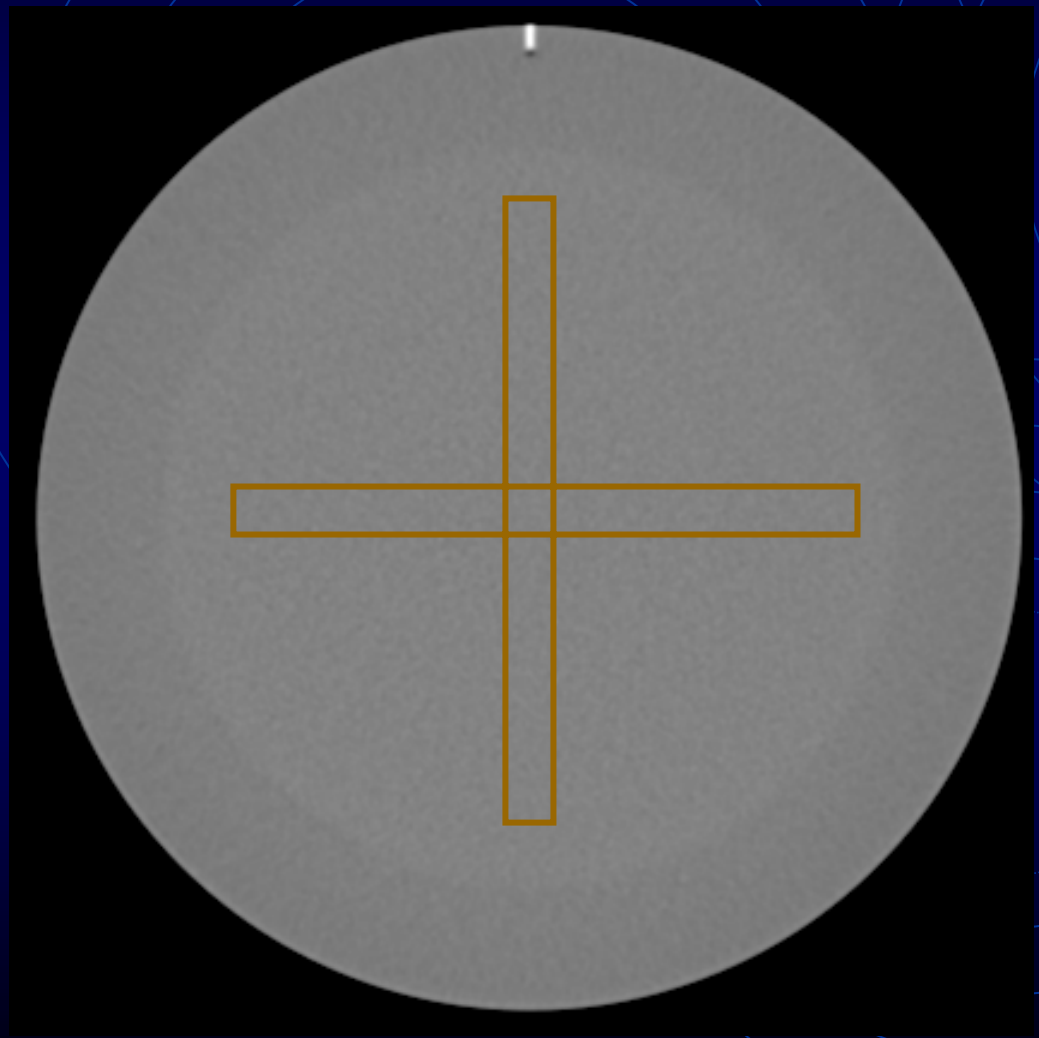
Retro-recon at 5cm FOV

Analysis Summary: Uniformity Slice



Assess noise by considering mean and standard deviation in central and peripheral ROIs

Analysis Summary: Uniformity Slice



Consider average horizontal and vertical profiles

Fractional uniformity = fraction of pixels in profile lying within tolerance limits about mean

(typically $\pm 2\sigma$)

Test Scenarios

- Phantom accurately aligned
- Experiment with range of fields of view
- Experiment with range of nominal slice widths
- Reconstruction so that (0,0,0) is not at centre of image
- Patient orientations other than HFS
- First slice at z=I500 mm rather than z=0
- Geometrical offsets
  - large and small shifts in x, y, z directions
  - Plus combinations of all three
- Horizontal and vertical rotations

Accurately Aligned Phantom

- Most measurements agree well with both manual and Dundee/ImPACT software analyses
- Pixel size – exact agreement
- x, y, z alignment– exact agreement
- CT Num Linearity – agree ±0.5%
- Slice width – agree ±2%
- Phantom rotation – x and y agree, z overestimated
- MTF – agree ±8% with Dundee and GE software
- Noise – agree within ±5%
- Fractional uniformity – agree within ±10%
  - Not clear what tolerances are used in calculation

AutoQA Lite v1.5

Analyze | Test Results | Review Trend Reports | Options | Quit | About

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CT AutoQA Lite Ver 1.5

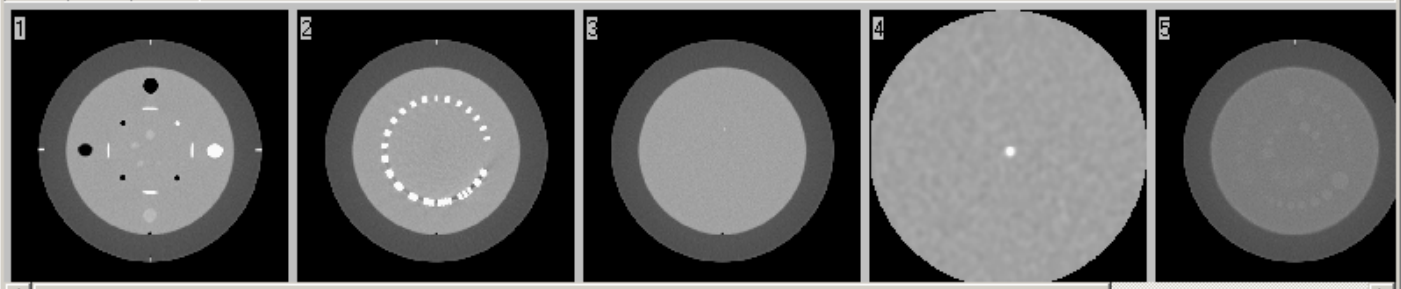

Image #	Test	Status
	Verification	Phantom ID: 500 Series (Phantom Labs) ; Orientation: 13 Phantom Center: 256, 258; CT# of Base : 92.00 +/- 3.01
1	Pixel Size	Expected(mm) X-Axis(mm) Y-Axis(mm) 0.49 0.49 0.49 0.49 0.49 Phantom Rotation : -0.5 degrees Phantom Center is 0.00 mm RIGHT OF CENTER and 0.98 mm BELOW CENTER
	CT # Linearity	Contrast Scale: 0.000204 Material TEFLON AIR LDPE ACRYLIC CT# 939.7 -993.7 -100.5 115.8
	Slice Thickness	Expected(mm) X-Axis(mm) Y-Axis(mm) 5.00 4.92 , 5.00 4.86 , 4.93 Avg Slice Width(mm): 4.93 Table Position Offset: 0.04mm Vertical Angle : 0.2 degrees Horizontal Angle : 0.2 degrees
2	Spatial Resolution	**Error**
3	Spatial Resolution (MTF)	Critical Frequencies (cy/cm) 50% 3.48 10% 6.04 2% 7.65
4	Spatial Resolution	**Error**
6	Noise	x(mm) y(mm) Mean(H) SD(H) 0.00 50.00 5.65 3.34 50.00 0.00 5.72 3.14 0.00 -50.00 6.46 2.93 -50.00 0.00 5.75 2.79 0.00 0.00 6.96 2.70
	Uniformity	X-Axis Y-Axis Uniformity Index 0.61 0.63 Std Dev (H): 5.3

Different FOVs

- Experimented with 25, 35 and 2x50 cm FOV
  - 50 cm FOV can be specified using either “Large SFOV” or “Large-S FOV”
- 25 cm and 35 cm FOV were successful
  - Agreement with manual measurements similar to ideal case
- Analysis failed for 50 cm FOV
  - Error: “Cannot find edges of phantom”

Different Slice Widths

- Scanned alignment slice using 1, 2, 3, 5, 7, 10 and 1 mm slice width
- All calculated widths agree with manual analysis to within ±4%
- Discrepancy increases with larger slice width
  - Due to location of ROIs for background value?
- Number of images in report printout is confused

Offset Reconstruction

- Image reconstructed so that centre of slice is 2 cm right and 2 cm anterior of scan centre
- Centre position correctly calculated
- Rest of analysis carried out to same accuracy as before

- NB: AutoQA Lite™ coordinates are in frame of image rather than in anatomical directions

Patient Orientation

- Scanned phantom with patient Head-First Prone
- Analysis failed
- Software only works if image slices are in the negative z direction (inferior under this protocol) with respect to the alignment slice
- Could turn phantom round, but awkward

Alignment Slice Offset by z=50 cm

- CT-simulator specific test
- Verifies travel of couch from external isocentre to centre of scanner
- Software automatically identifies slices and analyses images correctly
- BUT quotes wrong z position for alignment slice
- Appears to define alignment slice as z=0 and calculates offsets of other slices relative to this

Geometrical Offsets

- Shift phantom in x, y and z directions
  - X -5 mm
  - X +10 mm
  - Y –5 mm
  - Y + 10 mm
  - Z –3 mm

  All interpreted correctly, within experimental uncertainty
  - Z +8 mm

    - Shift identified but quoted as 5.2 mm
    - Slice width correct so phantom bars OK
- Combination of x, y and z shifts: (5,10,-5) mm
  - Interpreted correctly
- **Note:** X and Y shifts are quoted with direction, but z shift is not (i.e. no sign or direction indicator)

Phantom Rotation

- 2° rotation about x axis (superior end to anterior)
  - Calculated correctly by software
- Approx 4° rotation about y axis (superior end to right)
  - Angle significantly underestimated (2.3°)
  - Could be due to phantom alignment problem

Observation across entire study

- Phantom repeatedly scanned in same position
- Calculated angle varies by ±0.2°
- Rotation of phantom in image plane appears to be slightly overestimated in comparison with manual analysis (+0.2°)
- Horizontal and vertical axis rotations are not quoted with sign.

4. Retrospective Trend Analysis

- All results are stored in one of two databases
  - "Monitor database" – routine QA measurements
  - "Service database" – more specialised measurements
- Databases in DBase IV format
  - Can be loaded into Excel for graphing, etc.
- Basic reports can be generated showing all results for particular scanner
- Results outside IEC tolerances are highlighted

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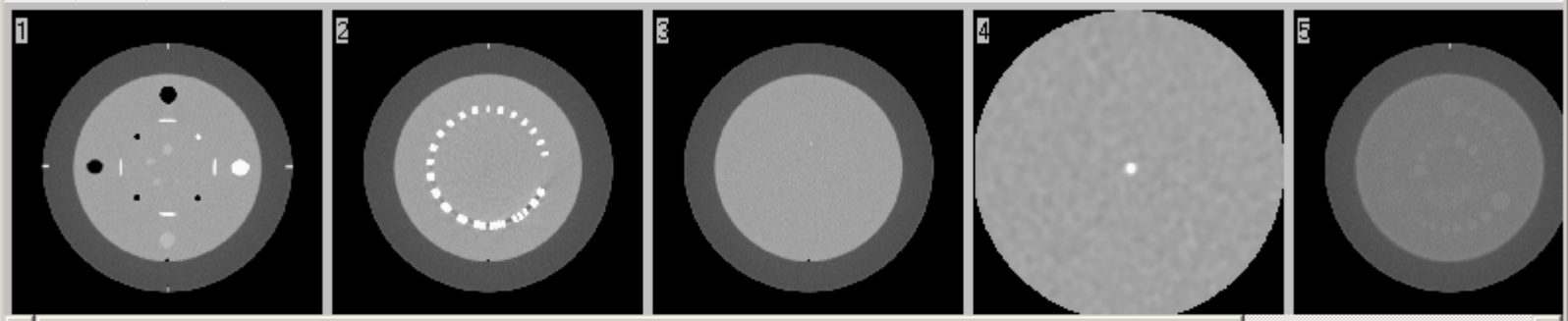
CT AutoQA Lite Ver 1.5



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5. General Impressions (1)

- User Interface
  - Generally easy to use
- Stability
  - When images are in acceptable format, very good
  - If ‘bad’ images are imported, program can crash or hang
  - Can be difficult to recover from crash without knowing exactly what went wrong

5. General Impressions (2)

- Documentation
  - PDF Format on CD-ROM
  - Describes basic analysis algorithms (similar to Catphan manual)
  - More DICOM information and advice would be helpful
  - More information on structure of phantom definition files would be helpful
- Customer Support
  - Excellent support available via phone / email to IRIS Inc
  - Advice can be given on tuning phantom definition files, etc

Comparison of Analysis Methods

Full manual analysis	2 hours
Dundee / ImPACT software + manual analysis	30 mins
AutoQA Lite™	5 mins

AutoQA LiteTM is fully automatic

- Great for routine QA
- No manual methods when automatic facility doesn't work (but there is the possibility of modifying configuration files under guidance from IRIS Inc)

Application: Reproducibility of Alignment against CT Lasers

- Catphan aligned on CT lasers and alignment slice scanned
- Catphan removed, realigned and scanned again.
- Repeated to give 10 scans in total
- Repeated for external laser gantry
- All scans analysed by AutoQA Lite™
- Results:
  - Z position out by 0.5 mm (external) and 0.7 mm (internal)
  - Alignment accuracy (1σ) of ± 0.1 mm (external) and 0.2 mm (internal)

Conclusions

- When it works it works very well!
  - Vast majority of the measurements performed agree well with external measurement tools
  - Software performs satisfactorily in a wide range of scenarios
  - Once images are imported, analysis is nearly instantaneous
  - Very useful for routine QA programme
- Limitations MUST be understood before use
  - DICOM file formats, patient orientation, FOV, etc.
  - Glitches in user interface which must be avoided

Acknowledgements

- AutoQA Lite™ Software
  - The IRIS Inc – Steve Dyer (http://www.theiris.com)
  - Southern Scientific – Keith Thompson (http://www.ssl.gb.com)
- IDL Image Measurement Software
  - Dundee Medical Physics (http://www.dundee.ac.uk/medphys)
    - David Sutton
    - Julie Smyth
    - Benedikt Lubbers
    - Alexander Dietzel
  - ImPACT (http://www.impactscan.org)
    - Nick Keat