Operator influences on CT scanning: A round robin study

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X-ray CT Process





X-ray CT Process





CT Scanning – sources of variation

Source

- Type (reflection/ transmission/rotating)
- Misalignment/eccentricity of spot
- Heating of source
- Target material

Workpiece

- Material
- Orientation
- Varying path-length (e.g. high aspect ratio)

Geometric Alignment

Detector

- Tilt/misalignment
- Non-linear response

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- "Misbehaving" pixels
- Variation in pixel size

Environment

- Temperature
- Humidity

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Operator settings

- Beam energy
- Beam power
- Exposure
- Detector gain
- Filtration

• # projections

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- Frame averaging
- Continuous
- /stop-start

CT Audit



Organised by S. Carmignato (University of Padova) 2012



15 participants given four calibrated workpieces and asked to measure several dimensions (predominantly diameters and distances) using X-ray CT

Most were able to measure with sub-voxel accuracy

A notable exception is that 1/3 of participants results for distances on the tetrahedron were not sub-voxel. In fact, the error was > 2 voxels



AIM Understand individual centre XCT scanning capability and cross-centre variation in approach to scanning





Advanced Manufacturing Research Centre

(DECENC)





Manufacturing

Technology Centre

AIM Understand individual centre XCT scanning capability and cross-centre variation in approach to scanning

- How different are operator parameter selections?
- To what extent does this affect measurement?
- Are machine differences a greater influence?

Similar CT scanner available across centres (variation on Nikon 225)







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BDEING







- Plastic AM workpiece measured on CMM (hole diameter, centre-to-centre, plane-to-plane)
- Scanning to be performed at each centre by own operator
- Reconstruction, voxel scaling, segmentation and measurement using same method at WMG



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- Reconstructed, voxel scaled, segmented and measured using same method at WMG

The round-robin

- Scan selecting own parameters
- Scan with joint settings
- Comparison also given with repeated scans











	C1	C2	C3	C4
Voltage (kV)	120	65	60	160
Current (µA)	90	110	190	130
Power (W)	11	7	11	21
Filter	None			
Exposure (s)	0.5	1.0	2.8	1.4
Gain (dB)	30	24	24	18
Projections	3017	3142	1200	3142
Voxel size	91	91	96	90

91

91

96

Voltage (kV)

Current (µA)

Power (W)

Exposure (s)

Gain (dB)

Projections

Voxel size

Filter



90



	C1	C2	C3	C4
Continuous (CTS) Stop-Start (SS)	CTS	SS	CTS	SS
Scan time	26	157	56	222

Wide range of settings!

Scan times are significantly different. Is there any advantage?



	Centre 1	Centre 2	Centre 3	Centre 4
Source settings				
Voltage (kV)	120	65	60	160
Current (microA)	92	110	190	129
Power (W)	11	7.2	11.4	20.6
Filter	0	0	0	0
Detector Settings				
Exposure (s)	0.5	1	2.8	1.415
Gain (dB)	30	24	24	18
Manipulator				
CTS/SS	CTS	SS	CTS	SS
Projections	3017	3142	1200	3142
Voxel Size	90.8	90.1	96.3	90.8
Scan time	26	157	56	222







Centre 1



Centre 3

Centre 4

A note on voxel scaling

The source-object/object-detector magnification has some inaccuracy

Especially problematic over large distances

By using a workpiece with known threshold independent measurements within the scan, can apply a scaling to the voxel size

Alternatively can use known measurements on the object itself.









A note on voxel scaling



An example of un-scaled and scaled results



Prior to scaling voxel size = 0.09006 microns After scaling voxel size = 0.08922 microns





Own settings - measurements





Own settings - measurements





Maximum deviation -0.61 voxels

75% of deviations are within 0.27 voxels

Average absolute deviation 0.14 voxels

Own settings - measurements



Spread of deviations per centre



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Joint settings



While the machines are similar, there are some hardware differences.

If everyone uses the same

- Beam energy (spectrum)
- Exposure
- Detector gain
- Number of projections
- Continuous scanning Adjust current to suit

How do individual measurement results compare?

	joint
Source settings	
Voltage (kV)	130
Current (microA)	adjust
Power (W)	adjust
Detector Settings	
Exposure (s)	0.708
Gain (dB)	24
NA	
ivianipulator	
CTS/SS	CTS
Projections	3142
Voxel Size	90
Scan time	37

Joint settings - measurements





Maximum deviation -0.61 voxels

75% of deviations are within 0.17 voxels

Average absolute deviation 0.12 voxels

Joint settings - measurements





Own settings

Joint settings

Joint settings - spread





Joint settings - spread





Joint settings - spread







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- There is a large variation in operators setting parameters
- With the exception of low projection count, measurements have remained better than 0.6 voxel accuracy, <0.3 voxels for 75% of measurements
- Despite different system setups, by scanning with the same parameters greater consistency is achieved in measurement error
- Repeated scans results in significantly lower variation
 - Machine to machine variation accounts for a much larger proportion of error variation than parameter settings

