Intelligent Automation

EPSRC Centre for Innovative Manufacturing in Intelligent Automation

Evaluating 3D Vision Sensor Performance on Challenging Surfaces

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mtc Manufacturing Technology Centre

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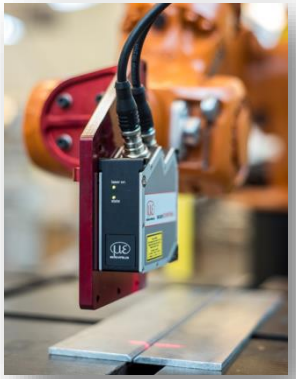
Freeform Bolting

Robotic Assembly

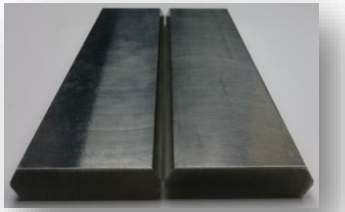


Freeform TIG Welding

Automated Panel Beating

Defect Detection

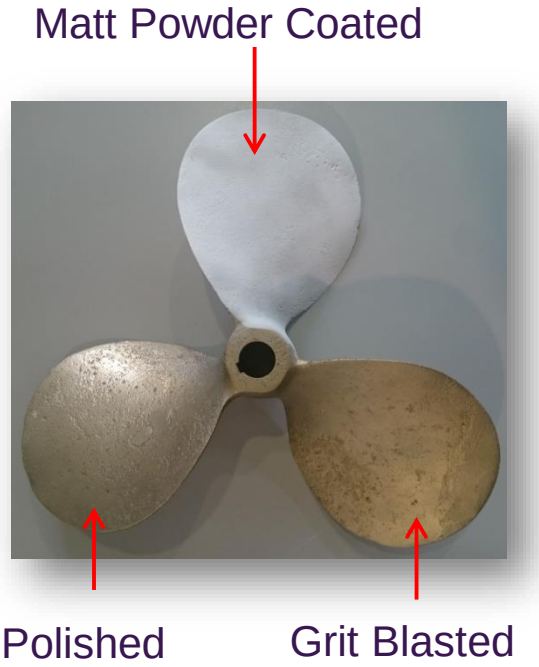
Robotic Assembly

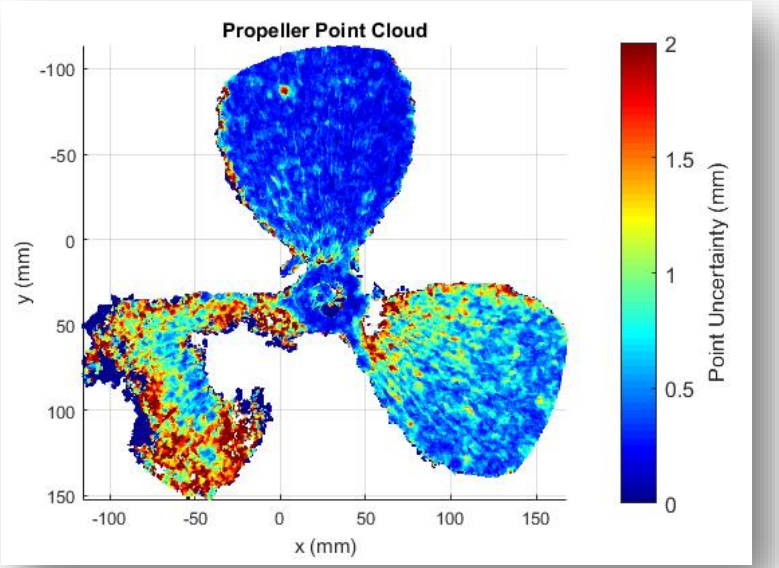


Weld Prep Inspection

Measuring Challenging Surfaces

Surface finish, position and orientation affect measurement quality:





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Objectives of Research

- Develop method to characterise scanner performance in terms of surface:
  - Finish
  - Position
  - Orientation
- Compare sensor appropriateness for a particular application.
- Use the method to model 3D sensors.

Current Standards & Literature

- VDI/VDE 2634. National standard.

Sphere and Ball-Bar [1]

Flat Plane [2]

VDI/VDE 3D Sensor Characteristics	
F	Flatness measurement error
P_F	Probing error (form)
P_S	Probing error (size)
SD	Sphere-spacing error

- ASTM E2919-14. International Standard
  - Arbitrary object to be chosen as artefact

[1] http://scanningspheres.com/wp-content/uploads/2016/05/7085-300x300.jpg
[2] http://www.3d-china.com/en/products_blank/86.html

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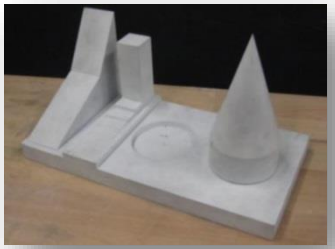
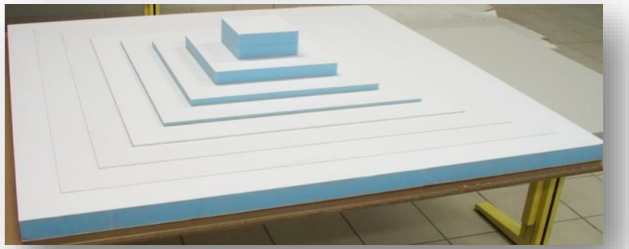
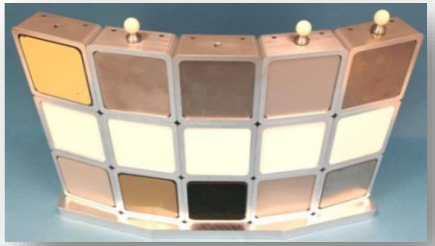
Current Standards & Literature



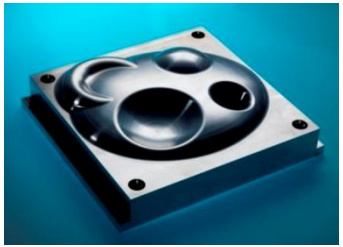
Primitive solids for testing accuracy and uncertainty. [1]



Step height accuracy. [2]



NPL 3D Material Coupon plate. [3]



NPL Freeform Artefact. [4]

[1] Guidi *et al*. Performance evaluation of Triangulation Based Range Sensors. *Sensors, 2001*
[2] Guidi *et al*. Low cost characterization of TOF range sensors resolution. *Proc SPIE-IS&T Electron. Imaging*, vol. 7864, 2011
[3] Dury *et al.* 3D Optical Scanner Dimensional Verification Facility at the NPL “National FreeForm Centre”.*Laser Metr.& Mach. Perf*. 2015
[4] McCarthy *et al.* NPL Freeform artefact for verification of non-contact measuring systems. *Int. Soc.for Optics & Photinics*. 2011

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Characterisation Model

Sensor images the sample with properties:

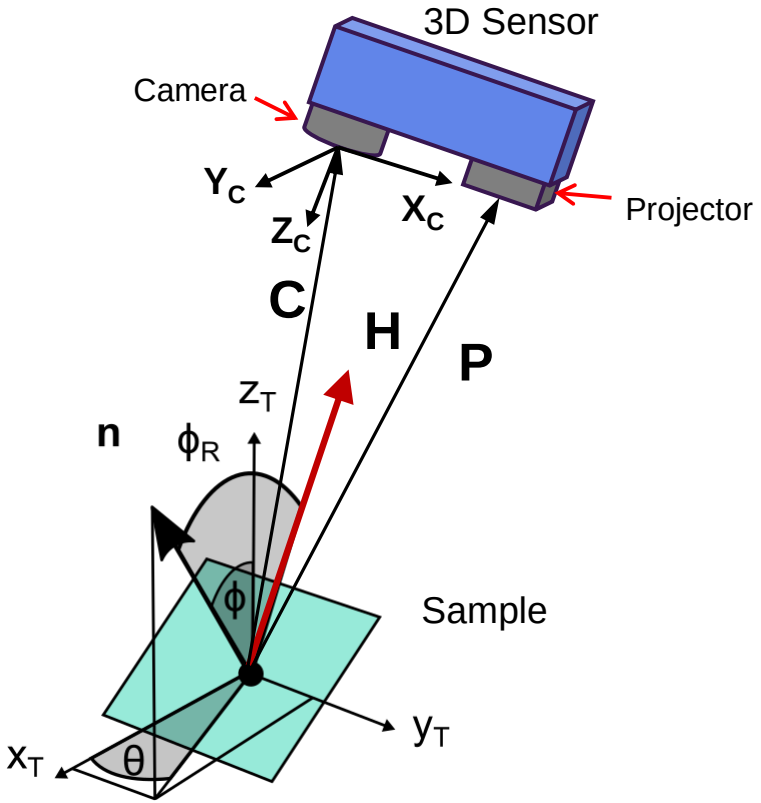
- Surface normal, **n**
- Sample position, **C**

Experiment is parameterised by:

- Sample surface finish
- Sample distance, |**C**|
- Angle between **n** and **H**

Assume:

- Surface texture is isotropic



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Experimental Setups

Fix sample, move sensor

+ Accuracy
+ Speed

– Cost

Fixed sensor, move sample

+ Cost

– Speed
– Accuracy

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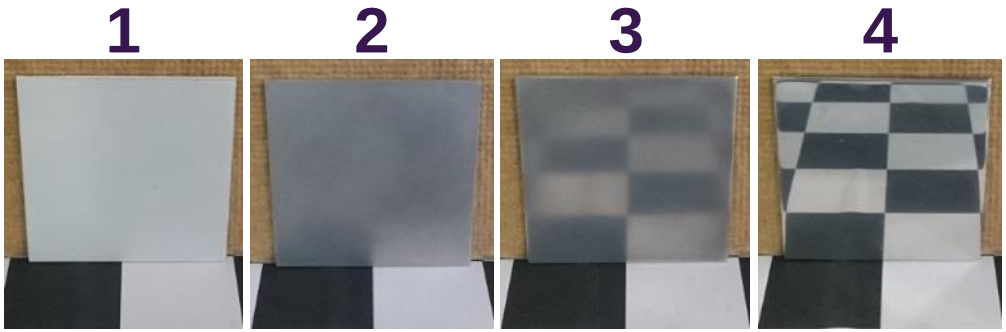
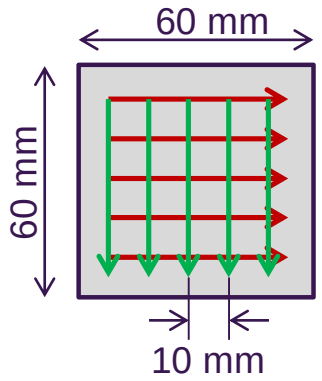
Sample Properties





Profile Locations

5 equally spaced profiles in X and Y. Talysurf CLI 2000

		Sample			
		1	2	3	4
Ra (µm)	X	0.46	0.39	0.09	0.82
	Y	0.46	0.34	0.09	0.66
Rq (µm)	X	0.59	0.54	0.13	1.04
	Y	0.59	0.45	0.13	0.83
Flatness (µm)	X	15.5	20.2	11.9	24.6
	Y	39.9	13.9	30.8	19.7

Performance Metrics

- **Fraction of Recovered points, *F***

$$F = \frac{number\ of\ recovered\ points}{maximum\ possible\ number\ of\ points}$$

- **Point standard deviation, *σ* (mm)**

  Represents measurement noise

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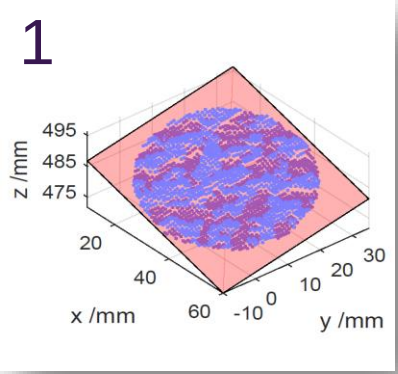
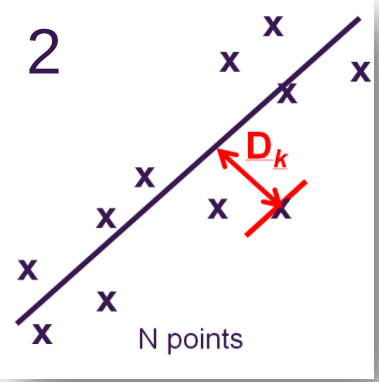
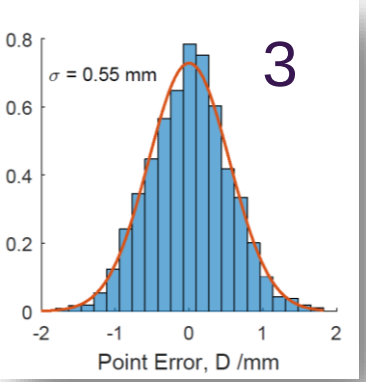
Point Standard Deviation







1. Fit least squares plane / line to data

2. Calculate point distance to plane

3. Calculate point standard deviation

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Sensors Tested

	Ensenso N10 - 304 - 18 [1]	**Micro - Epsilon 2900-100 [2]**
Technology	Active Stereo – IR Pattern	Laser Sheet Triangulation
Working Distance	170 – 2000 mm	65 – 120 mm
Z Resolution	0.5 mm @ 500 mm	4 µm
Image Resolution	752 x 480	1 x 1280

[1] https://en.ids-imaging.com/store/n10-stereo-3d-kamera-300.html
[2] http://www.directindustry.com/prod/micro-epsilon/product-5788-1561158.html

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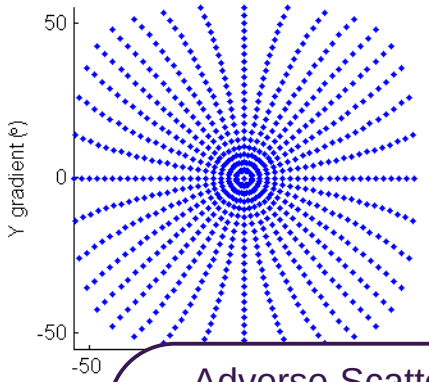
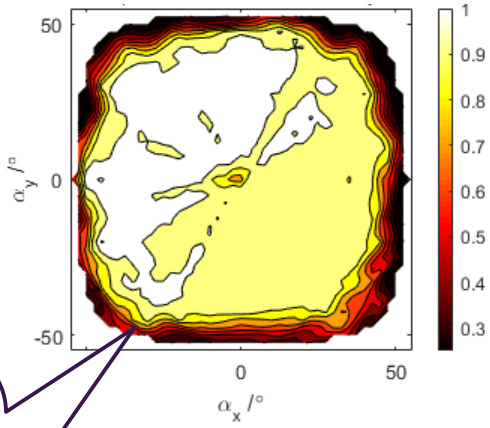
Results - Ensenso

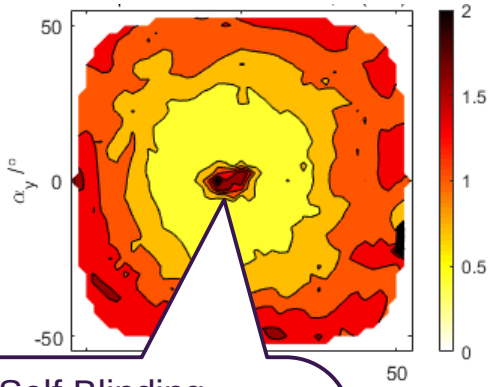
Measurement Locations



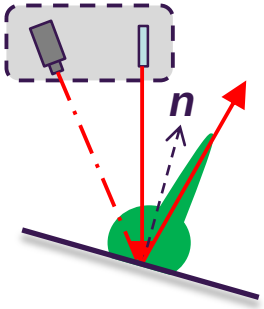
Point Fraction



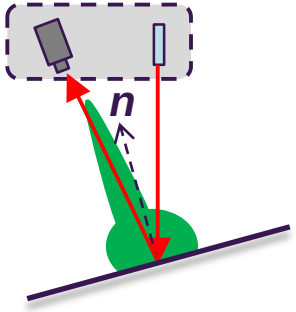
Standard Deviation



Adverse Scattering



Self Blinding



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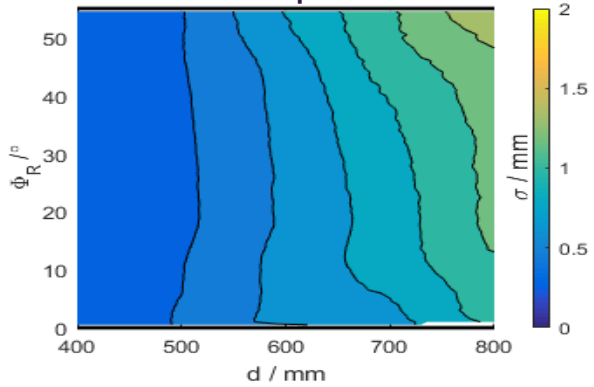
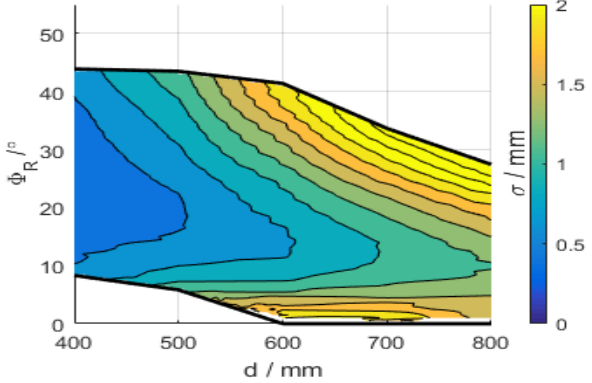
Results - Ensenso

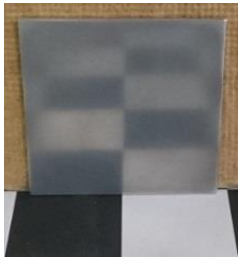
Sample 1

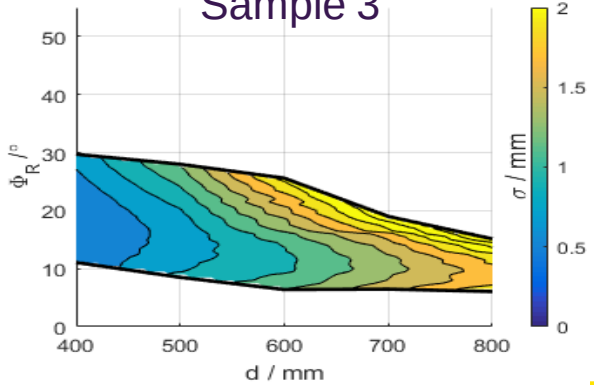


Sample 2

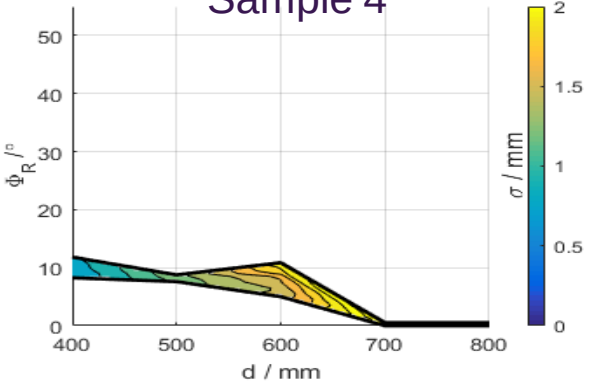


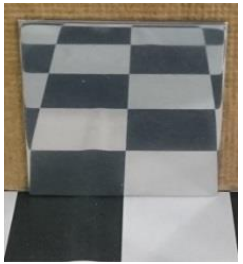
Sample 3





Sample 4





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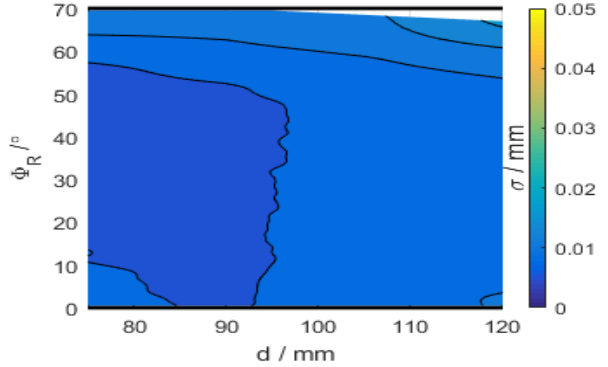
Results – Micro Epsilon

Sample 1



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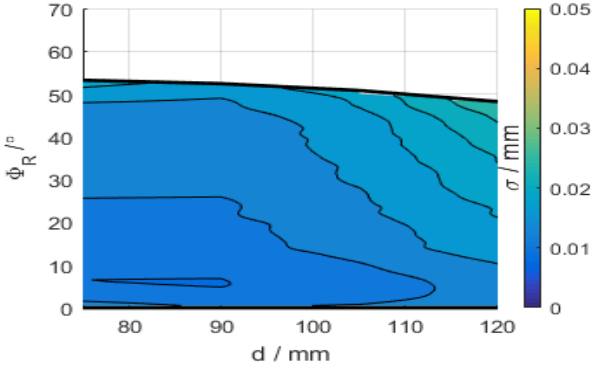

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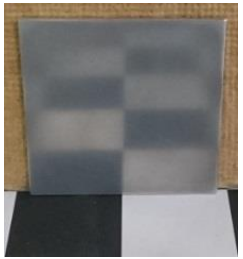

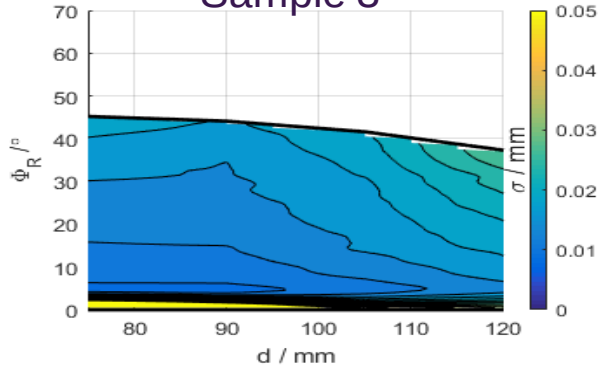

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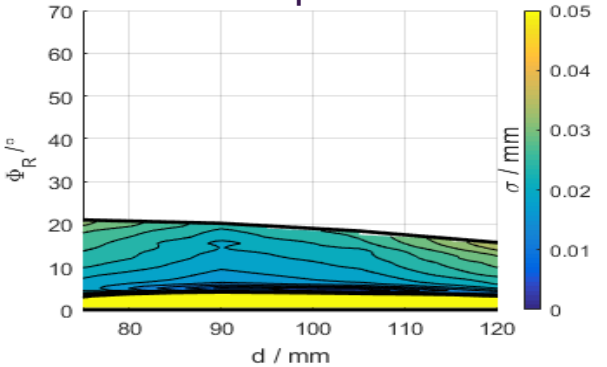

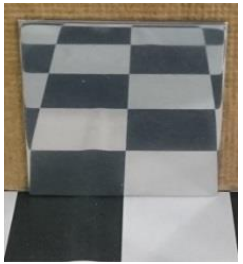

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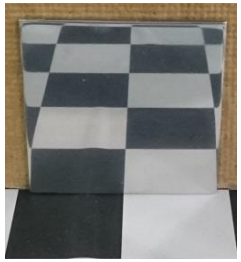
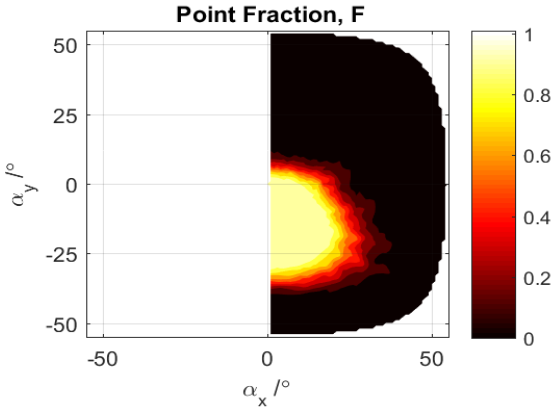
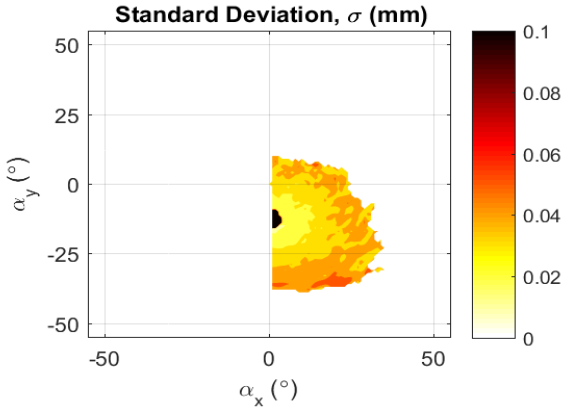
Micro Epsilon – Auto vs Manual

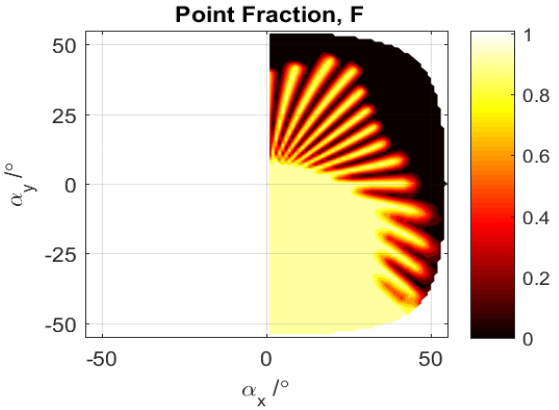


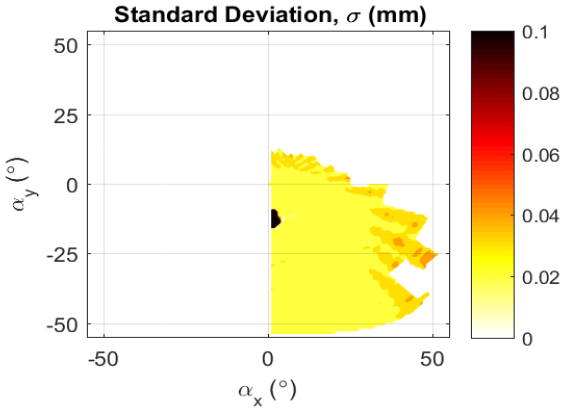
Manual Exposure (100us)





Factory Defaults – Auto Exposure





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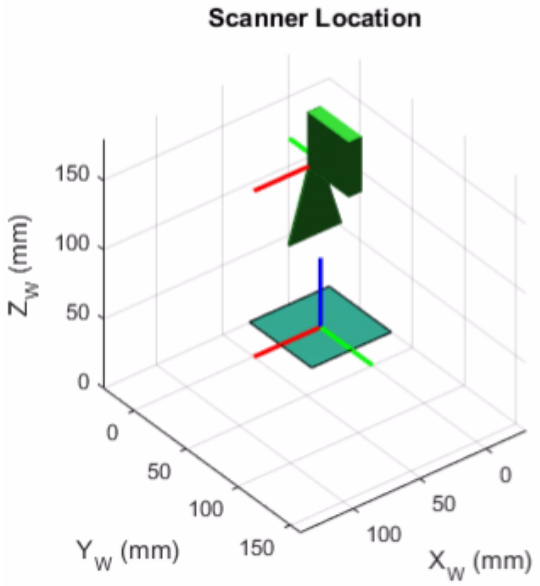
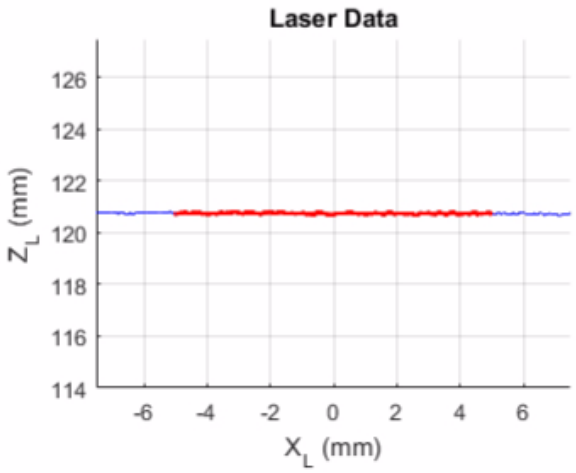
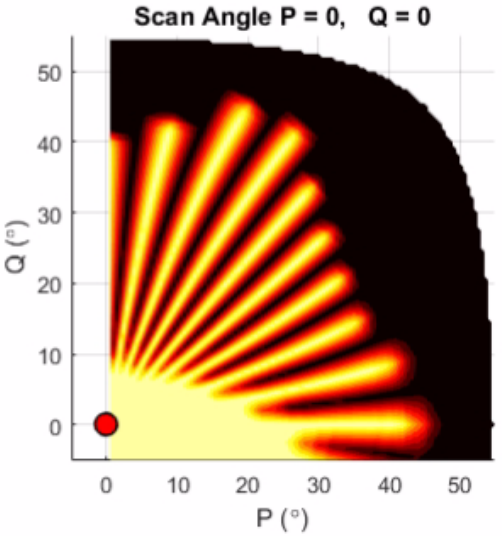
Micro Epsilon – Auto vs Manual

Theta = -5°, Phi = 0°







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Summary

- The aim of this work was to address how to describe and determine 3D vision sensor capability on challenging surfaces.

- A new sensor characterisation method that:
  - allows **real-world sensor performance** comparison.
  - provides better **understanding of sensor performance**.
  - provides an empirical **sensor performance model**.

- Next steps are to:
  - Develop a hybrid **empirical and physics based model**.
  - Use **models to predict point cloud quality** for arbitrary objects.