



University of
Nottingham

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MANUFACTURING
METROLOGY TEAM

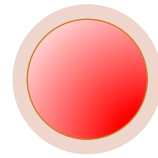
Determining the 6 DOF of a manufactured part from a stereo image and CAD model

Dr Samanta Piano

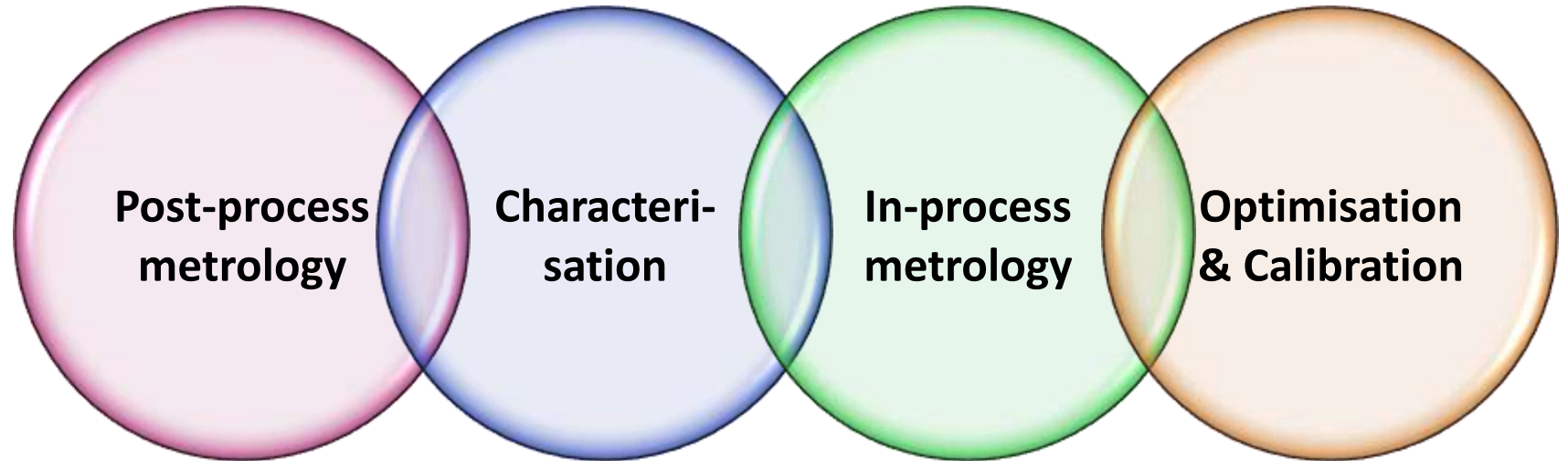
Head of Manufacturing Metrology Team

Associate Professor of Metrology

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Dimensional metrology for improving surface and form measurements.



(a) airplane wing, (b) automotive gears (c) instrument support frame and (d) hydrogel scaffold for implants



- Applications
- Medicine
 - Manufacturing
 - Heritage
 - Anthropology



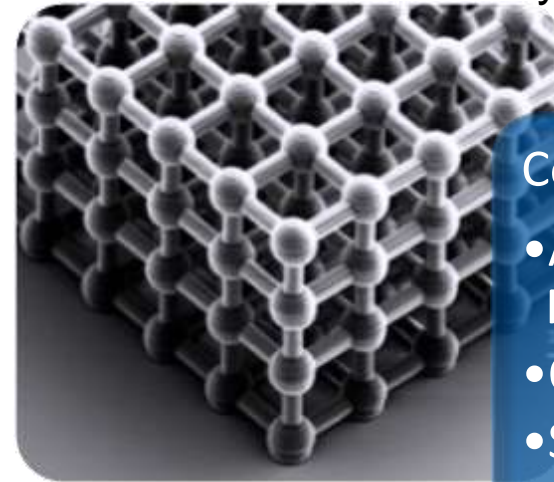
Panda



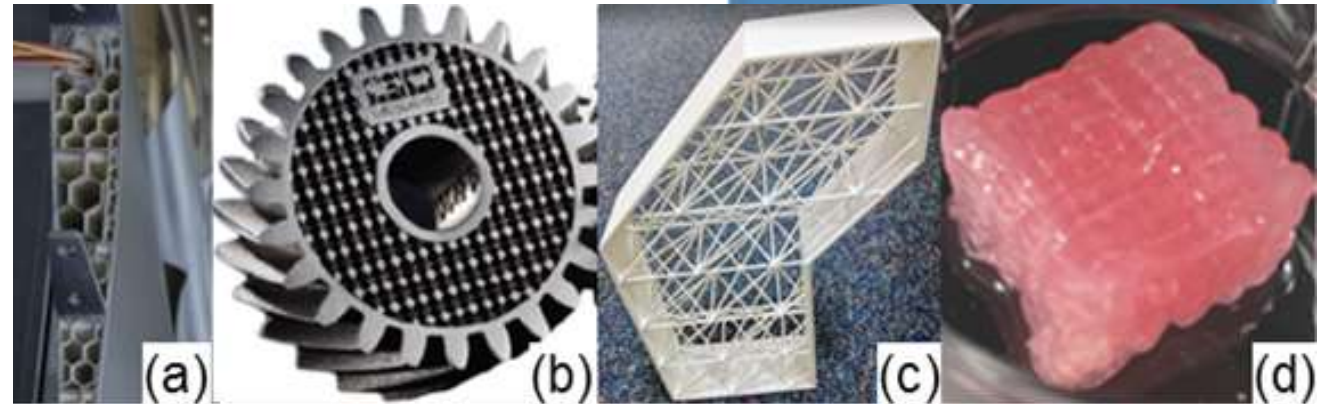
Lion



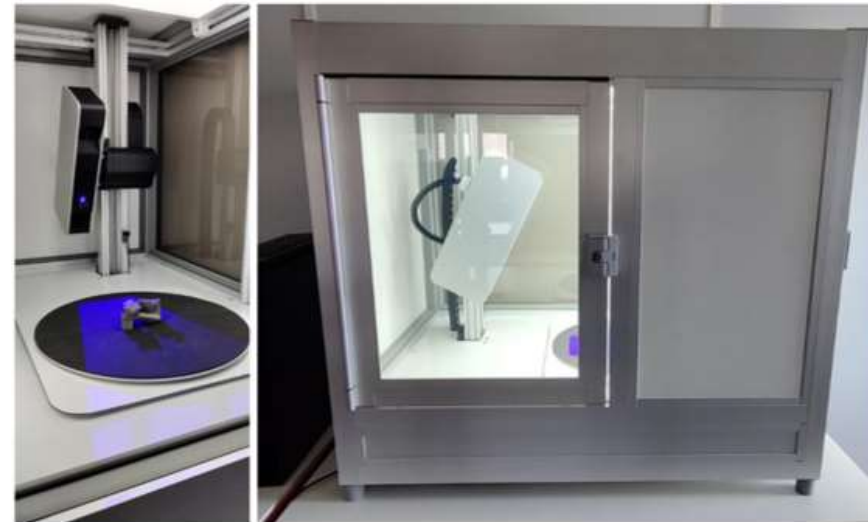
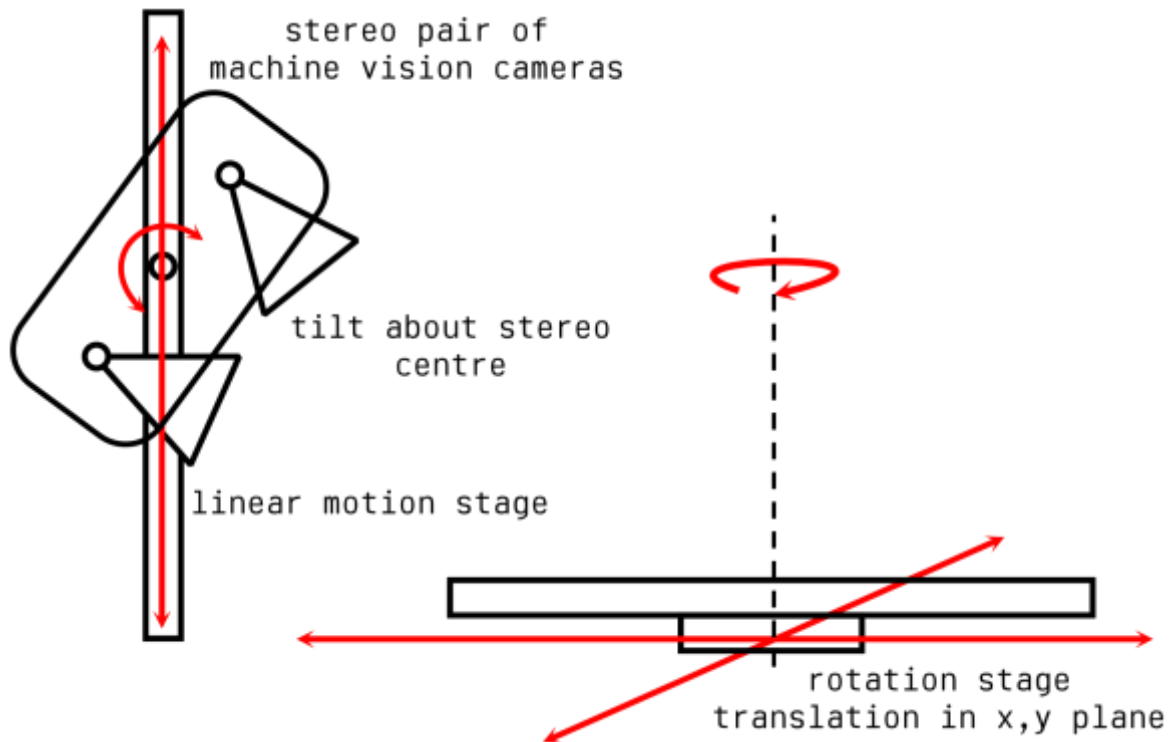
Cow



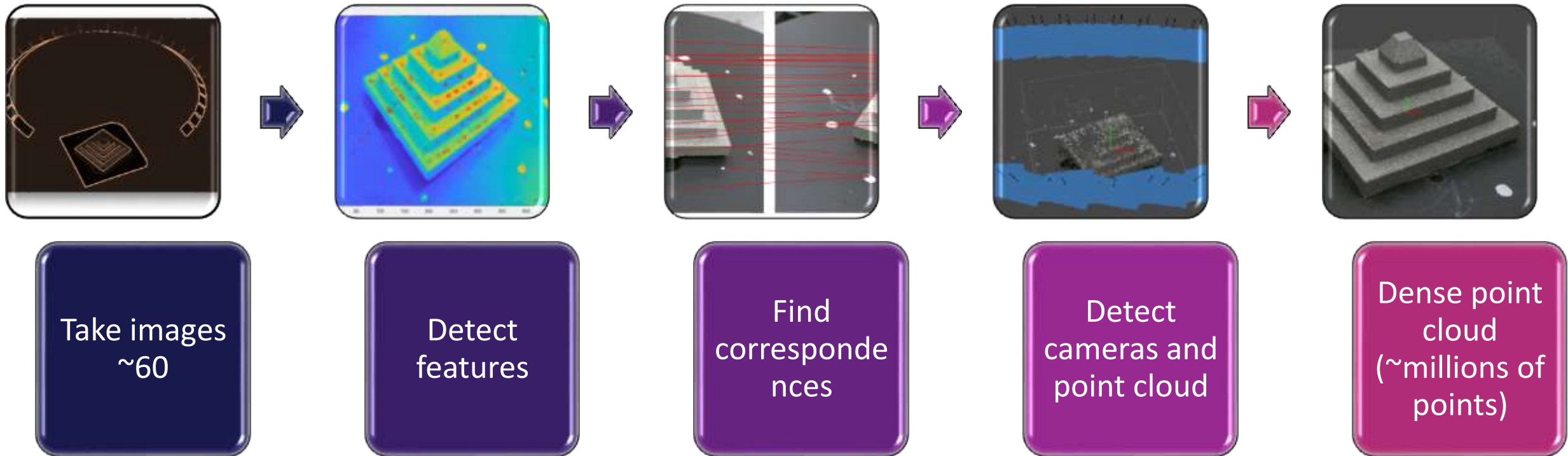
- Complex Shape
- Additive Manufacturing
 - Occlusions
 - Smooth surface



Photogrammetry is the **science of measurement through the use of photographs**

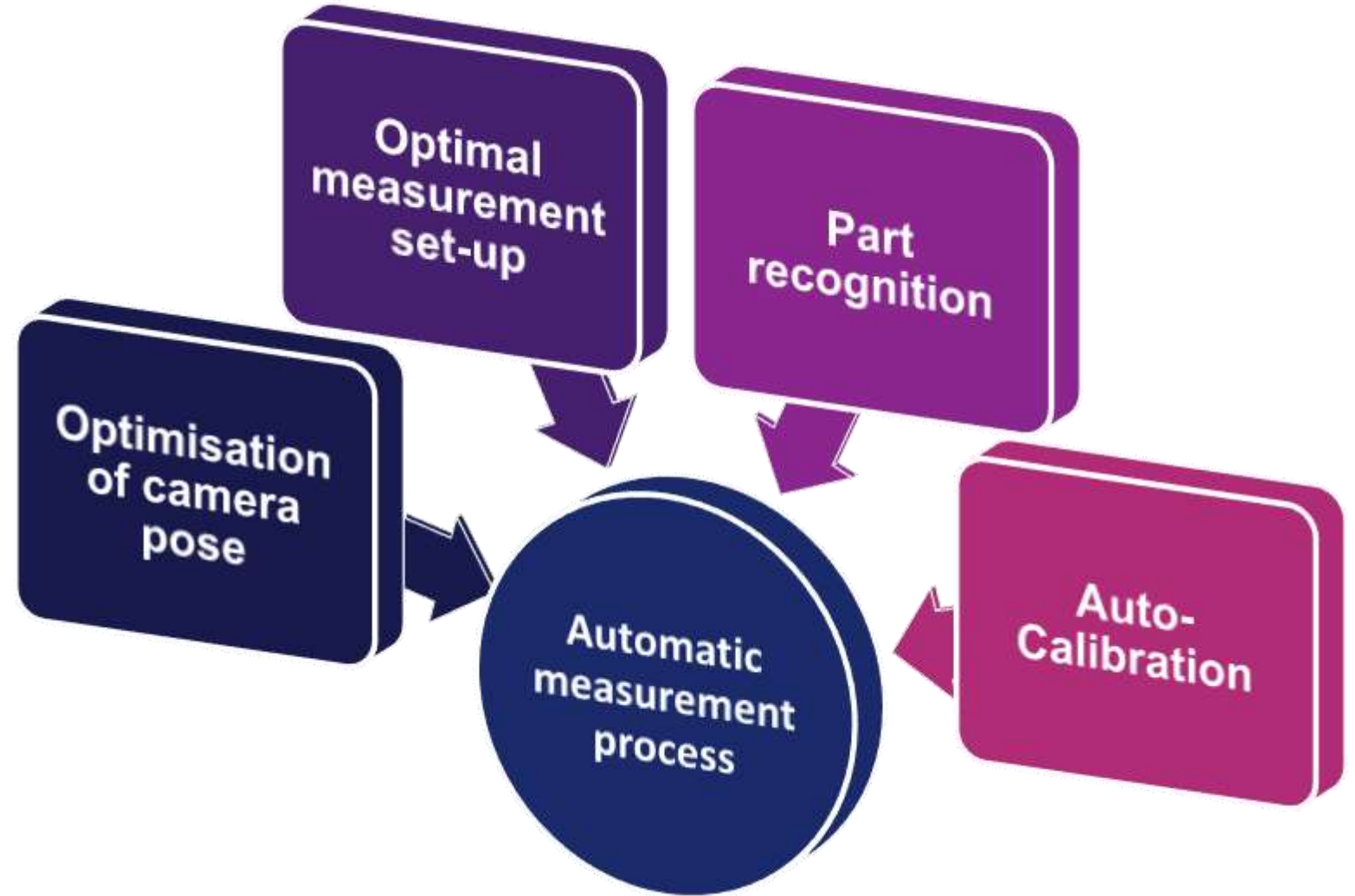


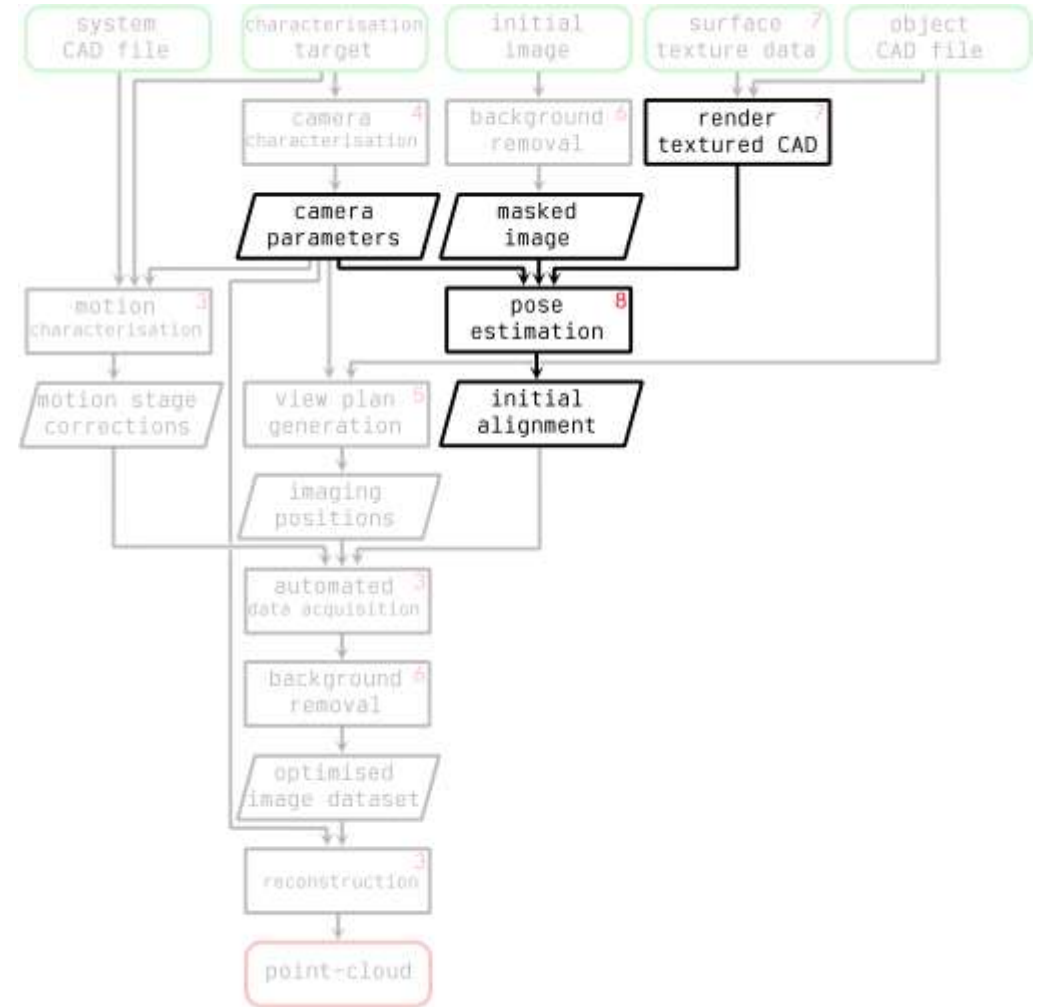
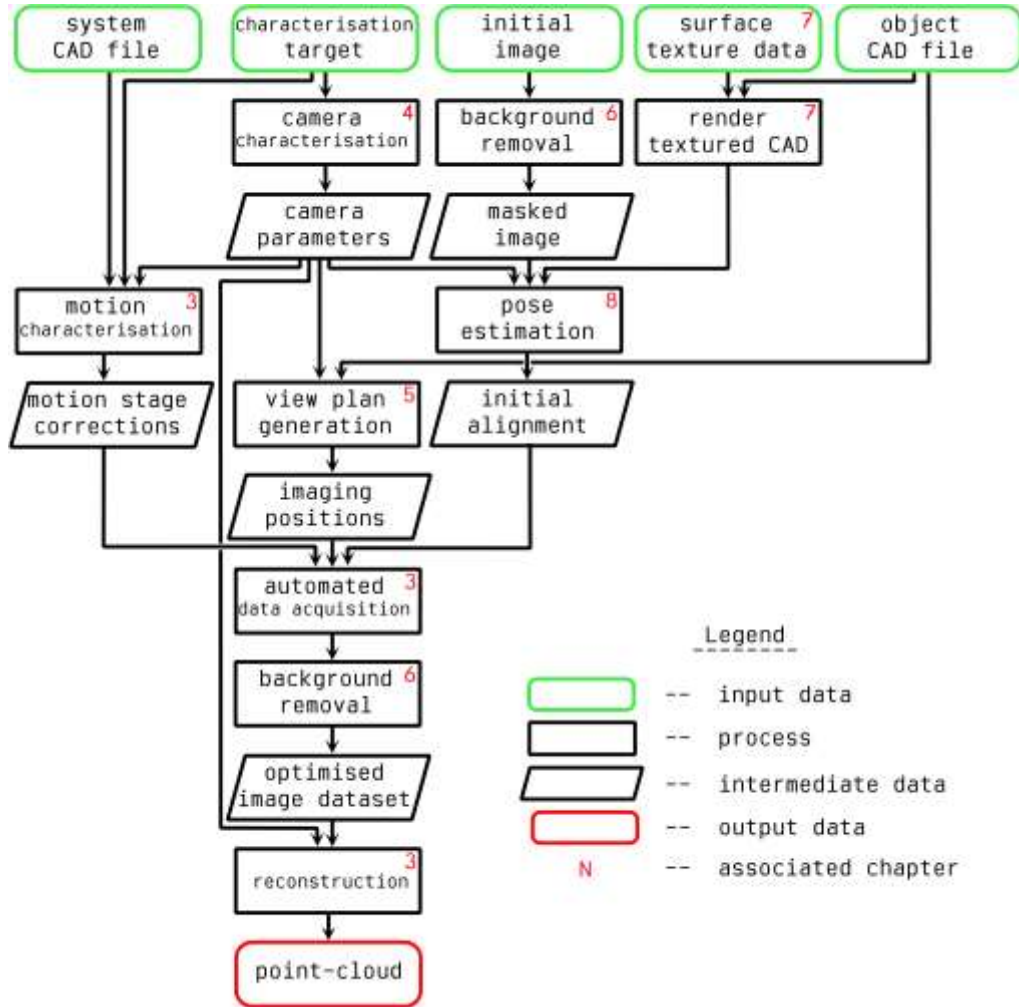
Taraz Metrology



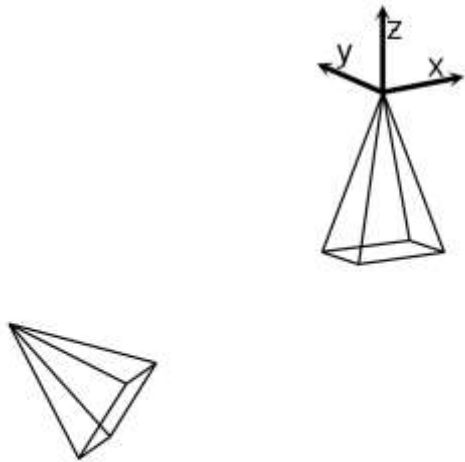
- high dependence on the user
- characterisation of the camera manual process: can cause poor measurement results
- measurement result highly sensitive to the imaging strategy very slow in the data processing stage: each feature in every image is a potential match with all features in every other image

- fast image of an object and its 3D reconstruction
- enable to measure smooth surface
- Highly robust and user independent



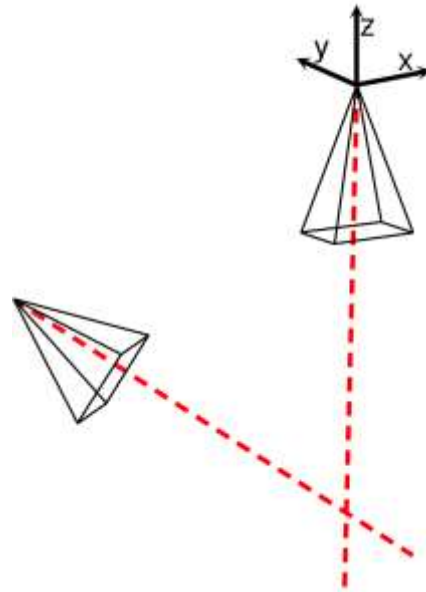


Camera alignment



- The **extrinsic matrix** $[R, T]$ of both cameras are determined.
- Cameras are placed in the **same coordinate system**.

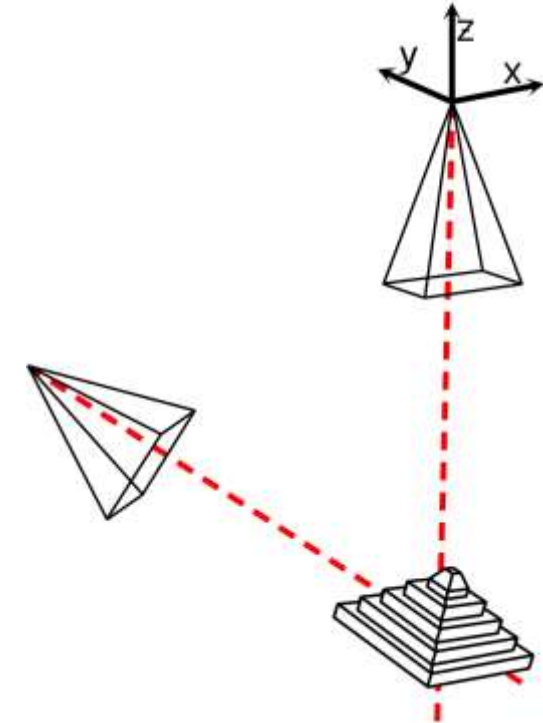
Raycasting



A ray is cast from each camera origin through each **centroid location**.

$$\begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}^T = (K \cdot [R, T])^+ \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}^T$$

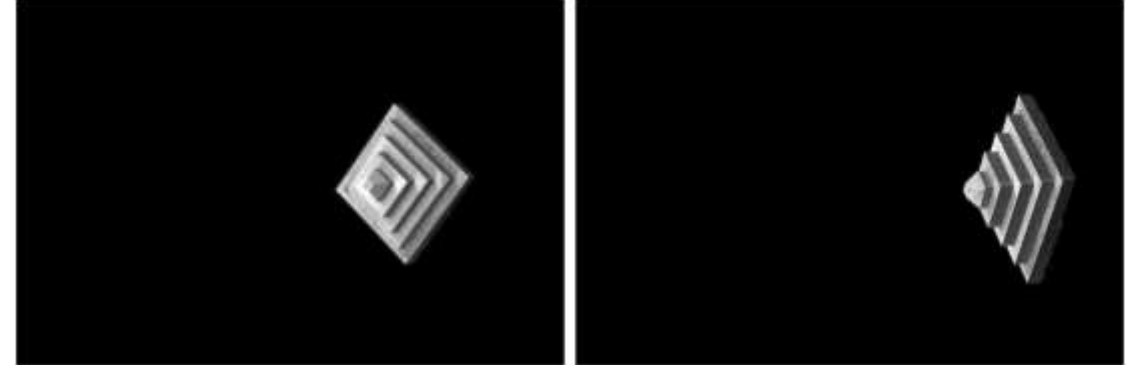
CAD placement



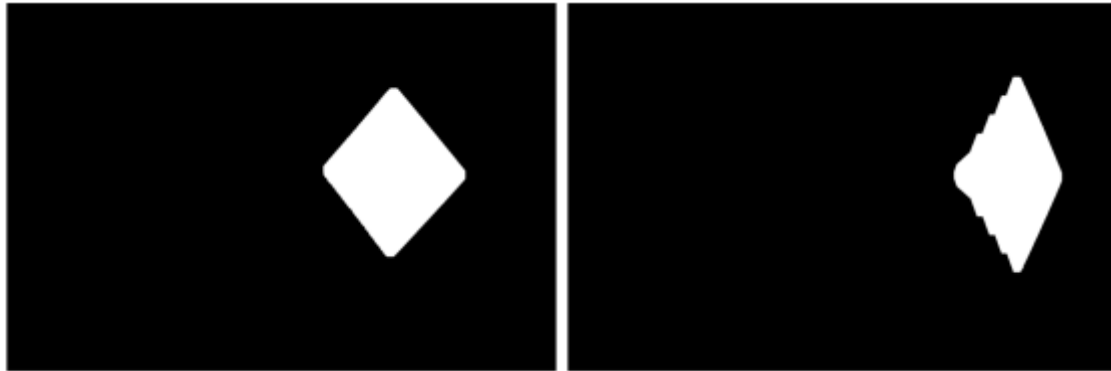
The point at which the two cast rays meet is taken as an initial estimate of the **location of the object**.



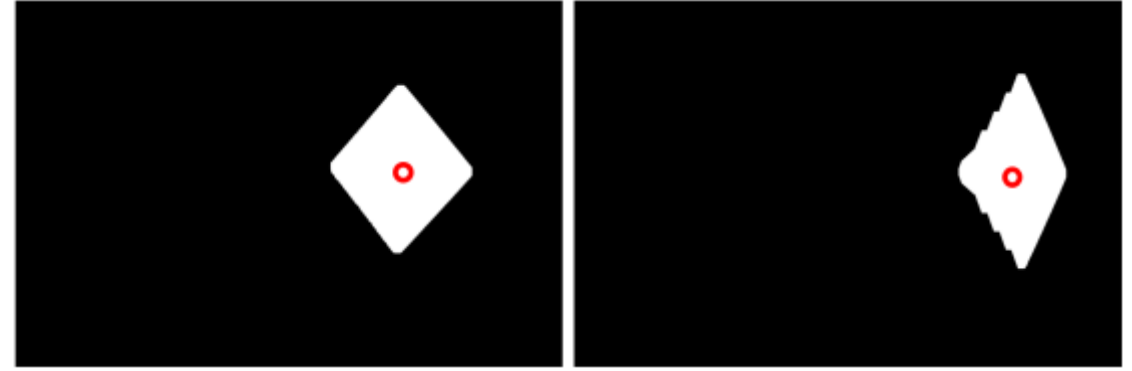
Stereo images: a pyramid artefact is captured from each camera



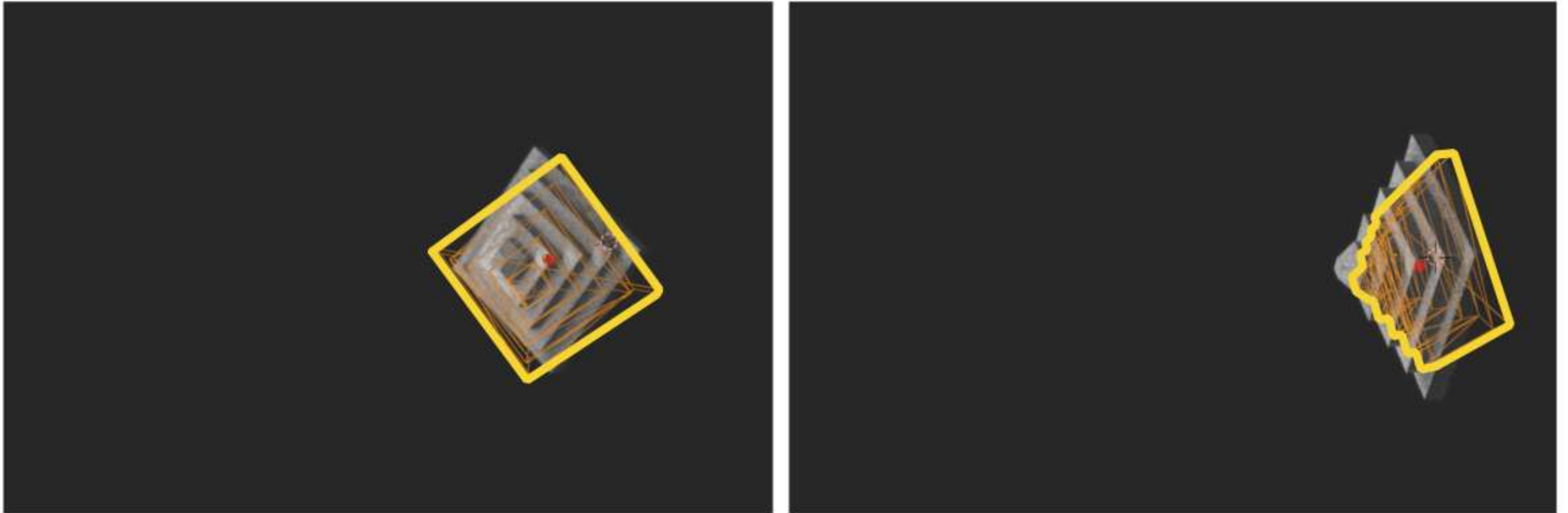
Background removal algorithm: to create a binary mask from each position



Binary mask: pixels on the object's surface are one and all other pixels zero.



Centroids: calculated by finding the average position of all the non-zero pixels

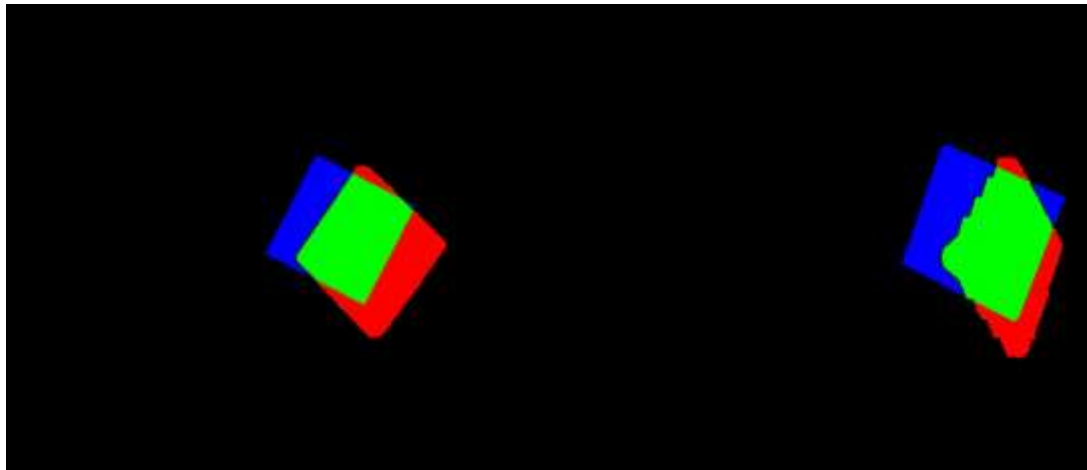


- **translation** of the CAD is close to the true location
- **rotation** less accurate as it has been randomised

- Binary mask is rendered using Blender and the camera parameters
- The six DoF is given by a translation vector and a rotation.

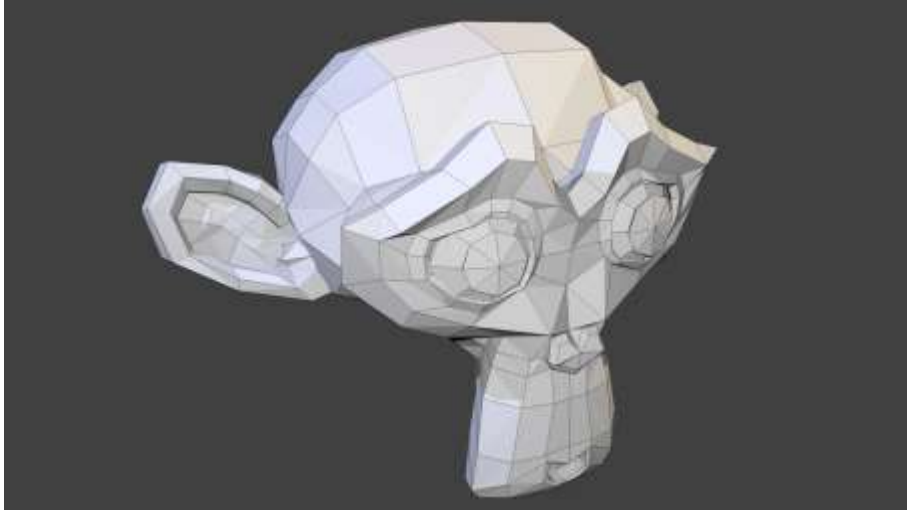
➤ Pose error

$$Loss = \sum \|real_{binary-mask} - predicted_{binary-mask}\|$$



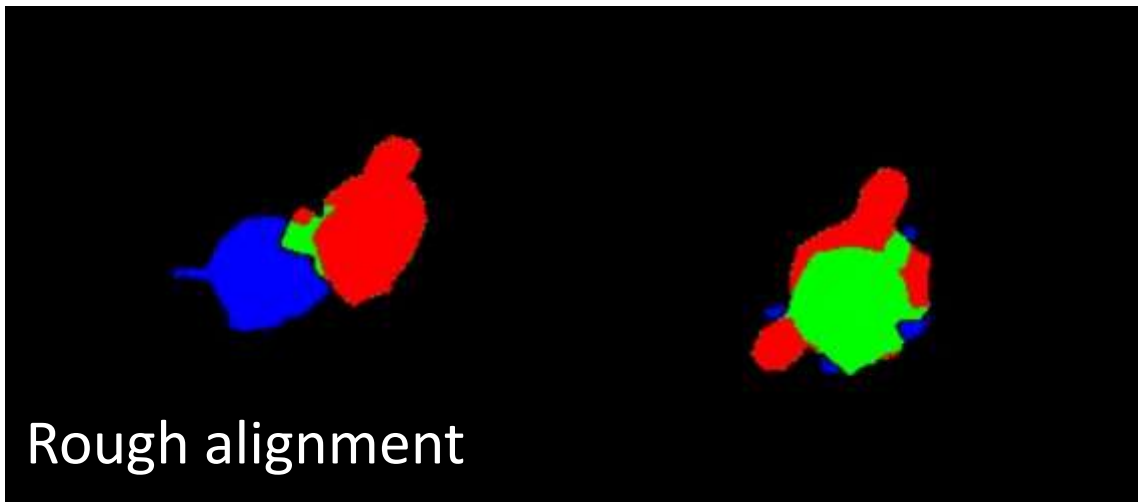
Green: Correctly classified pixels,
Blue: Misclassified background pixels
Red: Misclassified object pixels

- CAD pose minimisation: Powell's method and BFGS algorithm

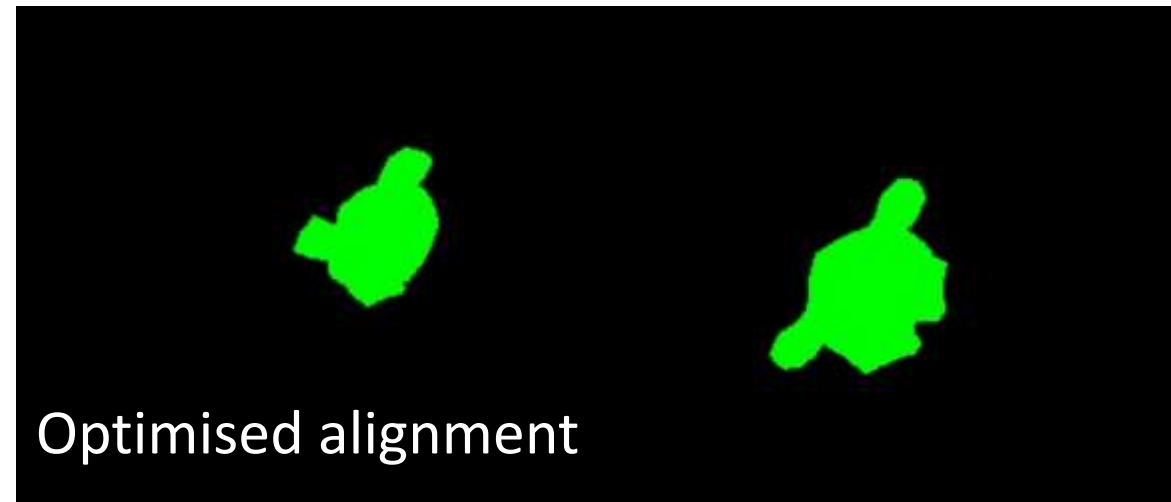


	Powell's method		BFGS	
	Mean	Std dev	Mean	Std dev
Loss /%	1.52	1.47	5.34	1.63
T residual /mm	0.18	0.39	2.75	2.61
R residual /rads	1.90	1.38	1.86	1.87
Time /s	165.38	33.07	75.40	44.94

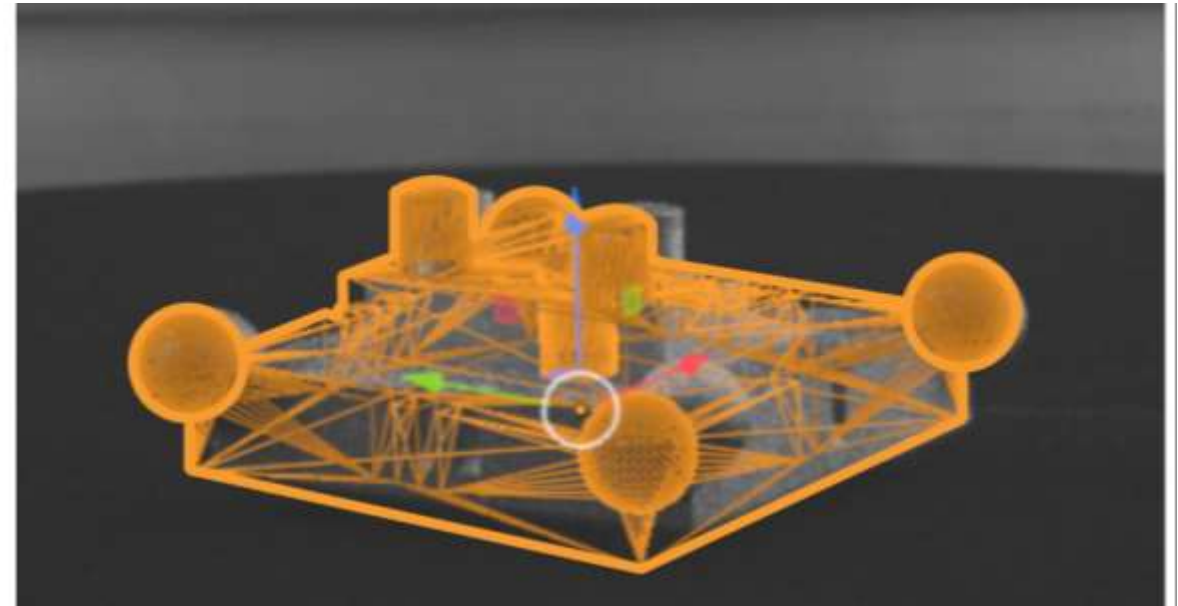
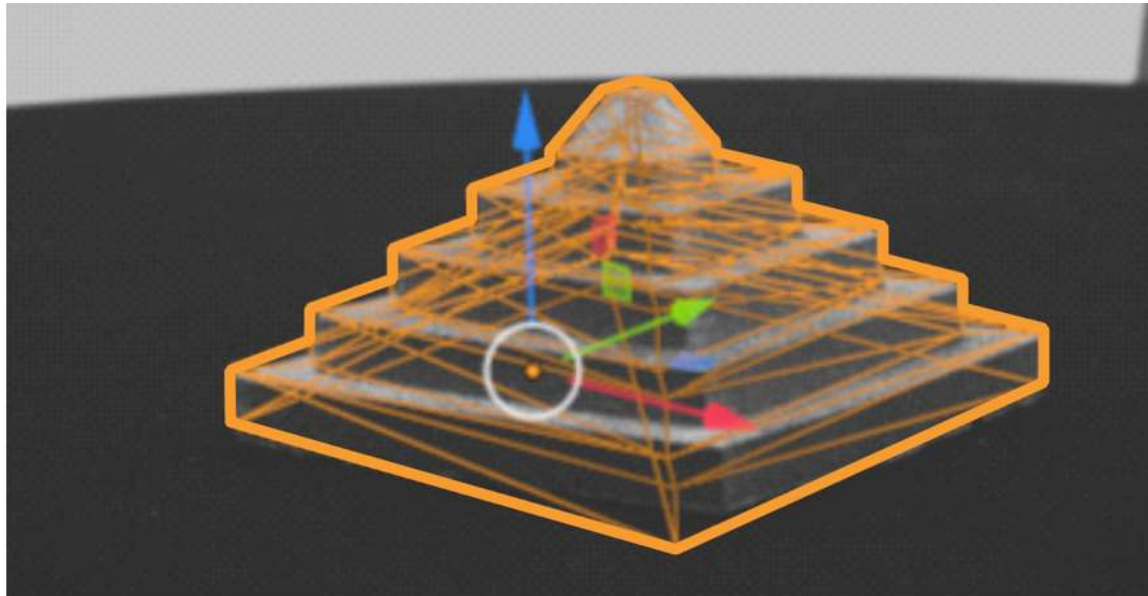
Blender "Suzanne" mesh



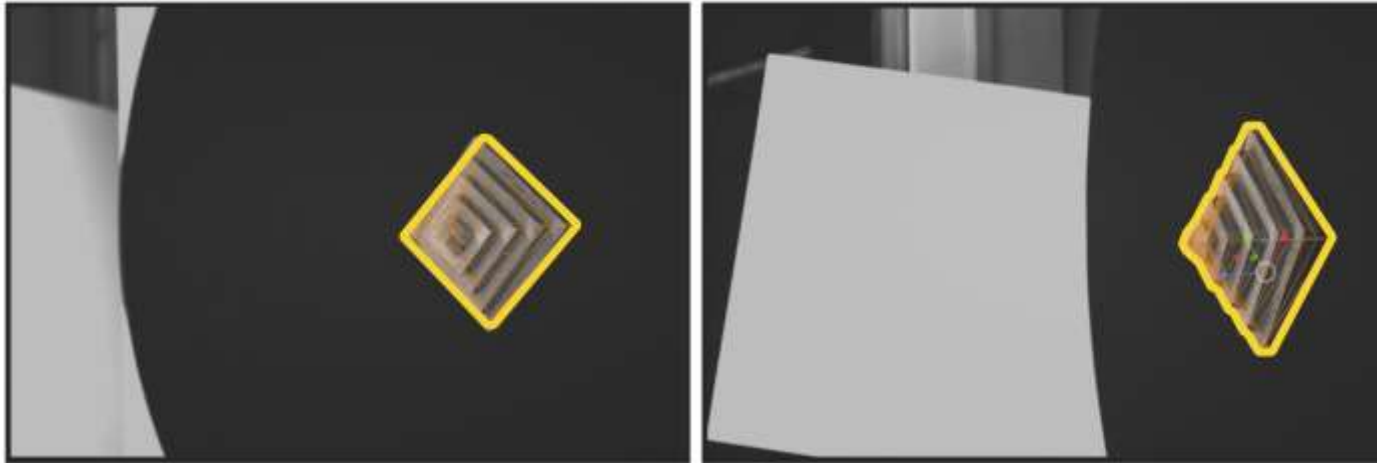
Rough alignment



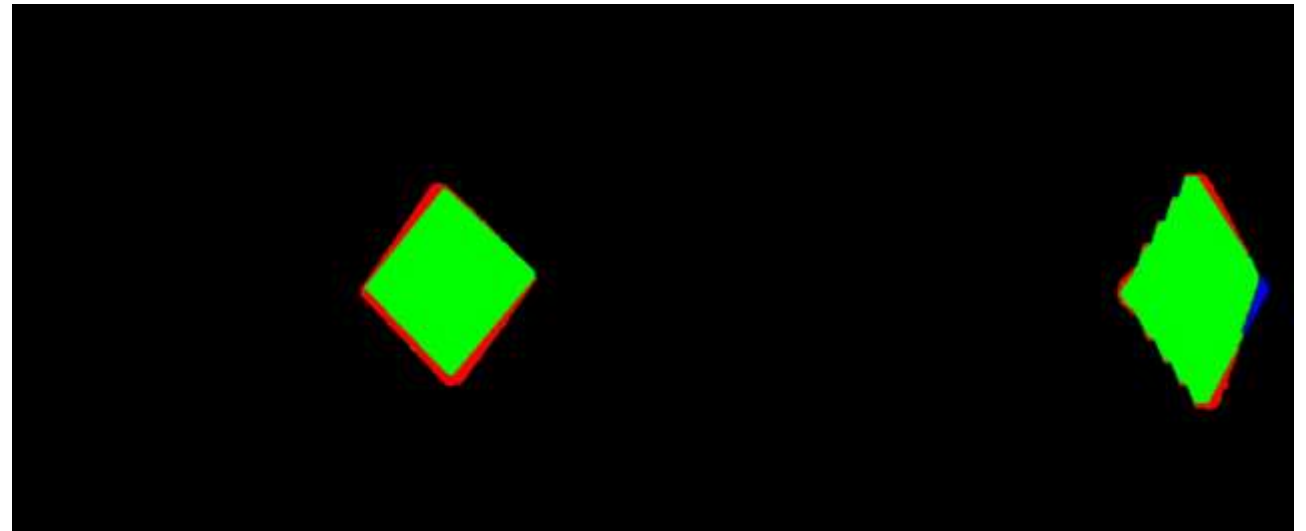
Optimised alignment



	RMS errors			Mean Residuals		Mean final loss /%	Mean optimisation time /s
	x /mm	y /mm	z /mm	T /mm	R /radians		
Pyramid	0.27	0.23	0.21	0.38	0.63	1.14	193.59
Tomas	0.38	0.22	0.17	0.44	2.13	1.55	155.00



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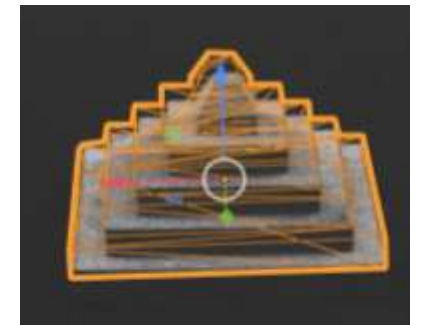
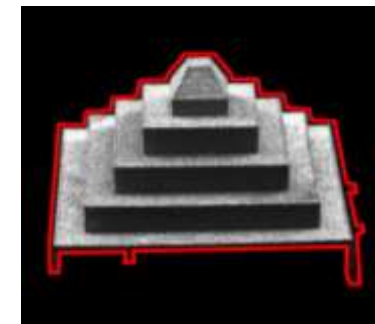


A method on **stereo pair of images** with a known baseline distance between the two cameras for pose estimation is proposed.

- The method accurately predicted the **translational position** of the artefact
- The optimisation on the synthetic data can reduce the loss function very close to zero, where for real data there is a **~1 % misclassification**.
- The oversizing of the real masks gives rise to the **imperfect matching**.

Future works

- Investigation of alternate loss functions
- improvements to the lighting conditions of the system
- generalisation of the stereo method onto multi-view systems





Research England



Joe Eastwood's PhD work



Talk S8:
Hernandez LedezmaUlises
"A closed-loop multi-system demonstrator for advanced optical measurement"

Poster 2:
Zhang Michael
"A novel method for point cloud-to-point cloud registration"