MANUFACTURING METROLOGY TEAM

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

A non-contact, information-rich, fast strategy for complex form measurement

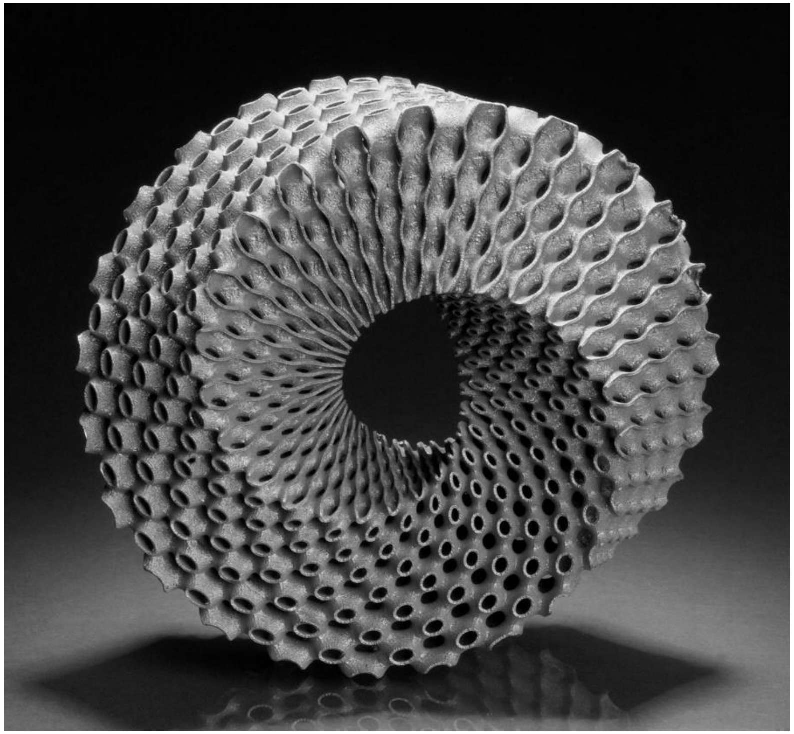
Petros Stavroulakis

Research fellow

Manufacturing Metrology Team, Faculty of Engineering

Our definition of 'complex' form measurement

Any measurement which involves freeform objects that contain a large number of occlusions, high slopes, voids and hence requires a lot of time for conventional equipment to obtain a complete measurement of the object's form.



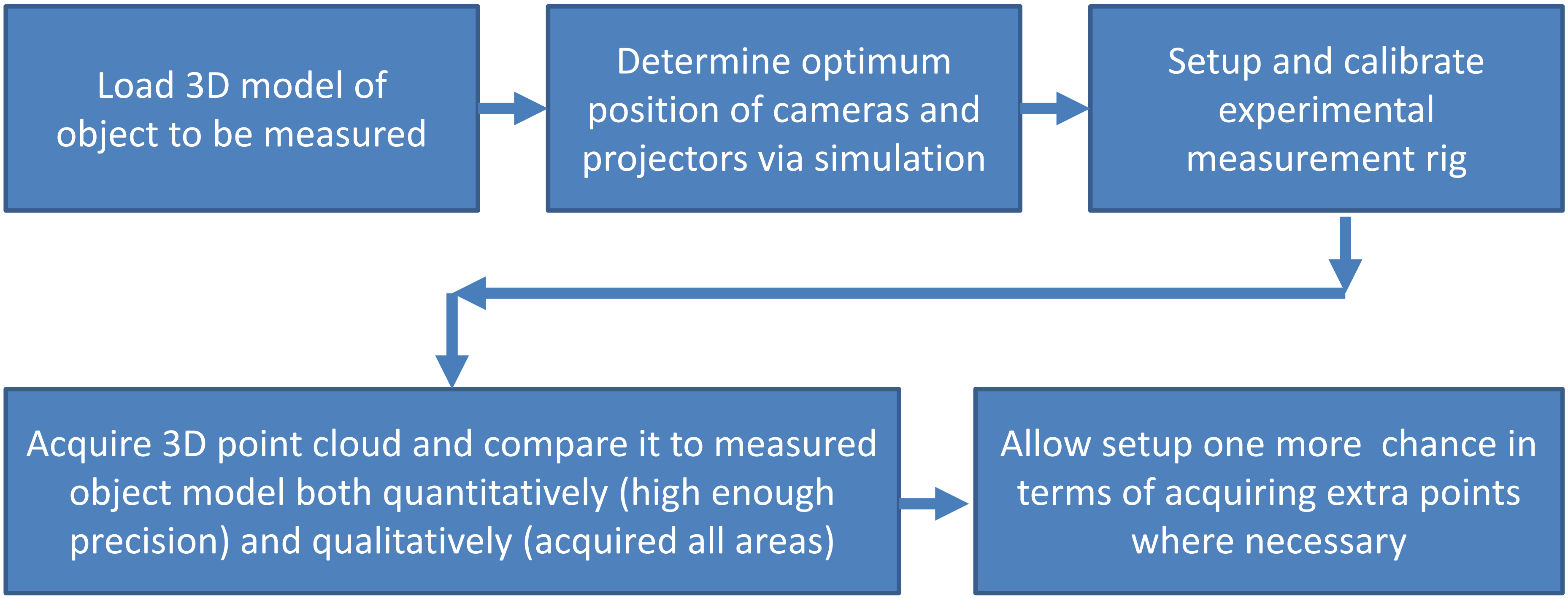
Typical solutions for complex form measurement

Strategy	Finishing time	Disadvantages
‘Dumb’ machine, expert user	Long, not completely predictable	Completion time and quality heavily dependant on user expertise and experience
Exhaustive machine, less expert user	Shorter, more predictable	Takes lots of redundant data
Optimized machine, novice user	Much faster, more variation in time required as it depends from algorithm efficiency	Cannot be used for objects which CAD data is non-existant

Fellowship Goals

- Demonstrate machine which can perform as near to one-shot 3D reconstruction as possible.
- To be efficienct, a flexible system is required which means frequent setup and calibration of the system is also required. This part of the measurement is sought to be accelerated close to real time, even done on the object itself in an automated fashion.
- Allow one more chance to ‘focus’ on areas which have not been successful before giving up.

Envisaged Measurement Pipeline

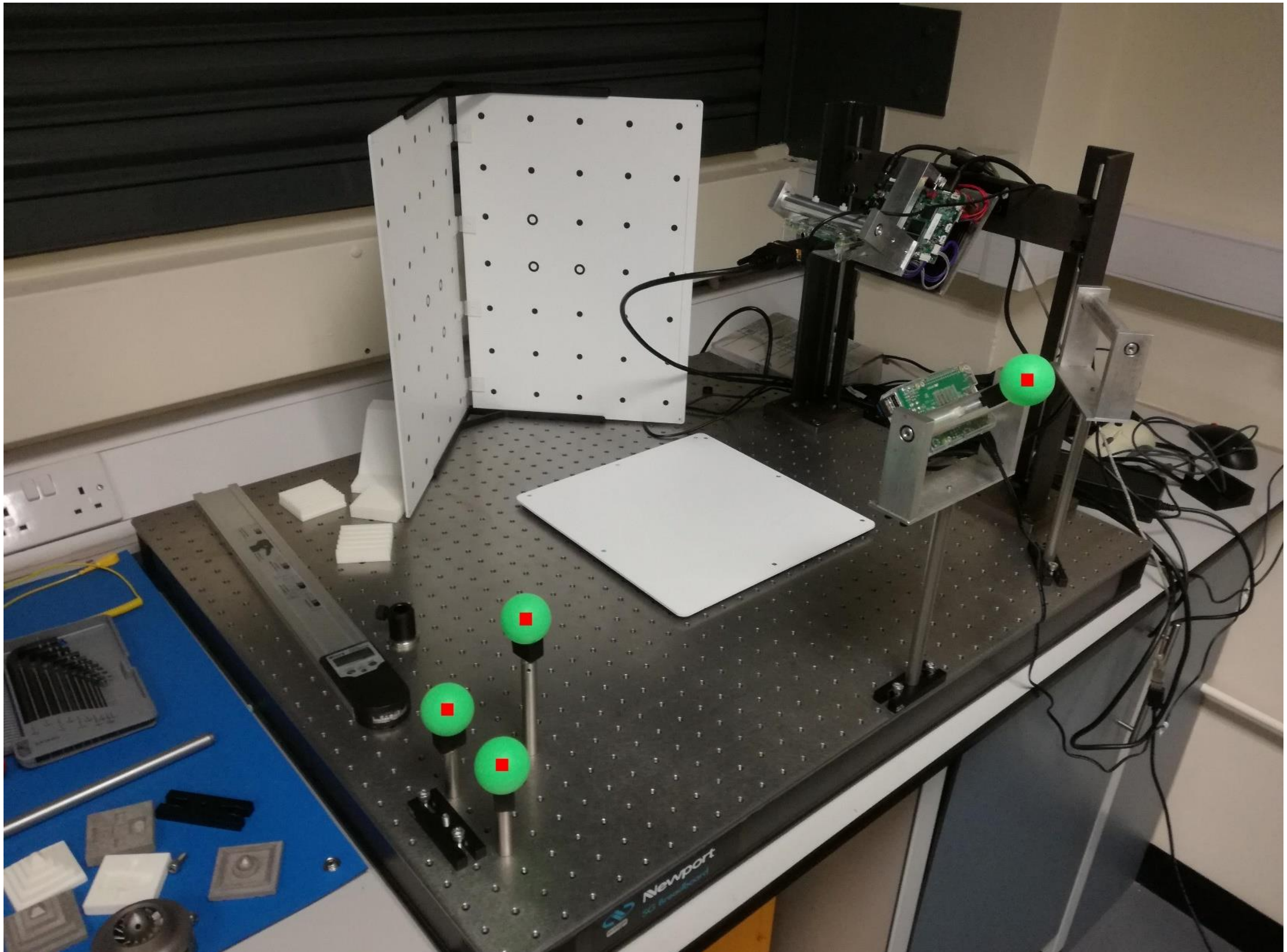


Status of AM form sub-group research streams

Priority	A priori knowledge that could be included in the measurement	Information Rich Metrology strategy employed
1	Use of position sensors and CAD data	Acquire information which would lead to faster camera and projector calibration and localization.
2	Knowledge of high slopes	Use of adaptive fringe patterns
3	Calculate next best view	Optimise camera viewpoints to fill-in gaps in scan using CAD model analysis
4	Know minimum set of camera positions required	One-shot complete point cloud for specific objects is achievable
5	Occlusion analysis	Combination of multiple views to ‘see behind’ occlusion
6	AM process characterisation	Mitigate effect of fine surface features due to AM process

And now for some results…

Self-calibration: Automatic localisation and tracking of 'flexible' setup



Self-calibration: Automatic object pose estimation using trained A.I. network

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Azimuth: 7.5°
Elevation: 30°

Azimuth classification results:

A

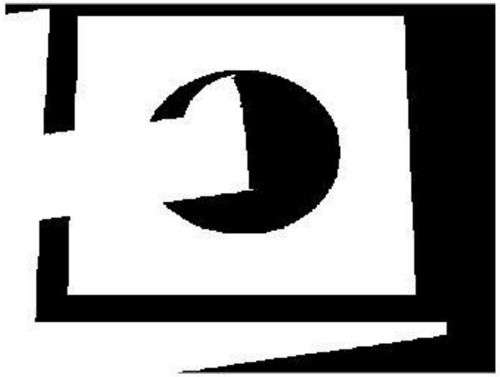
1st guess: A
0°-15°

2nd guess: M
165°-180°

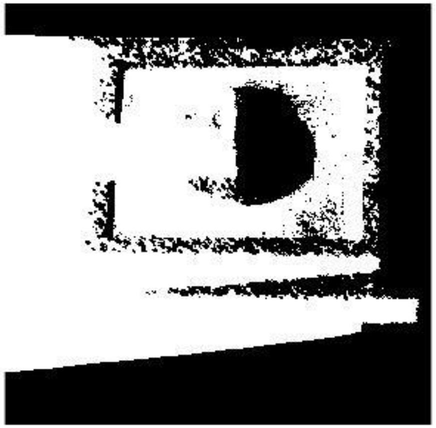
B C D ... V W X

Live rendering: matching binary thresholded images of image shadow to infer light direction

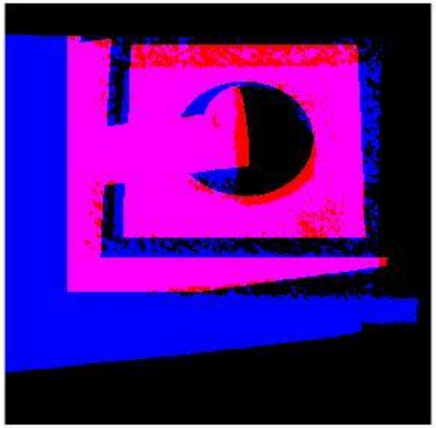
Cropped version of best match (Sim. No. 10)



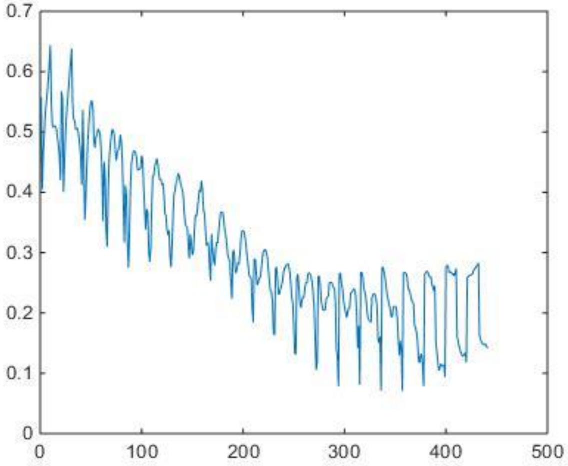
Binary mask of image shadow



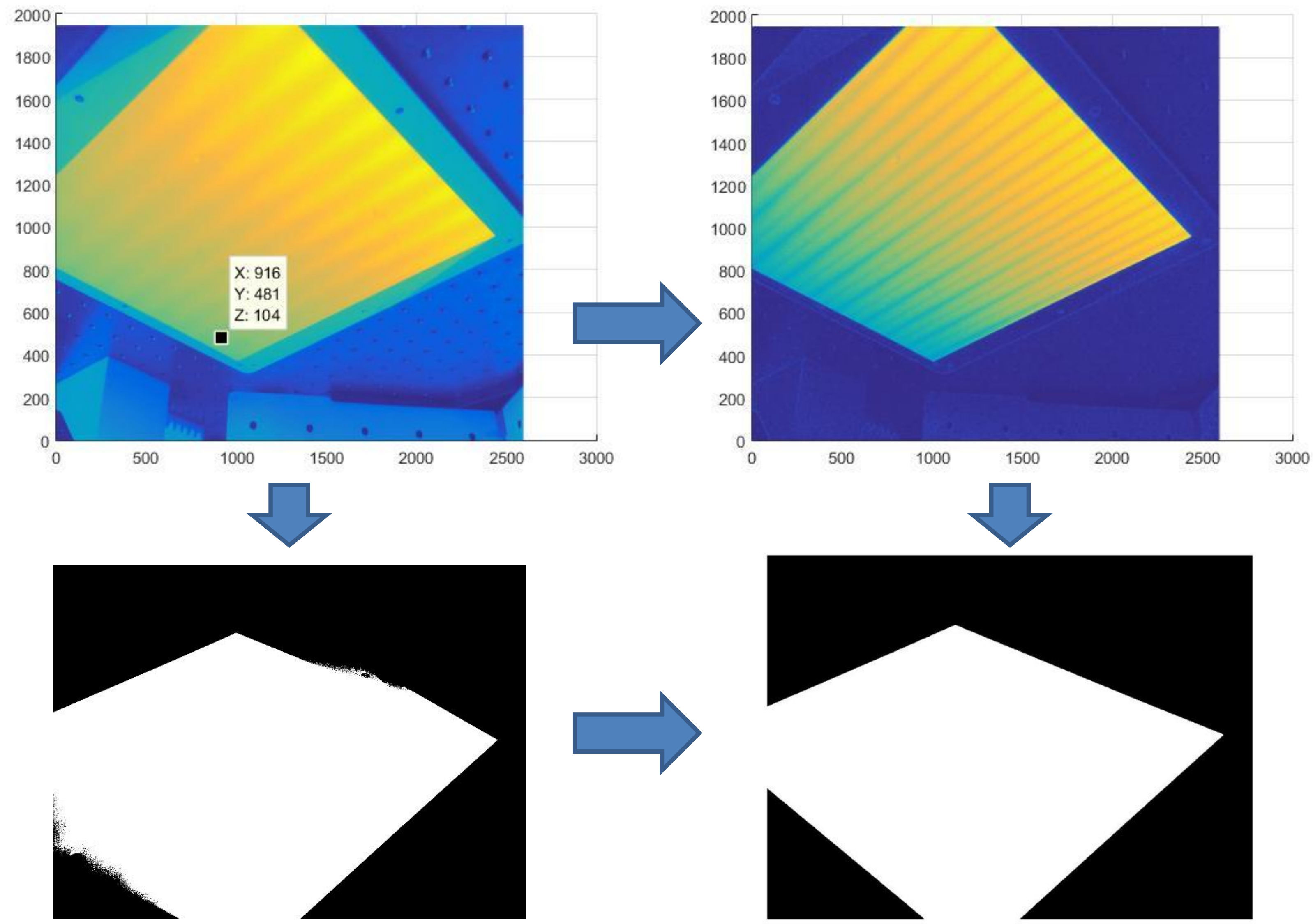
Match overlay



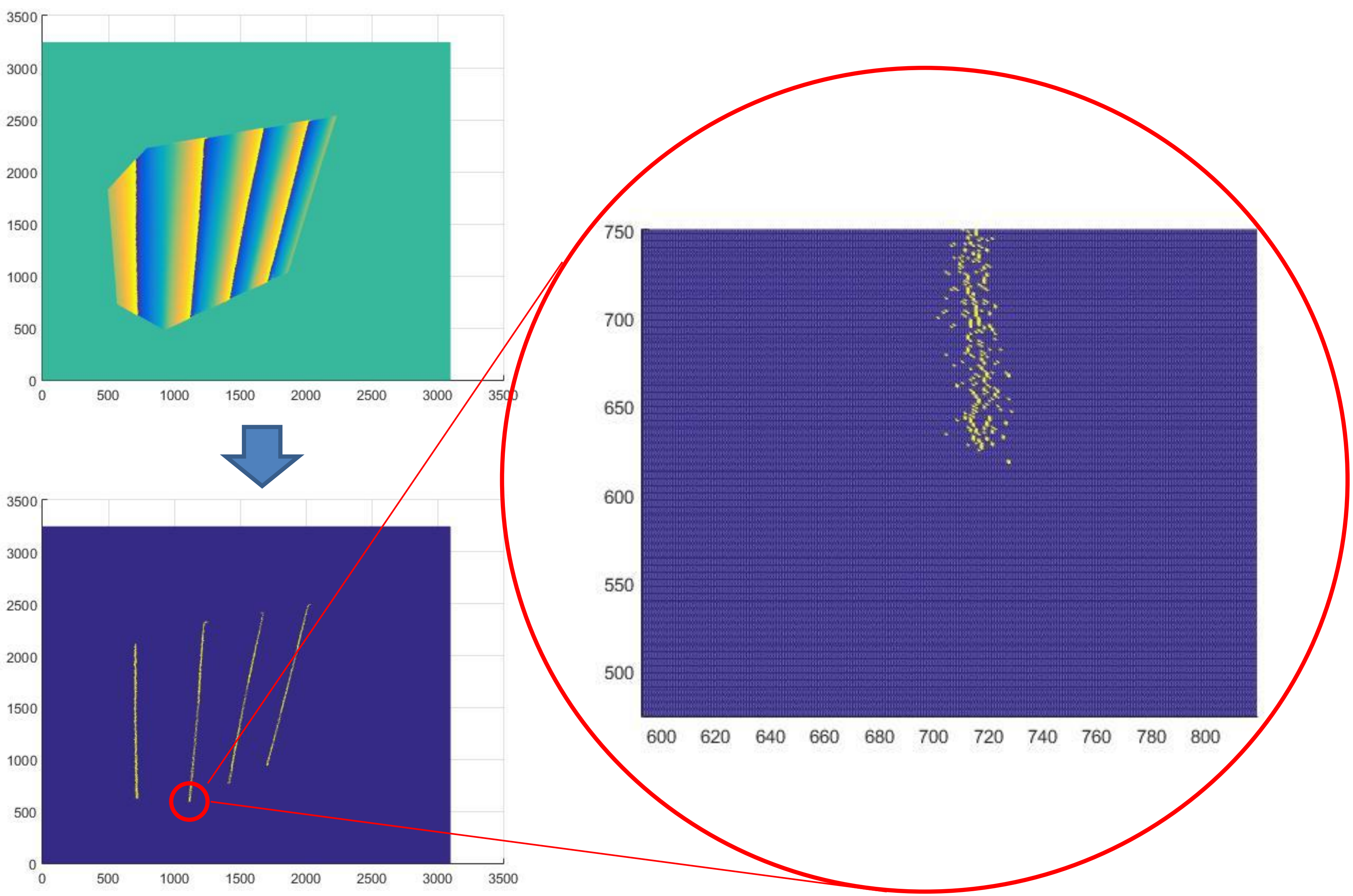
Cross correlation of all views at this scale



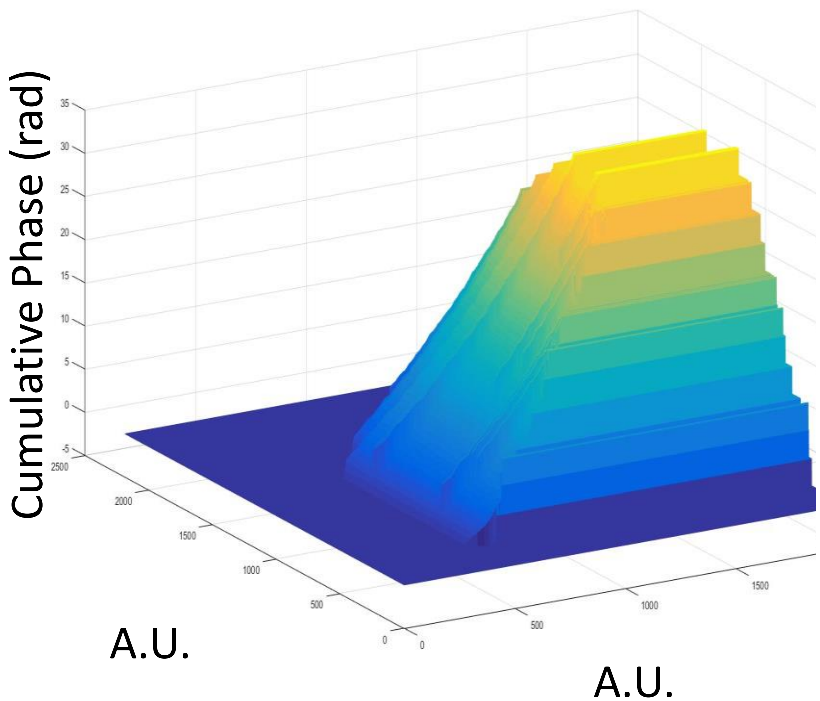
Reconstruction pipeline: Improvement in removing background and shadows

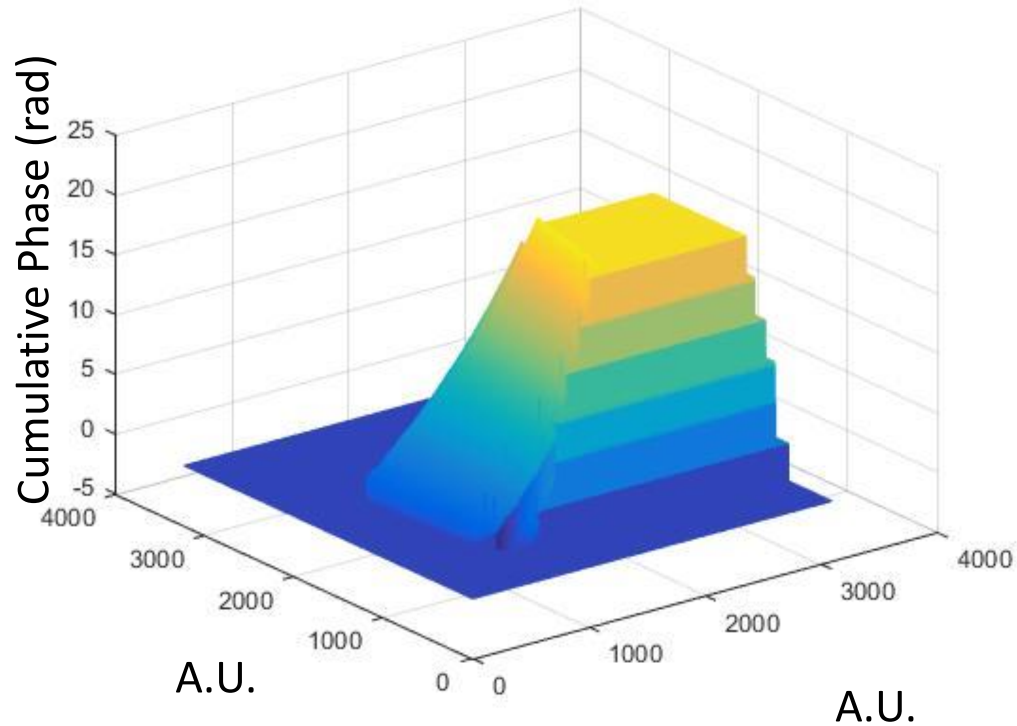


Reconstruction pipeline: Managing noise during unwrapping process



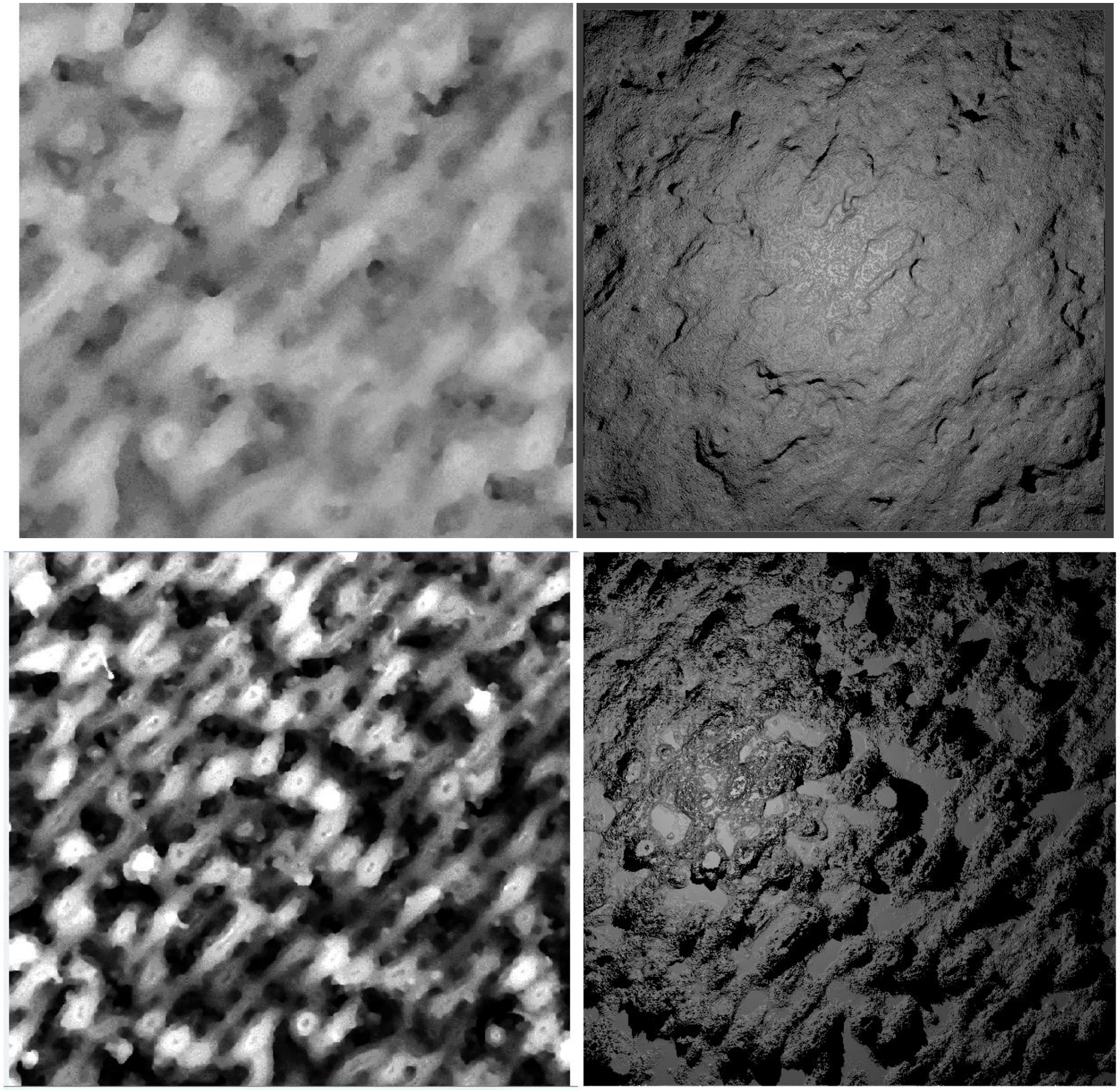
Reconstruction pipeline: Improvement of unwrapping on a flat plane





Realistic ‘live’ object rendering: Reproducing texture of AM process

Measured height map | Rendered texture



Realistic 'live' object rendering:

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Before AM texturization

After application of AM texture