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Investigation of the compatibility of X-CT measurement data to surface topography analysis

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I. Introduction

In recent years X-CT metrology becomes more popular as a promising geometrical measurement technique. In comparison to traditional tactile and optical metrology techniques, X-CT has the unique advantage: it is a non-destructive method which can measure both the complete internal and external geometry without constraint. Although X-CT has a limitation on the measurement of surface texture due to limited resolution, it is qualified for that of most of additive processed surfaces, which are featured by high roughness surface texture comprising a number of topographical features, such as bumps, step markings and surface pores.

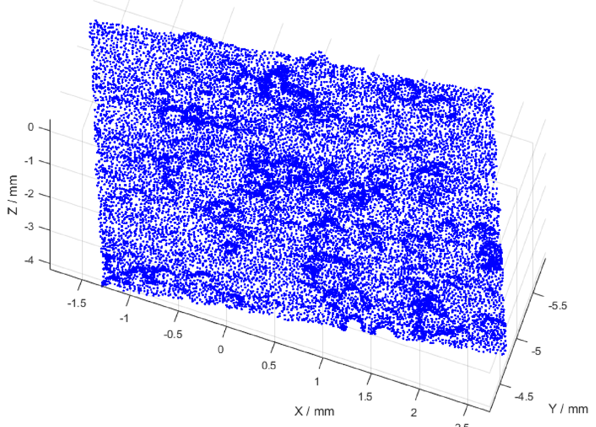
The X-CT generated data structures for the object surface, either point cloud or triangular mesh, differ from the grid structure of traditional surface measurement data. To enable X-CT data structures compatible with surface characterisation, two strategies are investigated. One is to interpolate scattered points into grid structure. The other is to perform surface analysis directly on triangular mesh.

II. Comparison of different data structures

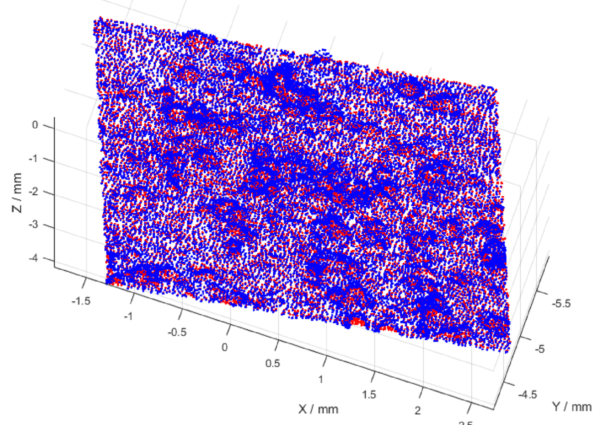
	Pros	Cons
Grid data	1. Default data structure for surface evaluation. All surface analysis software can support. 2. The connection of measured points is well defined.	1. Not straightforward available from CT. 2. They are specified by heights over the sampling plane, e.g. z = f(x, y). Not suitable for surfaces with complex geometry.
Triangular mesh	1. More general data structure. Specified by (x, y, z) and point connections. Suitable for surfaces with complex geometry. 2. Available from CT. 3. The connections of measured points are well defined.	1. No commercial surface analysis software support triangular mesh. 2. Not clear how triangular mesh is generated from point cloud by CT software.
Point cloud	1. Directly available from CT and most "reliable".	1. Raw data structure. Discrete points specified by (x, y, z) without connection. 2. Estimate where the surface is. 3. Surface analysis software does not support point cloud.

III. Strategy A: point cloud to uniform grid

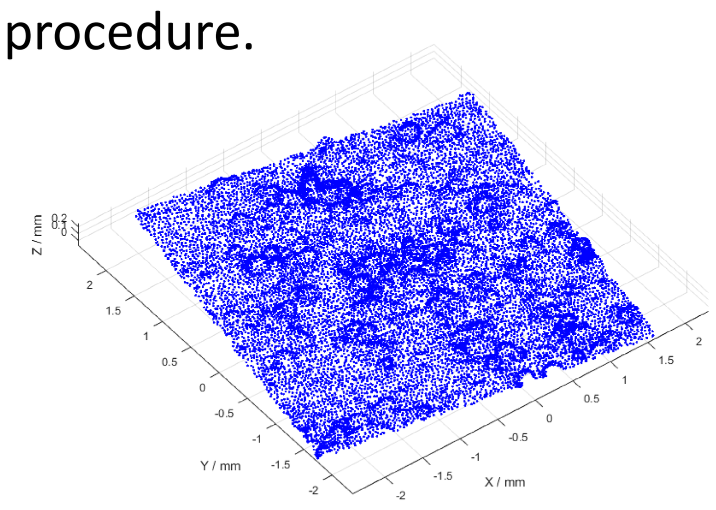
Point cloud is interpolated into grid data and thereafter conventional surface analysis techniques are applicable. This is suitable for surface data having nearly planar form. The following example illustrates the conversion procedure.



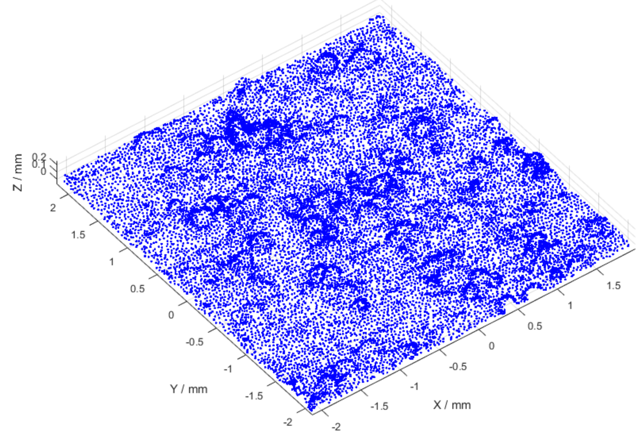
X-CT extracted point cloud from an AM part



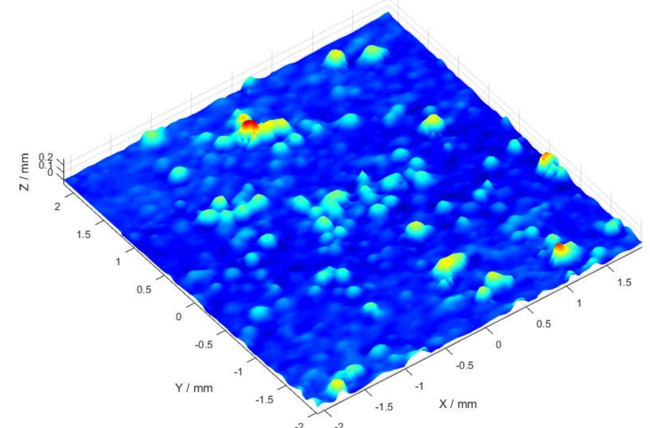
Orthogonal least square plane



Levelled point cloud

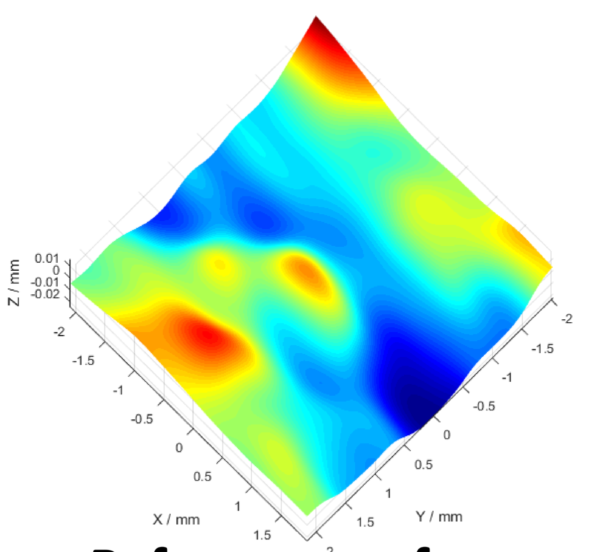


Positioned point cloud

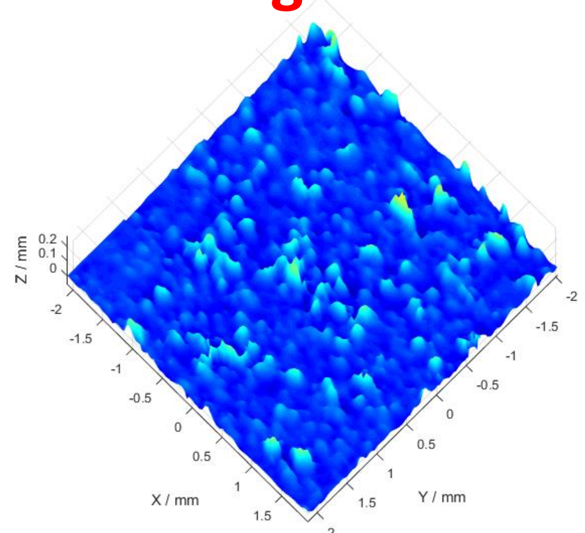


Grid surface obtained by cubic interpolation

Gaussian filtration – Surface roughness



Reference surface

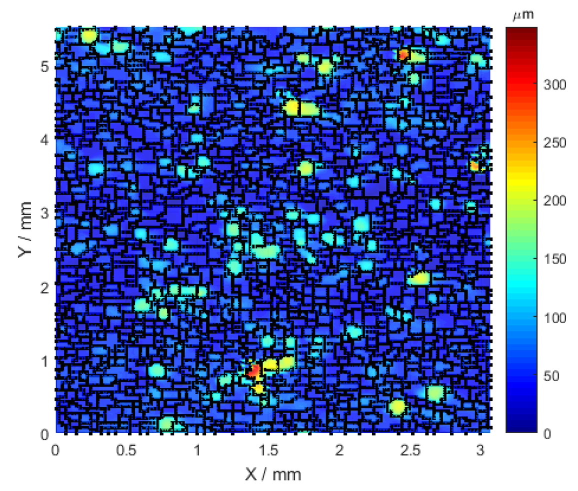


Roughness surface

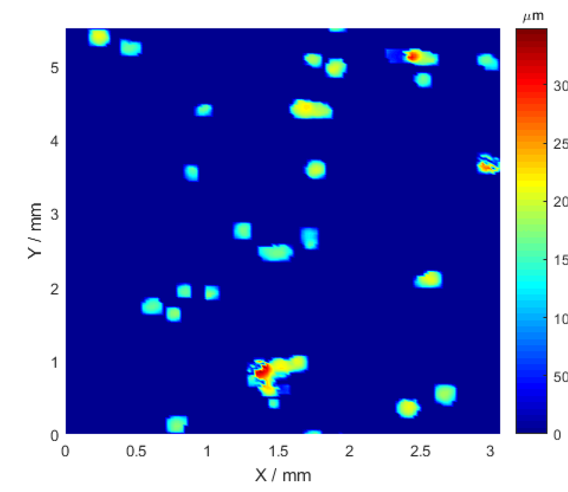
λcx: 0.8 µm
λcy: 0.8 µm

Sa: 20.7µm
Sq: 31.6 µm

Segmentation – Surface topographical feature analysis



Surface segmentation



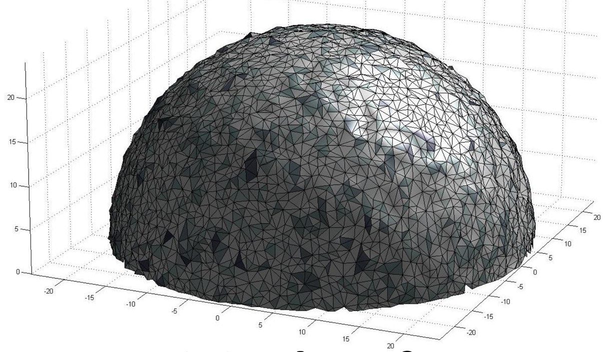
Extracted unmolten particle bumps

Threshold
Height: 140 µm
Underlying surface
Sa: 12.9 um
Sq: 17.7 um
Particle bumps
Area: 0.606 mm^2
Percentage: 3.6%
Volume: 0.018 mm^3

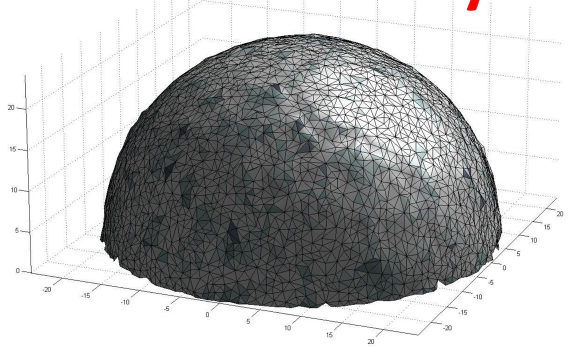
IV. Strategy B: triangular mesh

Triangular mesh is suitable for describing surfaces in complex shapes. A toolbox is under development for supporting surface analysis on triangular mesh, including PDE based Gaussian filter, morphological filter, wavelet filter, segmentation and parameterization.

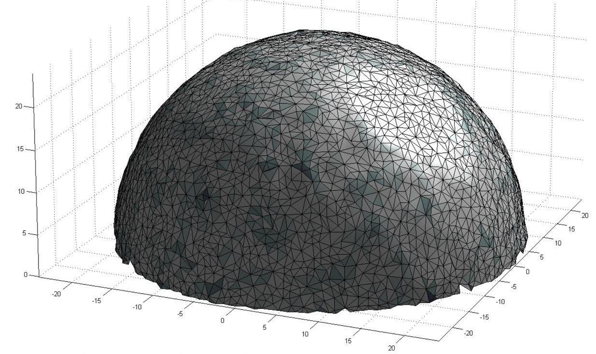
Wavelet filtration – Multi-resolution analysis



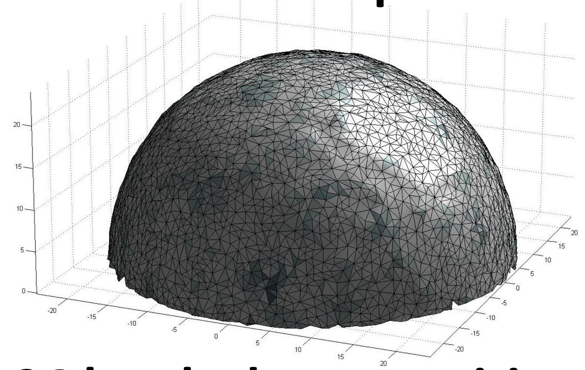
Original surface



6 levels decomposition

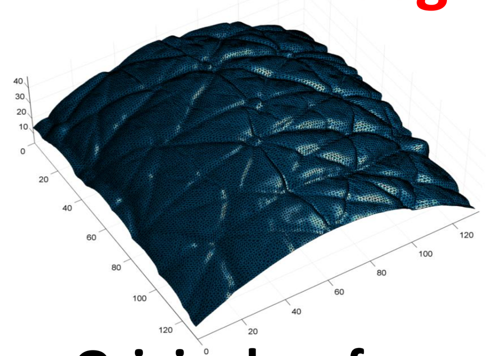


12 levels decomposition

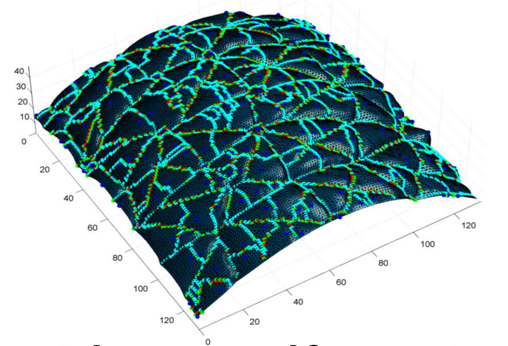


24 levels decomposition

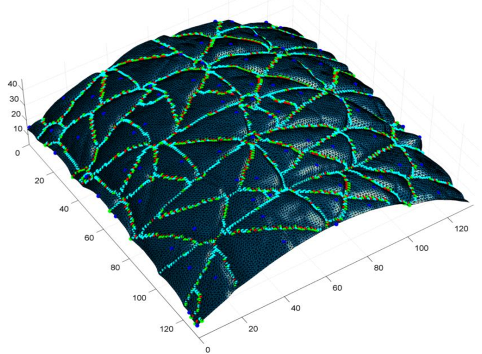
Segmentation



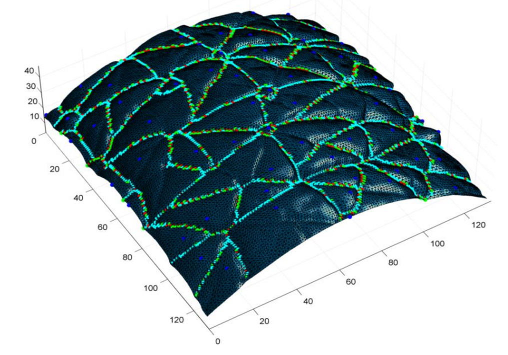
Original surface



Without wolf-pruning

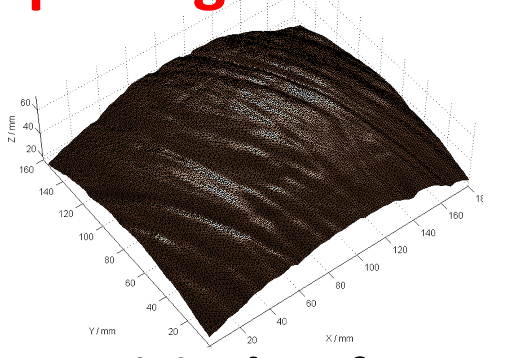


5% wolf-pruning

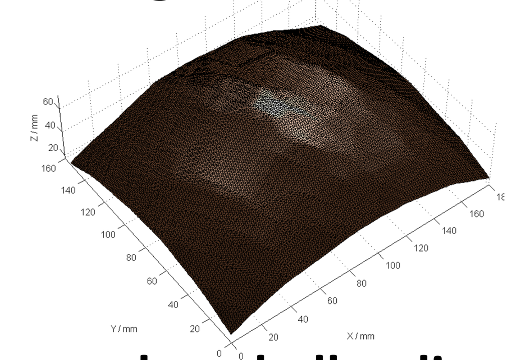


10% wolf-pruning

Morphological filtration



Original surface



Closing envelope ball radius 250 mm

V. Conclusion & Future work

Two data structures, i.e. surface point cloud and triangular mesh, provided by X-CT are not straightforward compatible to conventional surface analysis techniques. To enable that, point cloud needs to be interpolated into grid structure, or surface analysis techniques enhanced to support triangular mesh. Grid interpolation is a faster and easier way but its usage can be limited. The point connection of triangular mesh can better determine the surface especially in case of complex geometry, therefore it is more capable but challenging.

Further work is to explore feasible ways to bridge X-CT metrology and surface metrology. The development of surface analysis and parameterisation tools for triangular mesh will be focused.

VI. Acknowledgement

S Lou would like to thank the NPL X-CT measurement experts Wenjuan Sun and Stephen Brown for fruitful discussion and valuable suggestion.

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