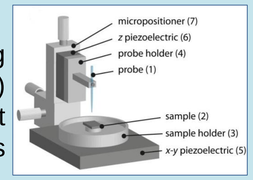
Application of Digital Image Inpainting in Electrochemical Scanning Probe Microscopy

Elena Kochkina[1], Kim McKelvey[2], Patrick Unwin[2]

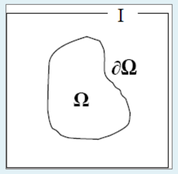
[1] Centre for Complexity Science, University of Warwick, [2] Department of Chemistry, University of Warwick

Introduction



- Electrochemical Scanning Probe Microscopy (EC-SPM) is a branch of microscopy that forms images of surfaces using a physical probe, containing electrode that scans the specimen by monitoring the chemical environment adjacent to a sample.
- Probe has different interaction modes with the specimen. Each type has its own drawbacks when acquiring data, such as low speed, sparseness, non-gridded data pattern. Appearance of artefacts is also possible.
- Therefore we try to enhance the quality of the scans, restore process on the whole surface on the basis of available data by using image reconstruction techniques, namely PDE-based inpainting.

Methods



The image I, the region Ω to be inpainted and its boundaries $\partial\Omega$.

Before applying inpainting algorithm data undergoes preprocessing such as filtering and regridding.

Linear interpolation (IDW)

$$Y = \frac{\sum_I (X/D^p)}{\sum_I (1/D^p)}$$

Heat equation inpainting

$$\frac{\partial^2 \Omega}{\partial x^2} + \frac{\partial^2 \Omega}{\partial y^2} = 0$$

Bertalmio inpainting

$$I^{n+1} = I^n(i,j) + \Delta t I_t^n(i,j), \forall (i,j) \in \Omega,$$

$$I_t^n(i,j) = \overrightarrow{\partial L^n(i,j)} \cdot \overrightarrow{N^n(i,j)},$$

where N is an isophote direction; L is Laplacian.

Perona – Malik inpainting

$$I_t = div(c(x,y,t)\nabla I) = c(x,y,t)\Delta I + \nabla c \cdot \nabla I,$$

$$c(x,y,t) = g(\|\nabla I(x,y,t)\|)$$

Results

Hopping mode

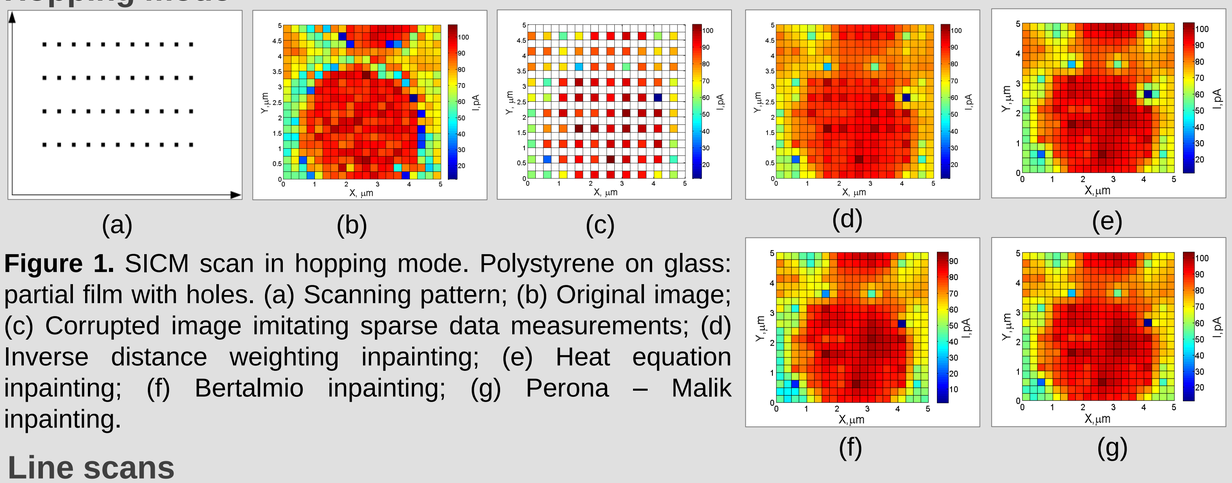


Figure 1. SICM scan in hopping mode. Polystyrene on glass: partial film with holes. (a) Scanning pattern; (b) Original image; (c) Corrupted image imitating sparse data measurements; (d) Inverse distance weighting inpainting; (e) Heat equation inpainting; (f) Bertalmio inpainting; (g) Perona – Malik inpainting.

Line scans

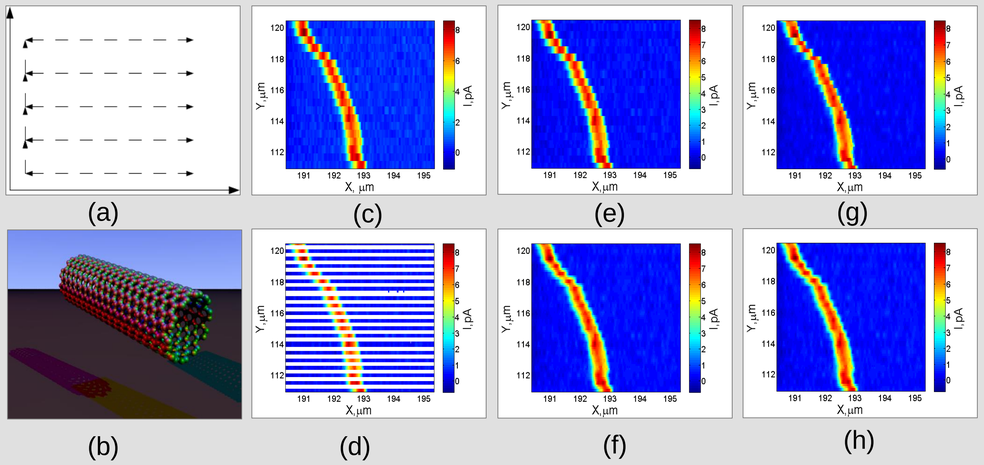


Figure 2. SECCM line scan of a carbon nanotube. (a) Scanning pattern; (b) Scheme of a CNT; (c) Original image; (d) Image with gaps; (e) IDW inpainting; (f) Heat equation inpainting; (g) Bertalmio inpainting; (h) Perona – Malik inpainting.

Spiral scans

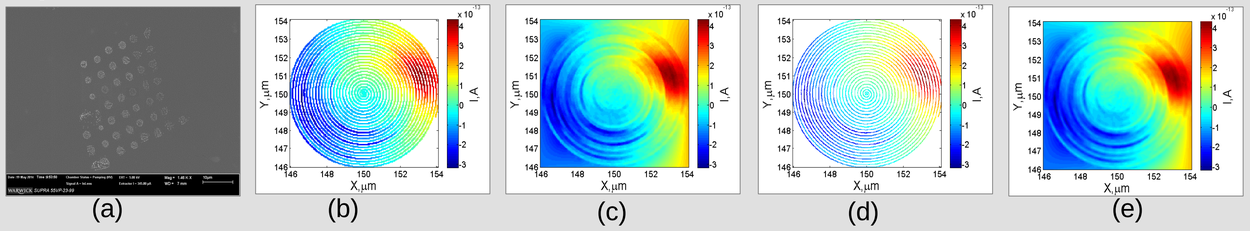


Figure 3. (a) FESEM scan of deposition of Pt nanoparticles on HOPG; (b) Image with gaps, grid size 400; (c) Heat equation inpainting for (b); (d) Image with gaps, grid size 800; (e) Heat equation inpainting for (d). Data for (b-e) via SICM spiral scan.

3D inpainting

Possibility for reconstruction of dynamic evolution of surface processes was investigated using a combination of the fast scanning technique data and inpainting in 3 dimensions.

Conclusions and Further Research

- Inpainting techniques can represent a solution in several scenarios common for microscopy imaging, such as the presence of artifacts, and acquisition impossibility for particular sample regions.
- Heat equation inpainting is the favoured choice of inpainting algorithm, based on accuracy and overall performance, high speed and absence of parameters.
- The quality of the results depends on choosing an optimal value for the grid size.
- The ability to preserve edges over larger gaps needs to be improved through further work.

References

1) Ziegler D. et al. Improved accuracy and speed in scanning probe microscopy by image reconstruction from non-gridded position sensor data, 2013.

2) Bertalmio M. et al. Image inpainting, 2000.

3) Perona P., Malik J. Scale-space and edge detection using anisotropic diffusion, 1990.

centre for complexity science

THE UNIVERSITY OF WARWICK

Erasmus Mundus

Contact Information E.Kochkina@warwick.ac.uk