Generating 3-dimensional images of pollen grains from their scattering patterns using deep learning

James A. Grant-Jacob*, Matthew Praeger, Robert W. Eason and Ben Mills

Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK

*E-mail: Correspondence: J.A.Grant-Jacob@soton.ac.uk

Abstract

Pollen grains can be found in a variety of shapes (e.g., spheroidal), and range in geometrical size from a few microns to ~100 microns[1]. Healthwise, pollen can lead to hay fever, with individuals being susceptible to different types of pollen. Additionally, pollen can be an indicator of the state of the environment[2], with a pollen's hydration level, for example, affecting its morphology[3]. Therefore, being able to 3D image individual pollen grains throughout the country in real-time would be invaluable for both hay fever mitigation and for environmental scientists. For this, a small footprint, low-cost sensor would likely need to be developed. Here, we use lensless sensing[4] to produce scattering patterns of pollen grains, and then use a deep learning neural network[5] to transform these 2D scattering patterns into 3D reconstructed images of pollen grains. We illuminated pollen with a laser to obtain scattering patterns from different pollen grains within a laser beam focus. For each pollen grain, we also obtained 3D Z-stack images using a microscope. Since only one scattering pattern was obtained for each pollen grain, but 2D image slices vary within the 3D Z-stack, for a neural network to transform the same 2D scattering pattern into different 2D images, additional information is needed. Thus, the position in the Z-axis information was encoded into the scattering pattern image via values in the green and blue channels. 3D images of pollen were then constructed using a stack of 2D images that were generated by the neural network.

1 Halbritter, H. *Biotech. Histochem.* 73, 137–143 (1998)

2 Ejsmond, M. J. *et al. Ecosphere* 2, art117 (2011)

3 Pacini, E. *et al. Protoplasma* 228, 73–77 (2006)

4 Grant-Jacob, J. A. *et al. Environ. Res. Commun.* 2, 075005 (2020)

5 Isola, P. *et al.* in *2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)* 5967–5976 (IEEE, 2017)