Machine learning-based envelope extraction from downsampled coherence scanning interferometry signal data

Ruidong Xue, Helia Hooshmand, Mohammed Isa, Richard Leach

Manufacturing Metrology Team, Faculty of Engineering, University of Nottingham, UK

Ruidong.Xue@nottingham.ac.uk

Abstract

Coherence scanning interferometry (CSI) is a widely used optical technique for measuring surface topography. In CSI, surface heights are derived from a series of images that consist of three-dimensional fringe patterns. A common approach to obtaining the surface height map involves extracting an intensity envelope from the fringe patterns along the scanning direction of the CSI instrument. The interferometric nature of CSI makes the signal data highly sensitive to environmental noise and vibrations, posing a significant challenge to the efficiency and robustness of envelope-based reconstruction methods. This work explores a data-driven approach for envelope extraction that does not heavily depend on prior knowledge. We introduce a neural network designed to extract the intensity envelope from a downsampled, noisy simulated fringe pattern. We aim to improve robustness by reducing noise. Our experiments use simulated CSI signal data with modelled noise that varies randomly in each run. Figure 1(a) shows a simulated intensity map of a sinusoidal profile with an amplitude of 0.1 µm, a period of 5 µm, and a signal-to-noise ratio of 20 dB, where the mean wavelength of the light source is 0.63 µm. We compare the results obtained by our method with those derived from the Hilbert transform, a well-known model for envelope extraction from CSI signals. The signal data is sampled in 70 nm steps along the vertical axis. Our machine learning method allows us to use fewer points while still extracting complete signal envelopes. In the experiment, we used a downsampling step size of three, which improves measurement efficiency. Figure 1(b) shows a random original signal and the corresponding downsampled signal. Figure 1(c) illustrates a comparison between the original envelope used to simulate the intensity map, the envelope derived from the Hilbert transform using the original signal data, and the envelope obtained by the neural network using the downsampled signal. Our findings show that in noisy conditions, where the accuracy of the Hilbert transform decreases, our neural network model maintains high accuracy for envelope detection from downsampled data points, therefore, outperforming the Hilbert transform.

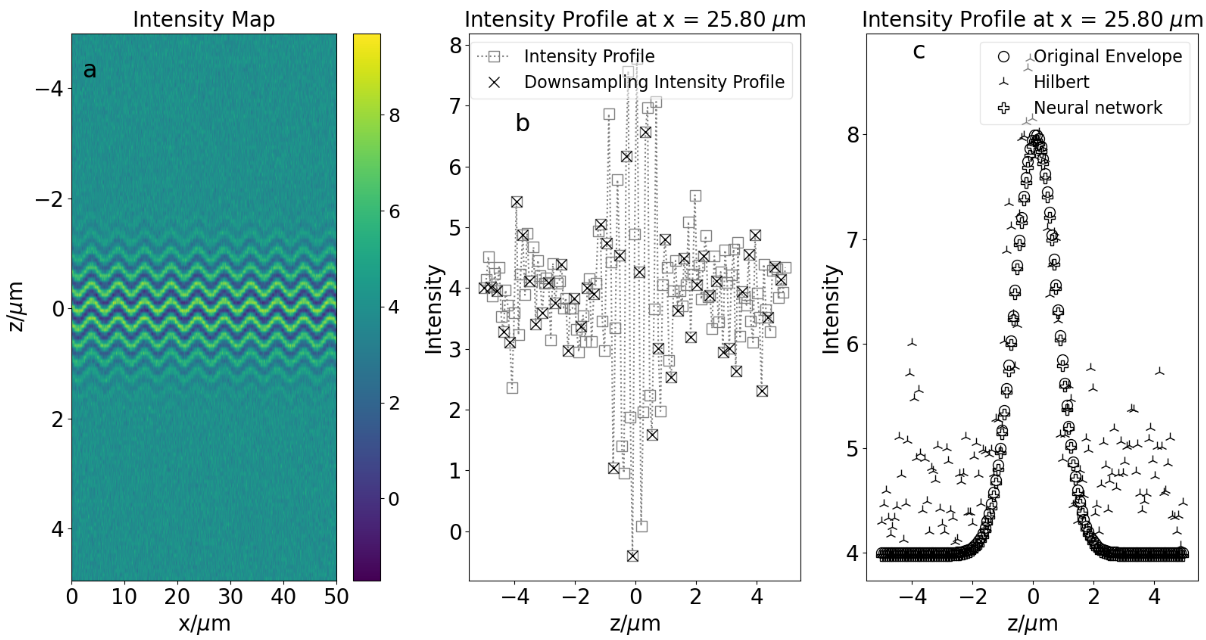

Figure 1: (a) Intensity map of a simulated sinusoidal profile with a length of 50 µm along the *x*-axis and a scanning length is 8 µm along the *z*-axis. The intensity map is simulated with added noise of 20 dB. (b) A randomly selected intensity signal at *x* = 25.8 µm. The number of original data points is 141; the number of downsampled data points is 47. (c) Comparison of the benchmark envelope compared with results obtained by the neural network and the Hilbert transform methods.

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