DOI: 10.1017/S1431927603443699
Microsc Microanal 9(Suppl 2), 2003

Particle Analysis Using Neural Networks And Image Processing In The SEM

NHM Caldwell, BC Breton, DM Holburn, and TCW Young

Department of Engineering, Cambridge University, Trumpington Street, Cambridge CB2 1PZ, UK

Automation of scientific instrumentation has steadily increased in recent years, with software support for human operators becoming available for scanning electron microscope operation and sample investigation. Recent SEM-related research and development at Cambridge University Engineering Department has focused on the application of knowledge-based techniques for instrument diagnosis and operation, particularly in the optimisation of microscope images [1,2]. Our current work is now shifting from optimisation of the SEM to understanding its results.

While image processing and analysis have been successful in many image classification problems, human expertise remains necessary in others for distinguishing specific features of interest. This expertise is difficult to translate into knowledge-based software as it is hard to verbalise – the expert recognises a particle by sight, but cannot easily describe what makes the particle so distinctive.

“Emergent” computational methods such as neural networks, however, “learn” how to classify a given input as a particular output through repeated training [3]. Initially a neural network is a topology of connected nodes such that the output from one node is fed into the inputs of many others with an identical weighting on each link. Example inputs are presented to the network, together with the desired outputs. The network then adjusts its internal parameters (such as connection weights) so that its calculated outputs become closer to the desired results. This “training” process is repeated until the network becomes an effective classifier – thereafter it should be capable of classifying hitherto unseen inputs correctly. Such image classifiers are conventionally used to extract image properties chosen by their designer and/or to classify an image based on predetermined properties.

In microscopy, there have been a number of very specialised applications of neural network techniques, ranging from identifying microfossils in sediment samples, fibreglass particles in lung tissue, distinguishing bird species from images of the interior surfaces of eggshells, to analysing wear particles deposited in lubricants from a variety of machines [4, 5, 6].

The aim of our research is to develop neural networks, which can themselves determine the most appropriate image properties and then classify the images by these properties, where the neural networks are sufficiently general to be applicable to a number of sample types. Particle analysis, initially of wear debris found in jet engine oil, was selected as the initial application area for investigation, with the MATLAB Neural Network Toolbox being chosen as the development platform for neural network design and implementation.

MATLAB’s Neural Network Toolbox has proven to be relatively easy to use to develop, train, and test neural networks. Images can be imported directly into the MATLAB workspace and supporting applications to create training data implemented as MATLAB scripts. As a simple test, an untrained backpropagation network was designed and used to classify gold particles on a gold-on-carbon test sample by examining the image in 5-by-5 pixel segments (see Fig.1). Particles in close proximity were distinguished by altering the training data to classify pixels near the edge of a particle as “not-particles", while adding the mean brightness value as a network input allowed dimmer particles to be located. Altering the square input window to a larger cross shape enabled larger particles to be detected more easily. In order to prevent multiple "hits" on the same large particle being counted as distinct particles, conventional image processing techniques were used to post-process the results, eroding the exterior pixels while simultaneously measuring and counting the particles. Using an 800Mhz Pentium-III PC with 128MB of RAM, the process located, counted, and measured all 1141 particles in a 600-by-600 image in 70 seconds.

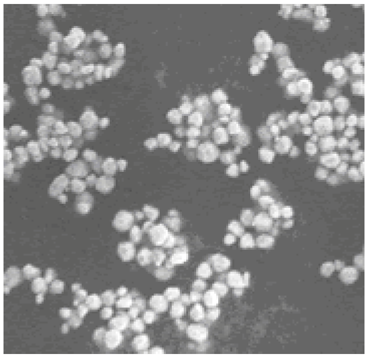

FIG.1. Au on C Test Image

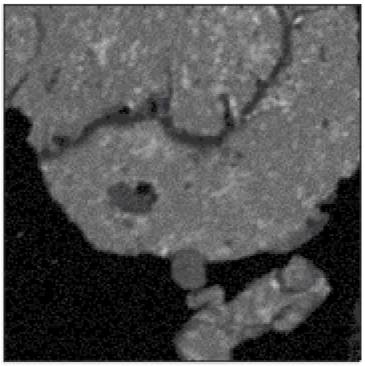

FIG. 2. Cracked Test Image

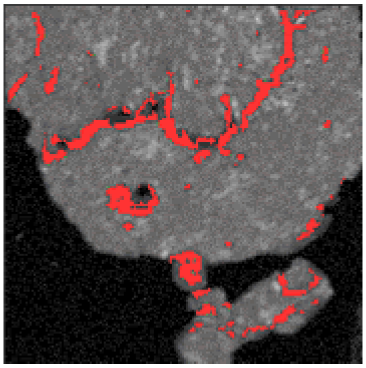

FIG. 3. Cracks Found

One criterion used to identify wear particles is whether or not they are cracked. A 3-layer neural network (8 inputs, 5 hidden, 1 output neuron) was trained to recognise cracks in particles using 5-by-5 pixels square sections, and then tested on a 150-by-150 image (see Fig. 2). The detector routines dismantled the image into the sections in 1 second and required a further 0.5 seconds to execute the network on every section. The results for a test image are shown in Fig. 3, where a red dot indicate a pixel that the neural network has classified as being at least 30% probable to be part of a crack. The system is very successful, even with such a low certainty threshold, and has few false positives. It is less successful at detecting very wide cracks owing to the limited size of its viewing window.

Ongoing work is concentrating on developing neural networks to determine other particle features with the aim of creating a library of routines, capable of classifying particles of interest along many dimensions, and potentially useful for a broader range of samples than wear debris specimens [7].

References

[1] N.H.M. Caldwell et al. Proc. 12th European Congress on Electron Microscopy (2000), 3, 411.
[2] N.H.M. Caldwell et al. *Microscoc. Microanal.* **7** (suppl. 2) (2001), 966.
[3] D.W. Patterson. Artificial Neural Networks Theory and Applications, Prentice Hall, Singapore 1996.
[4] O. Yanez-Suarez and M.R. Azimi-Sadjadi. Proc. International Conference on Image Processing (1997), Vol. 2, 438.
[5] I. ap Gwynn et al. Proc. 11th European Congress on Electron Microscopy (1996), Vol. 3, 495.
[6] B.J. Roylance et al. *Lubrication Engineering*, Vol. 50, 2 (1994), 111.

[7] NHM Caldwell and BC Breton would like to acknowledge the financial support of LEO Electron Microscopy Ltd. and the Isaac Newton Trust.