Application of a neural network based technique for track identification in Nuclear Track Detectors (NTD)

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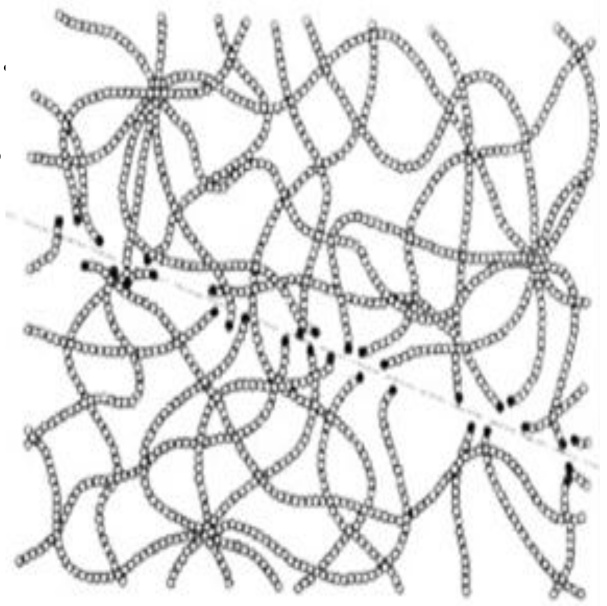
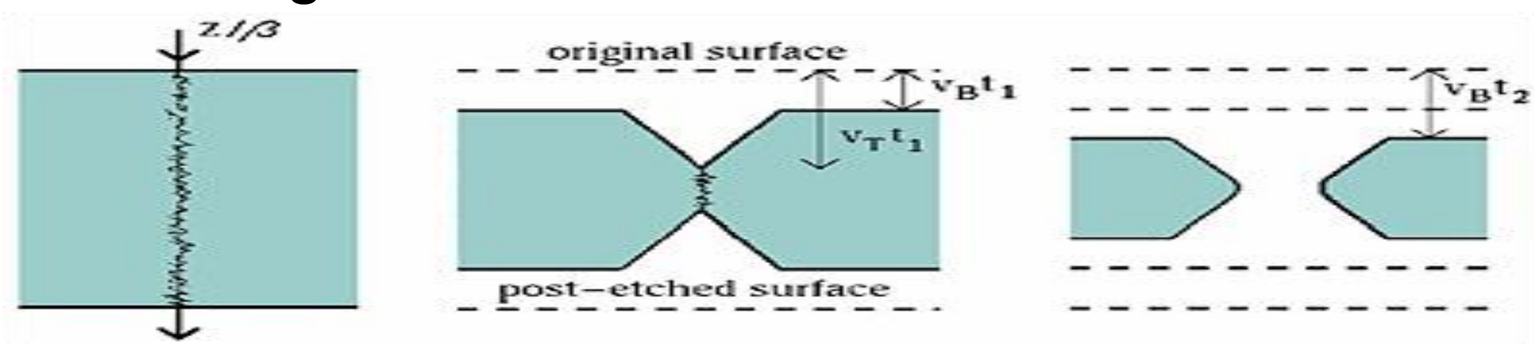
Nuclear track detectors (NTDs)

- NTDs (CR-39, Makrofol) are polymer films used as detectors of Highly Ionizing Particles (HIPs).
- Heavy Charged particles break polymer bonds and leave behind damage trails (latent tracks).
- Chemical etching with KOH solutions changes latent tracks into conical etch-pits (~10 μm).
- Study of etch-pit geometry under optical microscopes reveal vital information about particles forming tracks.



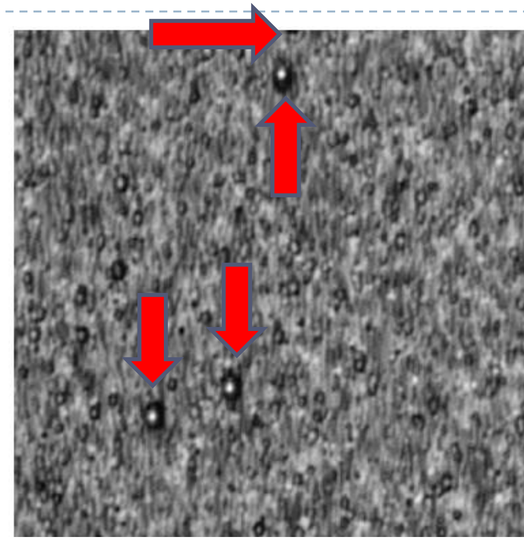


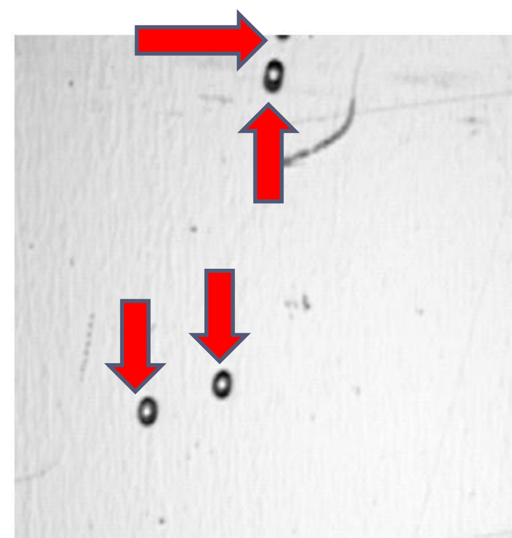
NTDs as detectors of rare events

- Existence of natural thresholds of registration eliminates much of the low-Z background.
- Great choice as detectors
  - in rare event e.g. monopoles, strangelets, Q-balls
  - search in cosmic rays e.g. SLIM
  - particle accelerators e.g. MoEDAL
- Passive nature
  - No power or readout electronics required.
  - Ideal for deployment in remote locations, like high mountain altitudes, balloons, space stations etc.

Challenges of scanning NTDs

- Locating particles tracks of interest on NTDs against background poses significant challenges.
- Background comes from defects in the plastic and the trails of other charged particles (neutron induced tracks, spallation products, radon alpha etc.).
- Current image analysis software using grey level discrimination, eccentricity cuts etc. are not up to the task.
- Painstaking work by human experts
- Error prone and time consuming



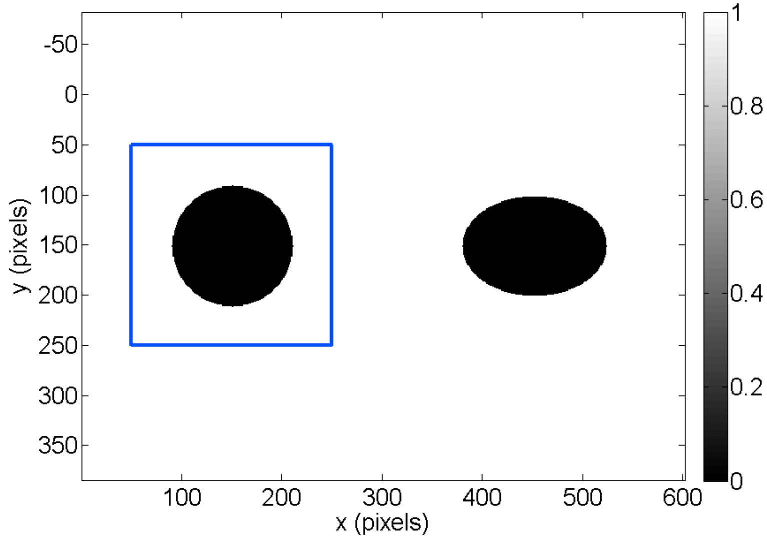


Proposed method – sequential deconvolution and convolution followed by ANN

- Step 1
  - Mask selection $M(x, y)$ using a suitable NTD track from objects $N(x, y)$ which is the image with NTDs
  - A gaussian mask $G(x, y)$ chosen for deconvolution with $N(x, y)$
  - Next, $M(x, y)$ is convolved with entire image which generates peak values at the centre of symmetric patterns depending upon their common area.
  - Manual threshold for separation of etch-pits from noises
- Step 2
  - Average of the image generated after deconv-conv and threshold are used for inputs to an artificial neural network (feed-forward)
  - Output produces predicted threshold after training, later applied to all other test images
  - Marking the actual etch-pits using morphological technique

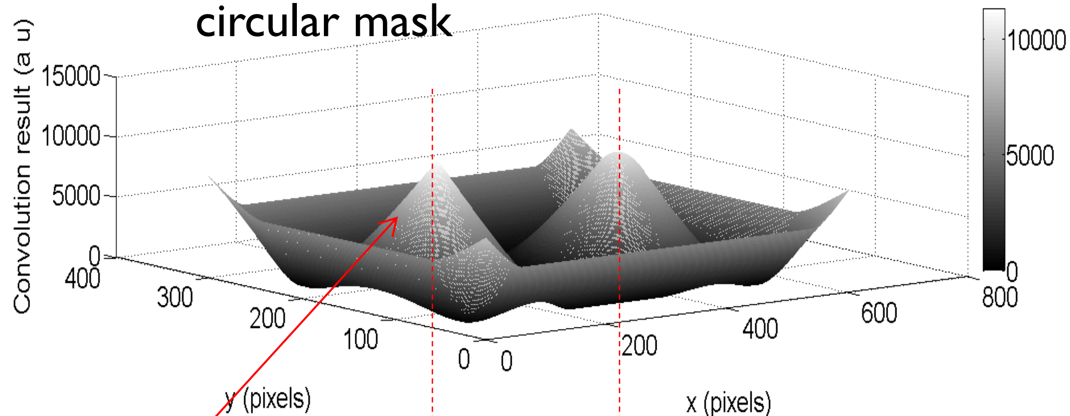
Kanik Palodhi *et al*, Convolution based hybrid image processing technique for microscopic images of etch-pits in Nuclear Track Detectors, Radiation Measurements, Volume 130, 106219, January 2020.

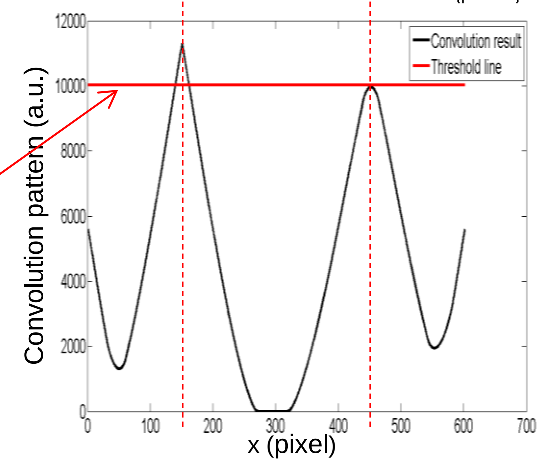
Proposed Method (cont'd) – simulations



1. Simulated image with a circle and ellipse with the circle chosen as mask

2. Mesh-plot after deconv-conv with the circular mask



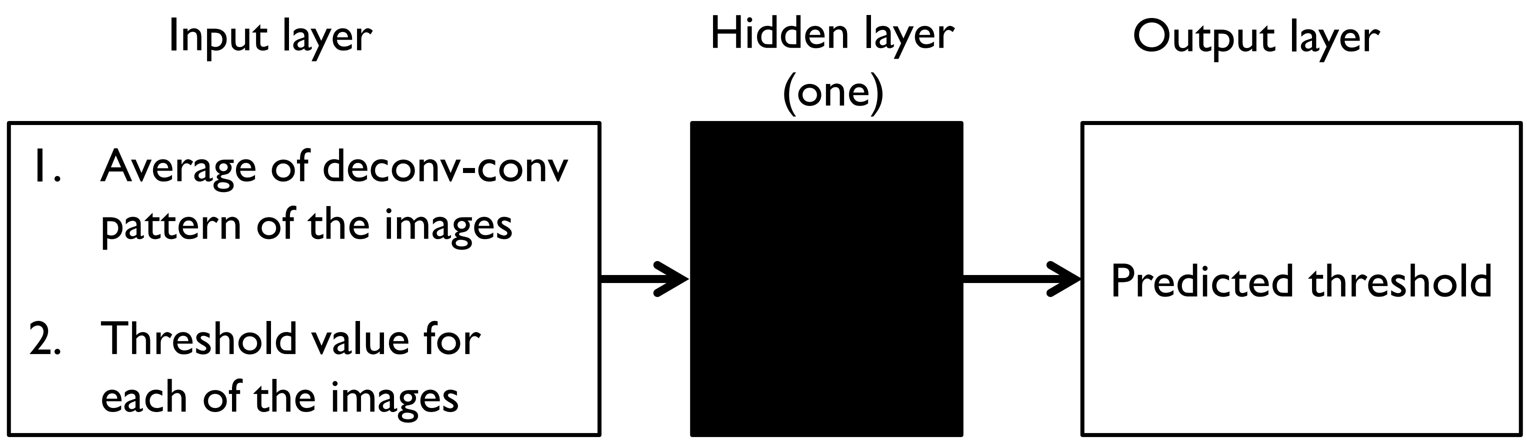


3. 1D plot of the above shows higher peak due to deconv-conv with the same mask

Two inputs to ANN
1. Average of fig. 2
2. Threshold in fig. 3

Kanik Palodhi et al, Convolution based hybrid image processing technique for microscopic images of etch-pits in Nuclear Track Detectors, Radiation Measurements, Volume 130, 106219, January 2020.

Proposed method (cont'd) – ANN model

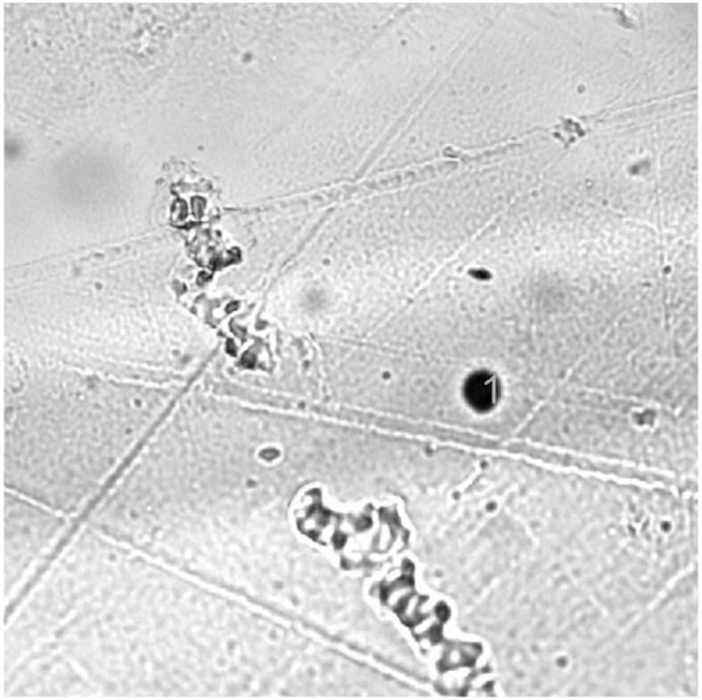


$$y_i = f\left(\sum_{j=0}^{N} w_{i,j} x_j\right)$$

Feed-forward architecture

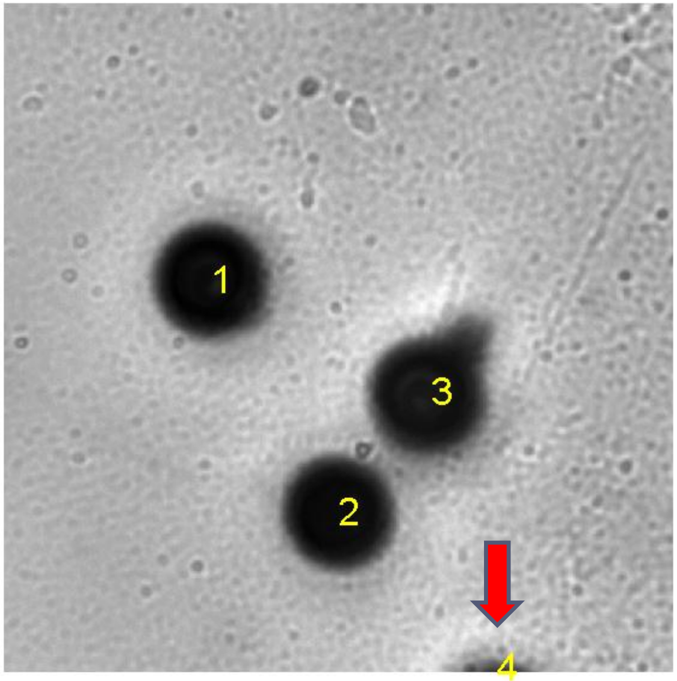
Using the predicted threshold and positional information, morphological techniques are used for marking the etch-pits within the images as shown later.

Experimental results – accelerator images with normal incidence

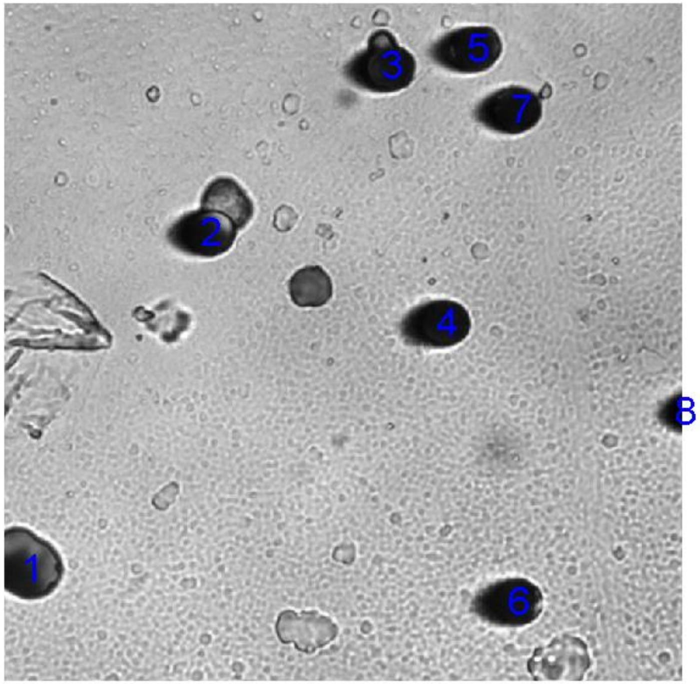


Huge scratch-marks and other background noises

Dent overlap with the etch-pit and finds one even at the edge

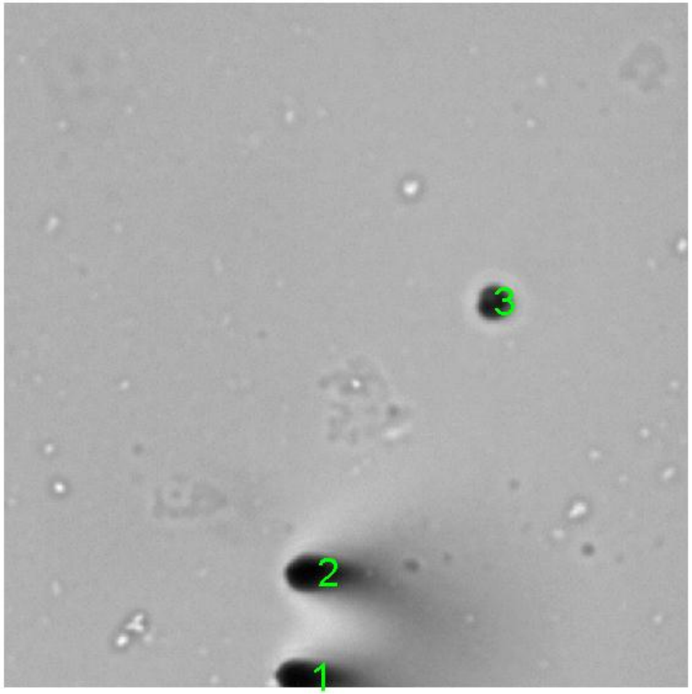


Experimental results – accelerator images with 30° incidence

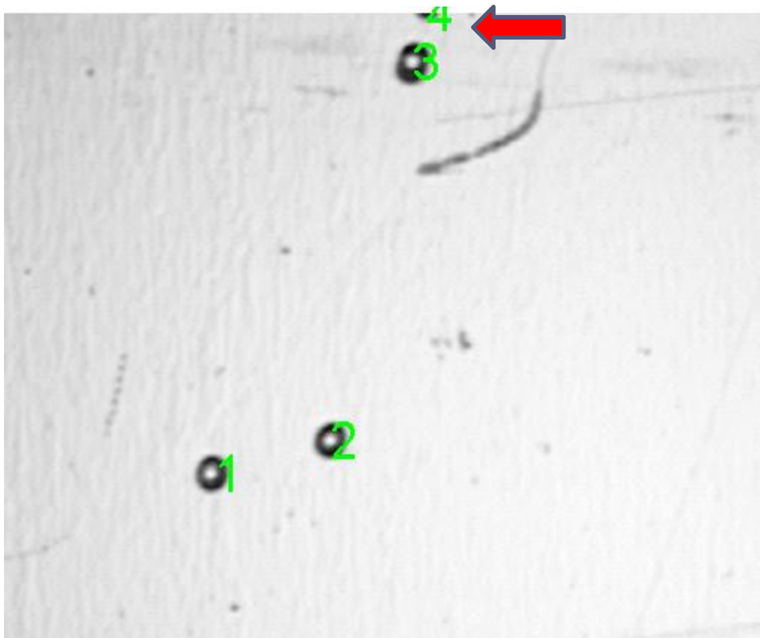


Huge scratch-marks and other background noises

Etch-pit detected at the edge

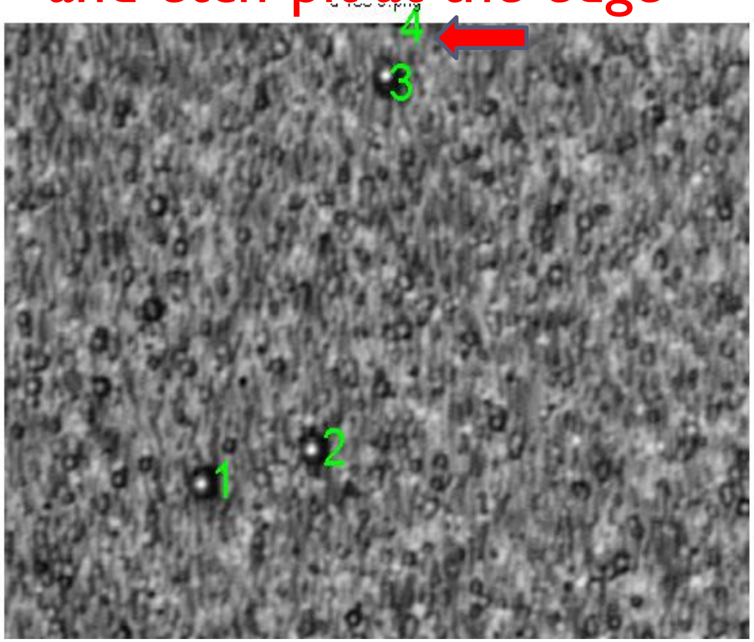


Other accelerator images



Etch-pit detected at the edge

Huge background noises and etch-pit at the edge



Results

Image source	Total no. of image frames	Training images	Test images	Accuracy	Over-count error	Under-count error
Accelerator exposed (normal (0°) incidence)	60	45	15	94%	3%	3%
Accelerator exposed (30° angle of incidence)	60	45	15	93%	4%	3%
Open-air exposed (at Darjeeling)	50	45	13	90%	3%	7%

The significance is with much less training images compared to other techniques, this method can achieve greater accuracy.

Conclusion

- A simple ANN based method is introduced for etch-pit detection from microscope images of NTDs.
- The method uses sequential deconvolution-convolution to generate peaks that, in turn, is used for setting the threshold for selecting etch-pits.
- The method is computationally efficient and achieves higher accuracy.

Work of our group on this topic

1. Kanik Palodhi *et al*, Convolution based hybrid image processing technique for microscopic images of etch-pits in Nuclear Track Detectors, Radiation Measurements, Volume 130, 106219, January 2020.
2. Joydeep Chatterjee *et al*, Application of Machine Learning on sequential deconvolution and convolution techniques for analysis of Nuclear Track Detector (NTD) images, arXiv:2005.07368, Fri, 15 May 2020, (submitted to Radiation Measurements)
3. "Etch-pit counter" – a software applied for Indian copyright

Thanks

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Appendix

- Deconvolution before convolution gives higher peak compared to only convolution shown in 1D.