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MDPI

A Dual-Threshold-Driven GUI Tool for Rapid Nanoparticle Quantification from Electron Microscopy Images

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Introduction

Nanoparticle (NP) size distribution critically influences performance in catalysis, biomedicine, and materials science. NP characterization via Electron Microscopy (SEM/TEM) is vital yet time-consuming. Current analysis is often:

Labor-intensive: Manual counting and measuring.

Subjective: User-dependent thresholding in software like ImageJ.

Non-Transparent: "Black-box" processing steps.

Our Solution: An open-source, Python-based GUI tool that automates NP quantification by intelligently combining two thresholding methods for accurate, rapid, and reproducible analysis.

Methodology

INPUT
SEM/TEM Image, Scale Bar

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PREPROCESS
Gaussian Blur

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DUAL-THRESHOLDING

- Adaptive Gaussian (Local Contrast)	- Otsu's Method (Global Contrast)	- SELECT optimal binary image via particle count

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CLEAN
Morphological opening (Remove noise <50 pixels)

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SEGMENT

Marker-controlled Watershed	- Distance Transform → Sure Foreground	- Dilation → Sure Background	- Watershed on negative distance map

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MEASURE
Equivalent Circular Diameters (px → nm via scale)

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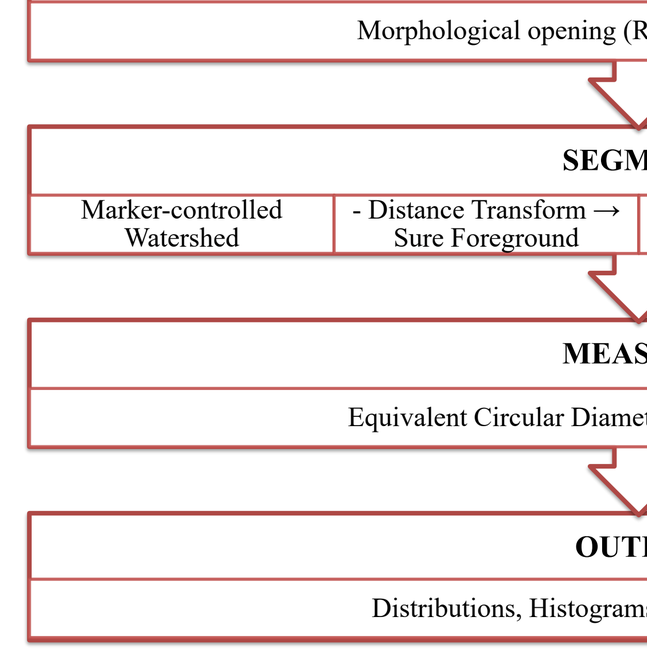
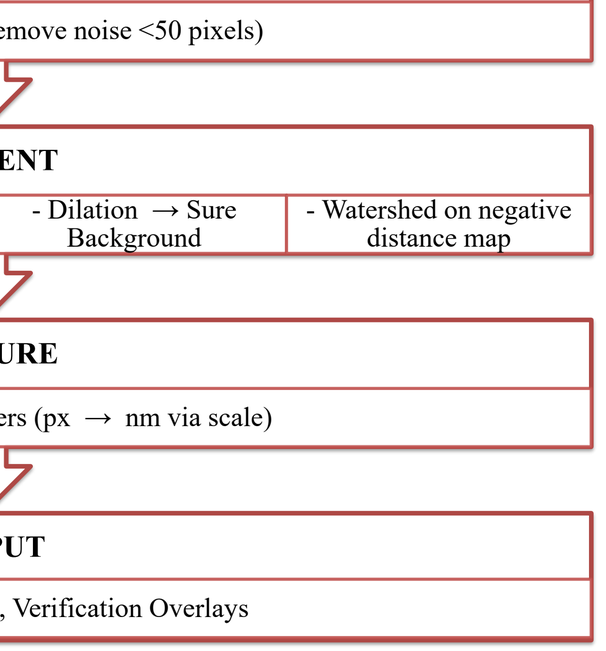
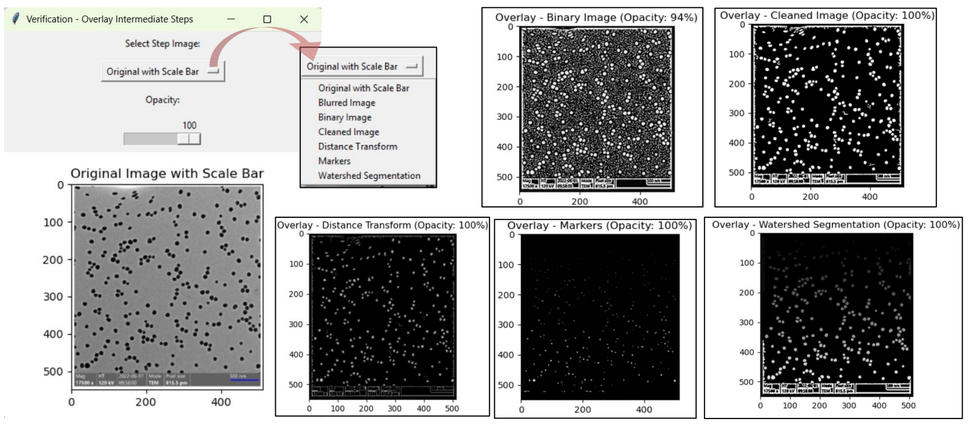
OUTPUT
Distributions, Histograms, Verification Overlays

Software Interface & Verification

User-Friendly Interface: Intuitive controls for image loading, scale calibration, and customizable visualization of results (histogram, Gaussian fit, data table).





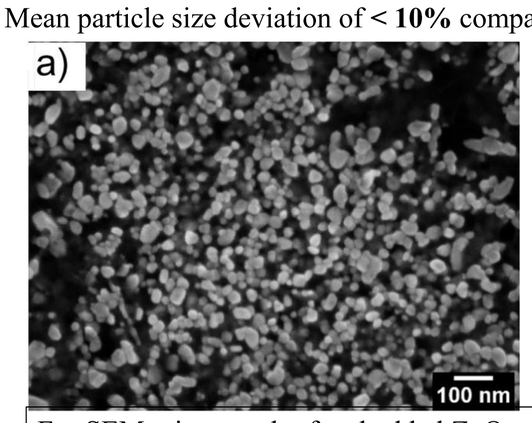


Unprecedented Transparency: The interactive verification module allows users to overlay any intermediate processing step (e.g., markers, binary image) onto the original, validating the segmentation accuracy and building trust in the results.

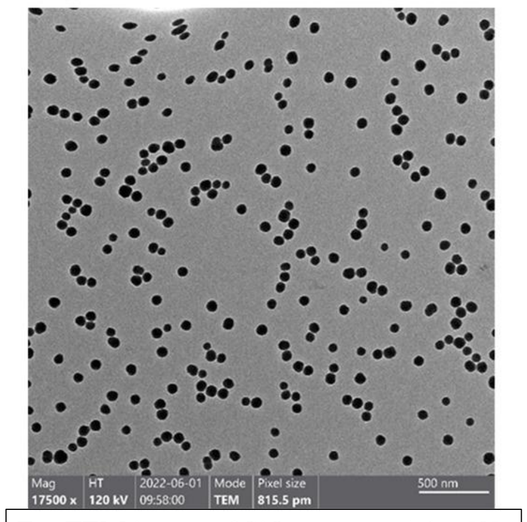
Benchmarking & Performance

A. Accuracy vs. ImageJ & Literature Data:

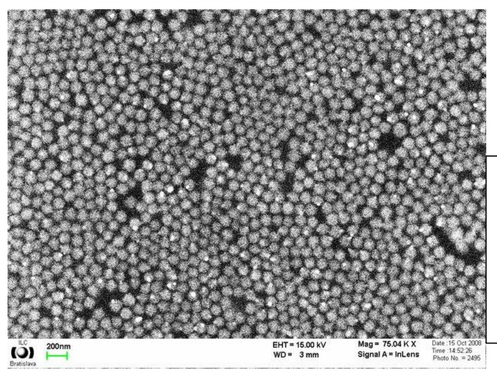
Mean particle size deviation of **< 10%** compared to established methods.



For SEM micrograph of embedded ZnO NPs [1], Mean ± SD using
ImageJ: 26.419 ± 12.604 nm
our software : 26.08 ± 8.16 nm
Deviation (%): 1.29%



For TEM image of SiO_2 nanoparticles [2], Mean ± SD from
Literature: 70.6 nm
our software : 70.79 ± 8 nm
Deviation (%): 0.27%



For SEM images of silver nanoparticle [3] monolayers, Mean ± SD using:
ImageJ: 74.81 ± 27.56 nm
our software : 69.57 ± 14.63 nm
Deviation (%): 7.26%

B. Processing Speed:

Significantly reduced average processing time per image compared to manual analysis.

Method	Average Processing Time	Consistency
Our Tool (Automated)	~30 seconds	High
Manual/ ImageJ Analysis	~5-10 minutes	User-dependent

CONCLUSION

Efficiency: Drastically reduces analysis time from minutes to seconds.

Accuracy & Reproducibility: Dual-thresholding and watershed segmentation provide consistent, unbiased results.

Transparency: The verification window makes the "black box" of image processing interpretable.

Accessibility: A standalone, open-source application for the community.

The tool delivers a practical, interpretable, and robust solution for high-throughput nanoparticle quantification.

Availability & Code

GitHub Repository: https://github.com/sabbir-nipu/Nanoparticle-Counter-from-SEM-Image
The software is open-source. Contributions are welcome.

References

1. Mrkwitschka, P., Rühle, B., Kuchenbecker, P., Löhmann, O., Lindemann, F., & Hodoroaba, V. D. (2024). Embedding and cross-sectioning as a sample preparation procedure for accurate and representative size and shape measurement of nanopowders. *Scientific Reports*, *14*(1), 511.
2. Zhang, S., & Wang, C. (2023). Precise analysis of nanoparticle size distribution in TEM image. *Methods and Protocols*, *6*(4), 63.
3. Gaála, A., Bugar, I., Capek, I., Polovkova, J., Szocs, V., Palszegi, T., ... & Uherek, F. (2009, June). Picosecond characteristics on transient absorption spectra of silver nanoparticles. In 2009 11th International Conference on Transparent Optical Networks (pp. 1-4). IEEE.