On the Segmentation of Inorganic Nanoparticles in TEM Micrographs

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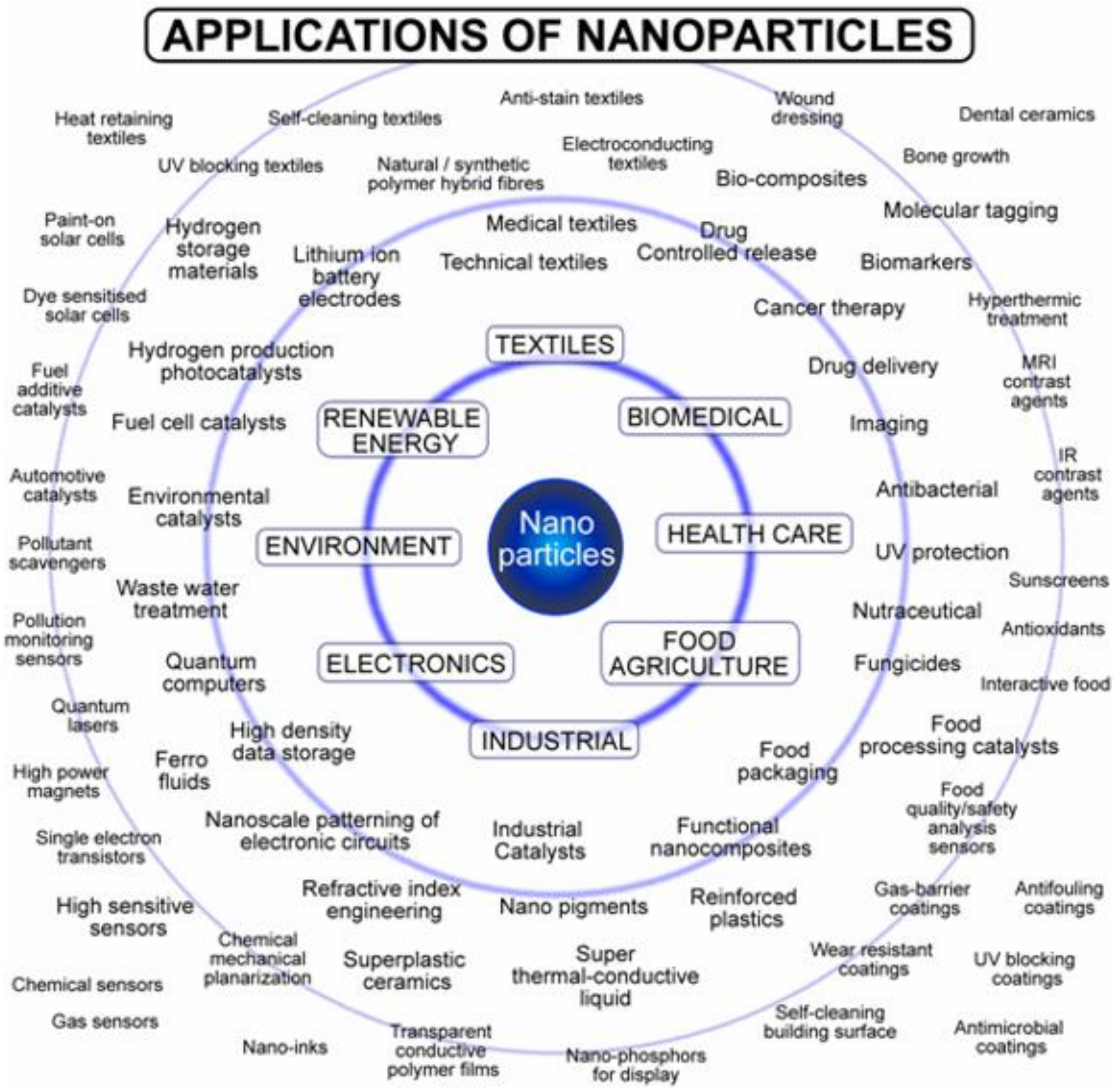
Motivation

Why study nanoparticles?

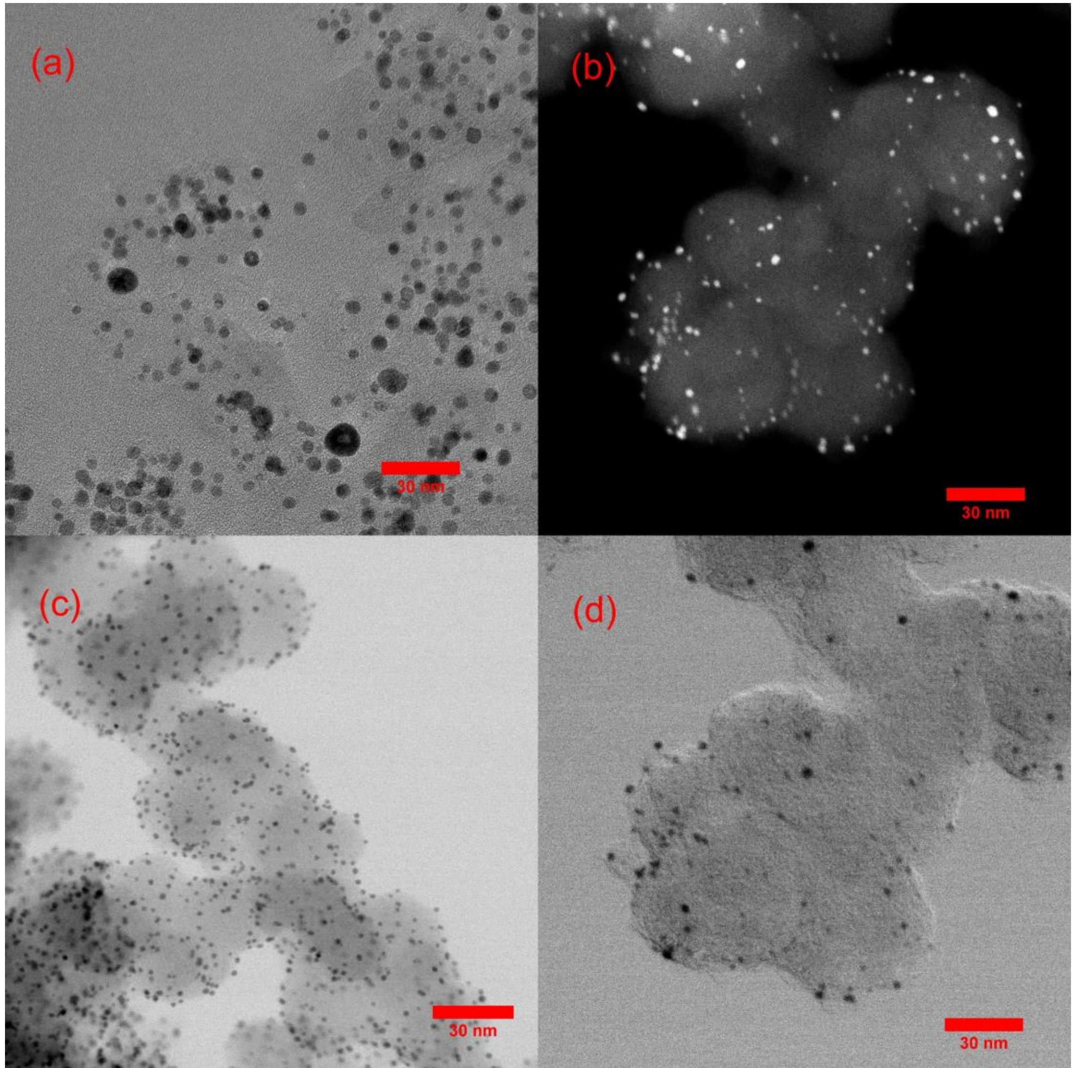


Tsuzuki, Intl. J. Nanotech., (2009) 6 p. 567-578

Motivation

How do we study nanoparticles?

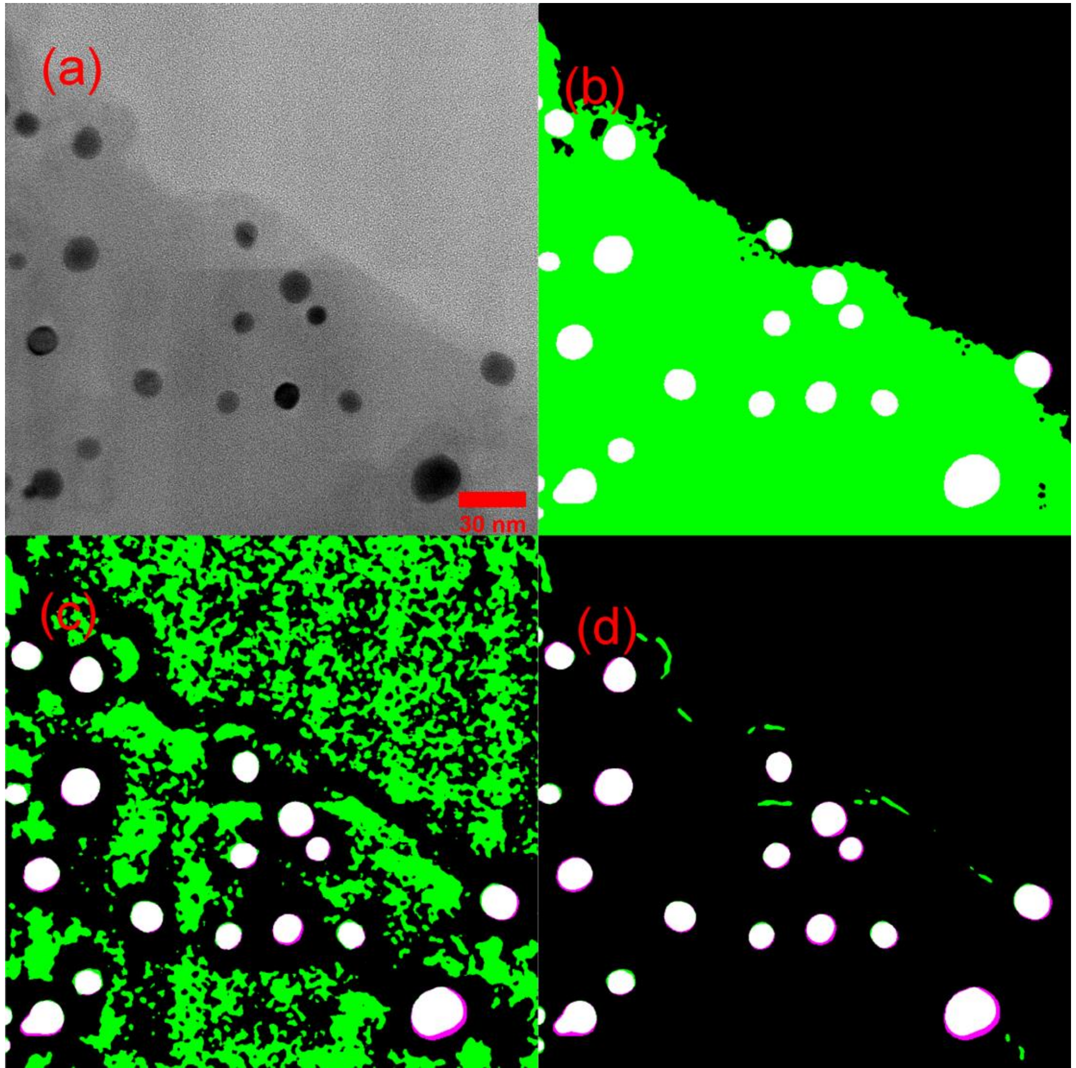
Modalities of TEM



TEM/STEM images using four different modes:

(a) Bright-Field TEM (BF TEM);
(b) High Angular Annular Dark Field STEM (HAADF STEM)
(c) Bright-Field STEM (BF STEM); and
(d) Low Angular Annular Dark Field STEM (LAADF STEM).

Semantic Segmentation

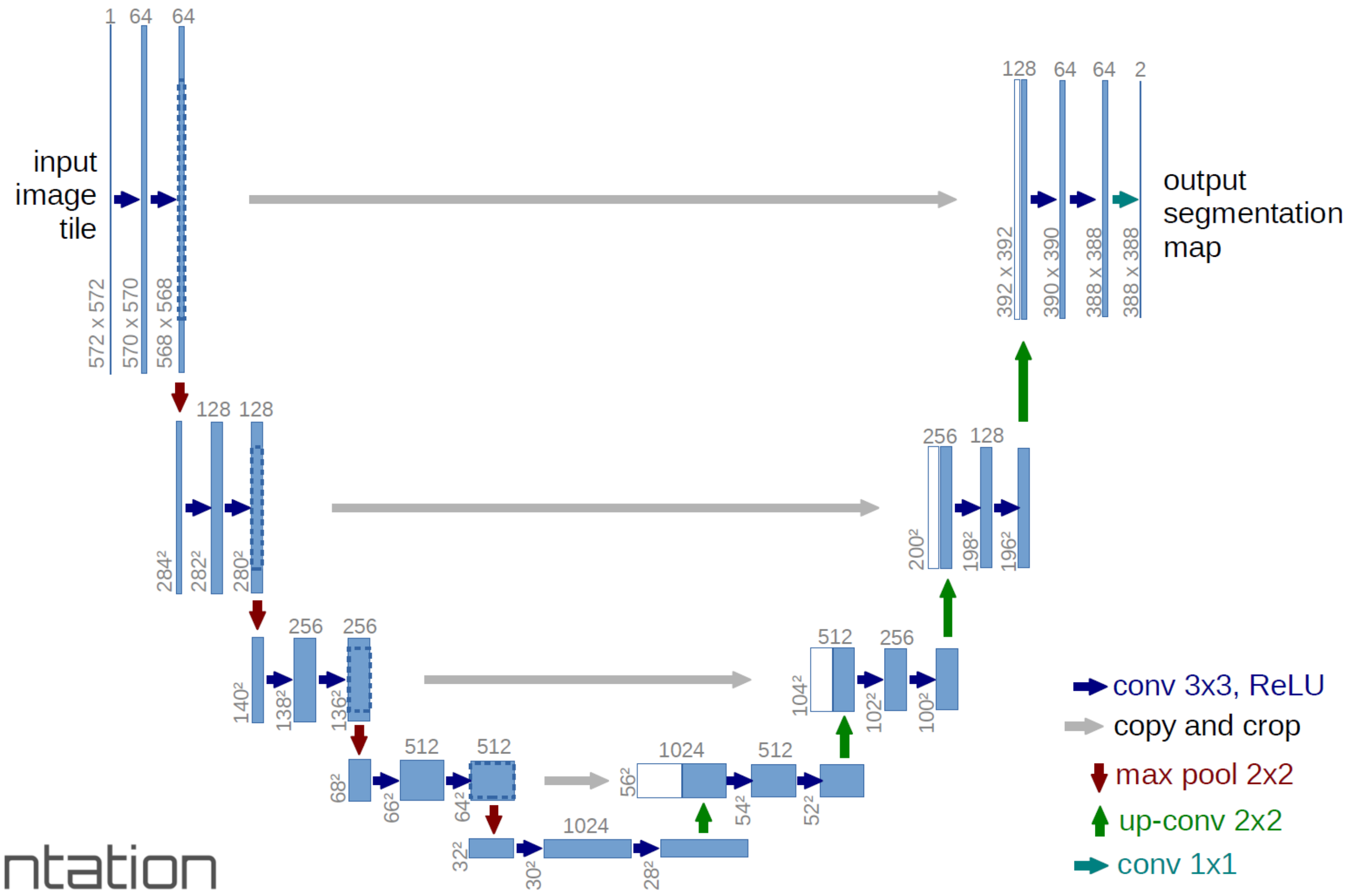


Sematic segmentation results in comparison to ground truth:

(a) original BFTEM image;
(b) global thresholding;
(c) local thresholding;
(d) hybrid thresholding.

In the images (b) to (d), black and white regions are areas of agreement, whereas colored regions are areas of disagreement.

UNET Architecture

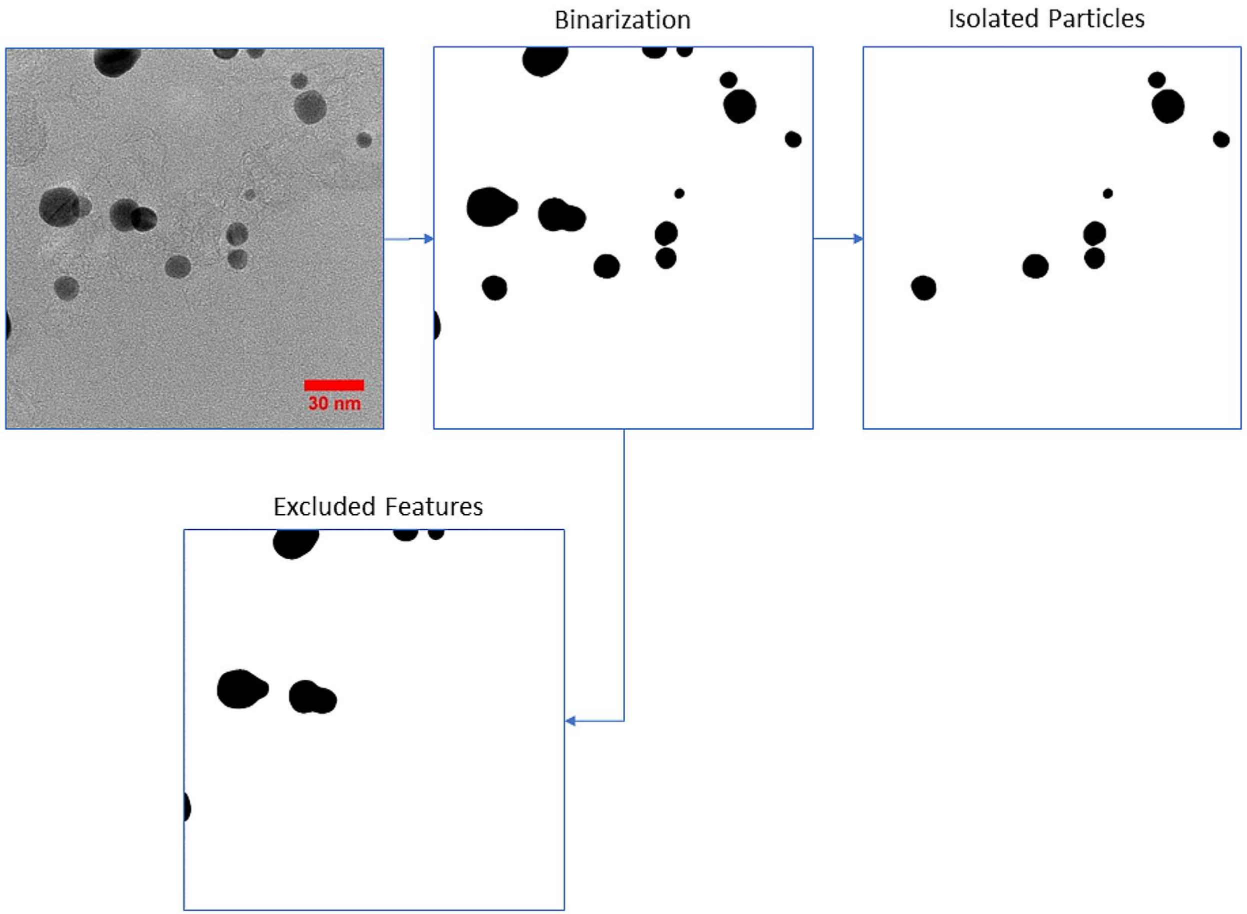


Training/Validation Databases

Validation Parameter	Variables
Particle Size	1. 2.0nm mean, Range = [0.8nm,3.3nm] (Pt/C) 2. 3.3nm mean, Range = [1.8nm, 5.6nm] (Pt/C) 3. 5.0nm mean, Range = [2.2nm, 9.5nm] (Pt3Co/C) 4. 5.9nm mean, Range = [2.8nm, 10.6nm] (PtNi/C) 5. 12.7nm mean, Range = [6.5nm, 27.0nm] (Pt/MEA)
Particle Composition	1. Pt 2. Pt3Co 3. PtNi
Environment	1. NPs supported on C powders 2. NPs in MEA cathodes 3. NPs supported on graphene
Modalities	1. BFTEM 2. BFSTEM 3. HAADF-STEM 4. LAADF-STEM
Instrument	1. JEOL 2010F in Austin TX 2. JEOL 2100 in Portugal 3. FEI Titan ChemiSTEM in Portugal 4. JEOL 200 in Japan

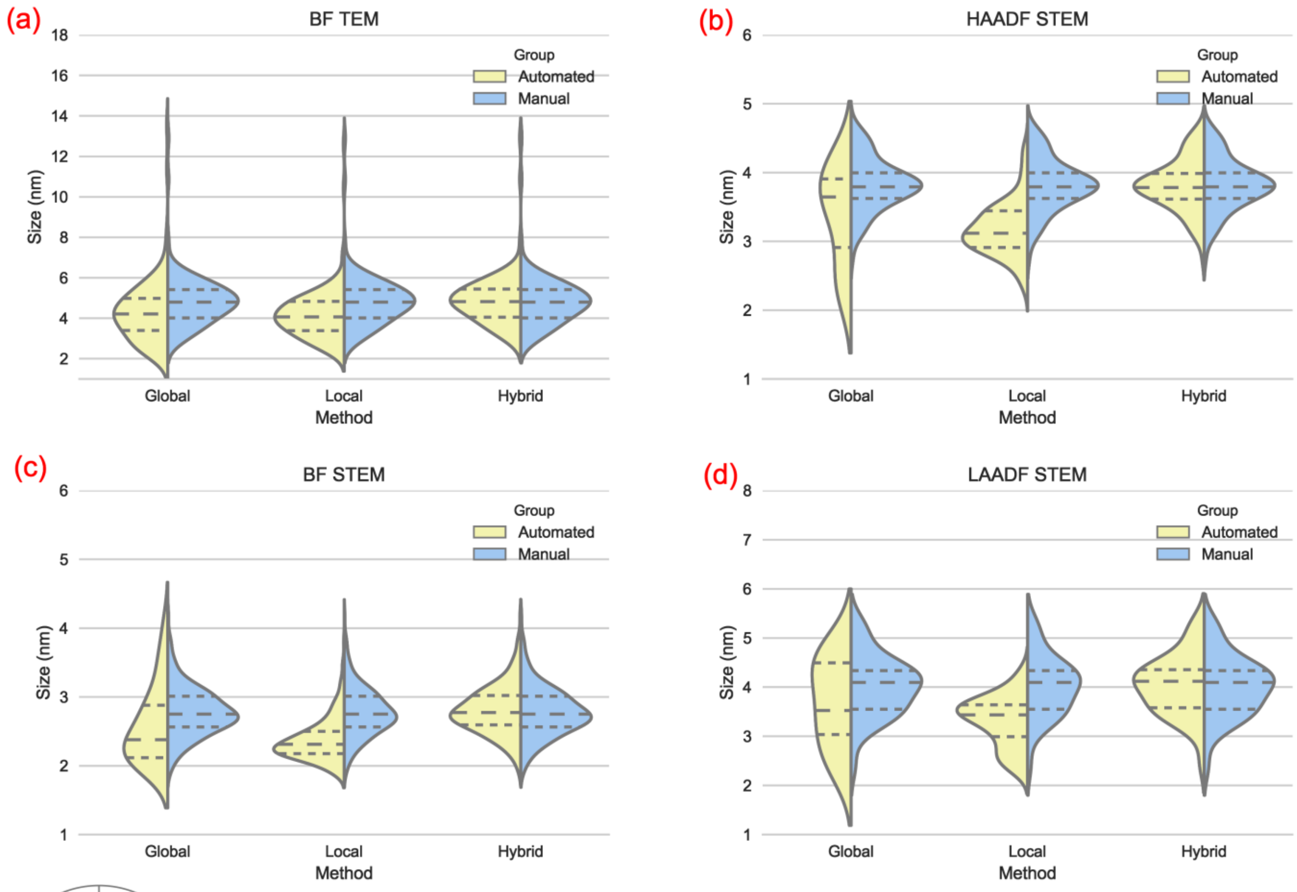
Training Database: 1150 images and ground truths
Semantic Validation Database: 100 images and ground truths
Instance Validation Database: A separate 100 BFTEM images and ground truths

Instance Segmentation



Traditional particle picking paradigm for segmenting isolated particles.

Instance Segmentation



Manual and automated particle sizing results from the images in Figure 1. The four different modalities are

(a) BF TEM;

(b) HAADF STEM;

(c) BF STEM; and

(d) LAADF STEM.

Automated results for global thresholding, local thresholding, and hybrid thresholding are shown in yellow, whereas manual segmentation is shown in blue. Notice how only hybrid thresholding reproduces manual particle sizing for all four modalities.

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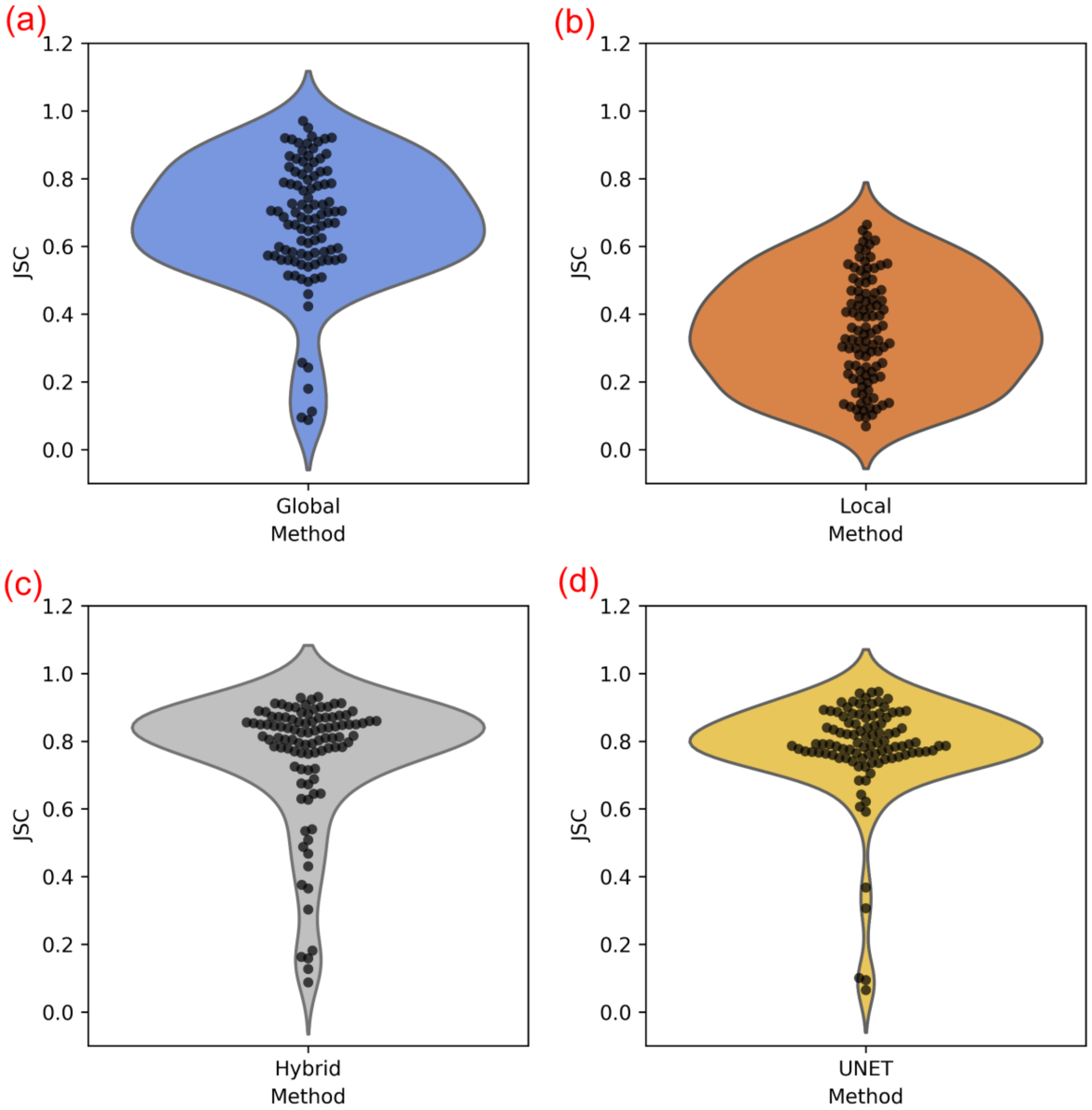
Results and Discussion

How did our algorithms perform?

Semantic Segmentation Results



JSC distributions for semantic segmentation algorithms

(a) global thresholding;

(b) local thresholding;

(c) hybrid thresholding; and

(d) the UNET architecture.

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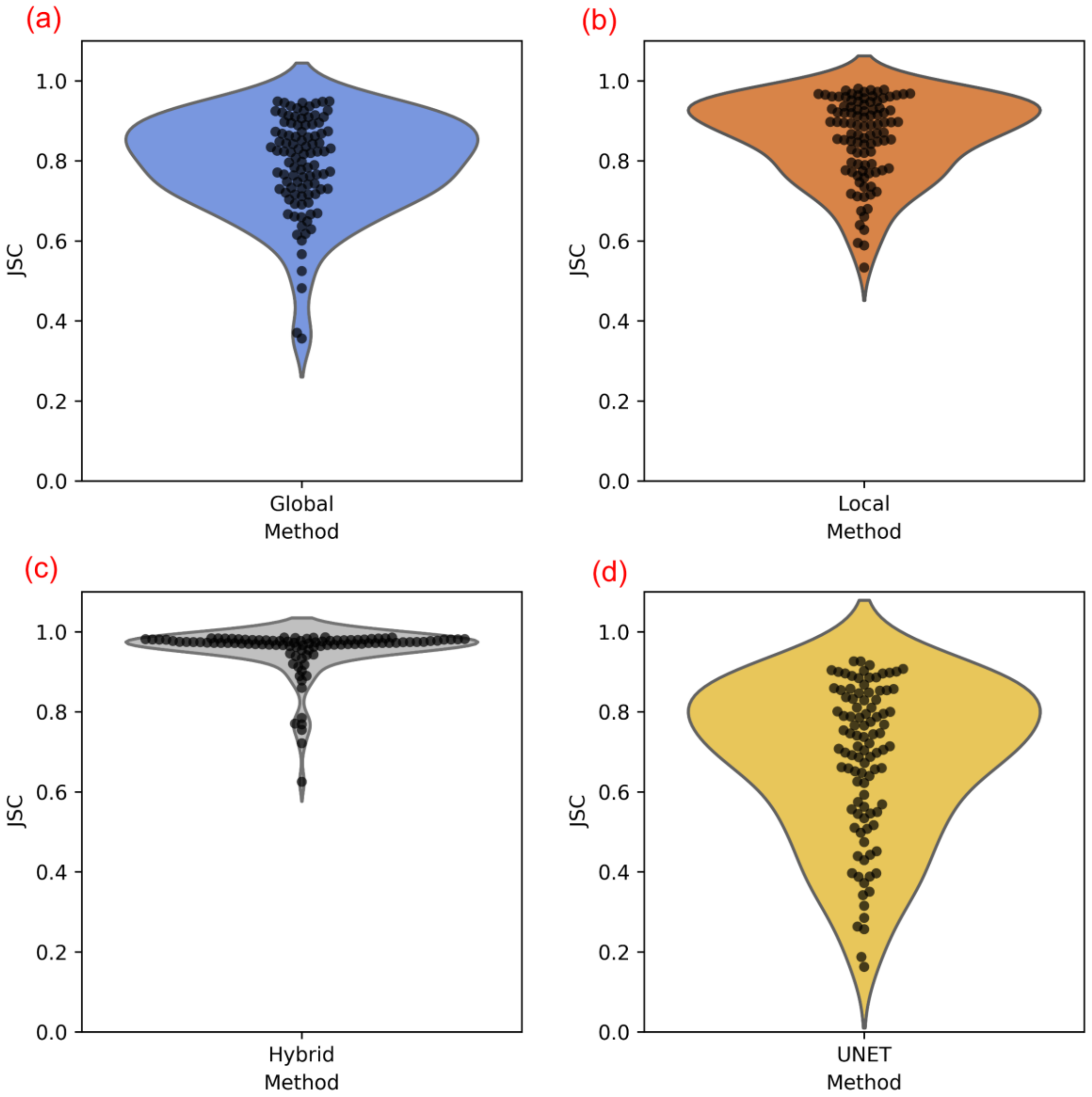
Instance Segmentation Results



JSC distributions for instance segmentation algorithms (isolated particles only)

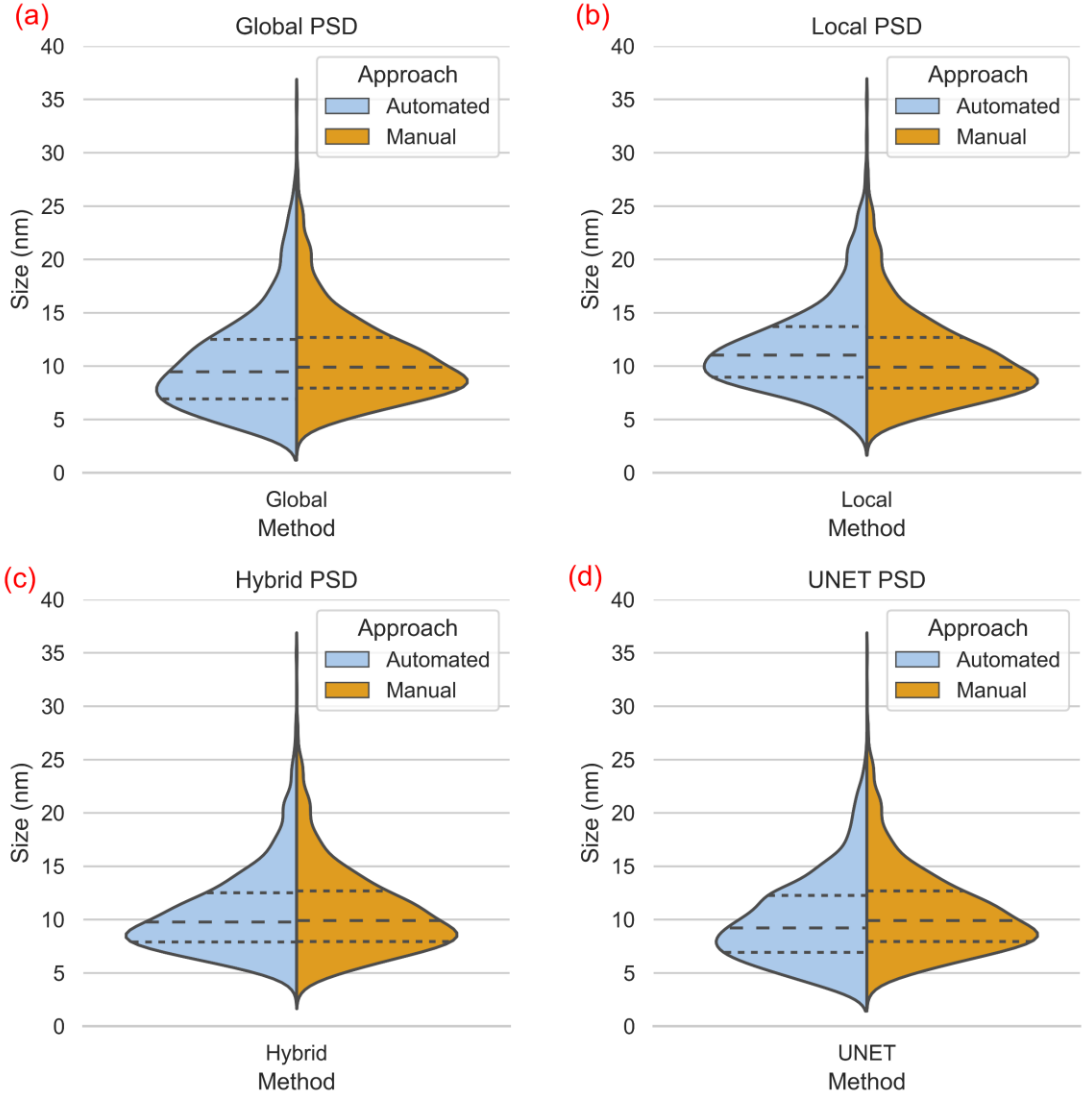
(a) global thresholding;

(b) local thresholding;

(c) hybrid thresholding; and

(d) the UNET architecture.

Instance Segmentation Results



PSDs for instance segmentation algorithms compared to manual (isolated particles only)

(a) global thresholding;

(b) local thresholding;

(c) hybrid thresholding; and

(d) the UNET architecture.

Conclusion

- UNET outperforms other algorithms with semantic segmentation.
- However, UNET underperforms all other algorithms when it comes to instance segmentation
- Future work should focus on creating a database of approximately 5,000 images or training, rather than 1150.