Ministry of Education of the Russian Federation
Federal budgetary organization of higher education
"Moscow State Pedagogical University"

Evaluation method of track membranes' images using computer vision

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Outline

1. Introduction
    - Definitions
    - Track membranes
    - Motivation of machine learning usage
2. Machine learning approach
    - Models, loss functions, metrics
    - Model comparison
    - Training, metric curves and results
3. Classical CV algorithms approach
    - Characteristics calculations
    - Comparison with manual approach
4. Conclusion

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Definitions

Machine learning - a type of artificial intelligence in which computers use huge amounts of data to learn how to do tasks rather than being programmed to do them

Image segmentation - process of partitioning a digital image into multiple segments

Computer vision - scientific field that deals with how computers can gain high-level understanding from digital images or videos

Machine learning algorithms

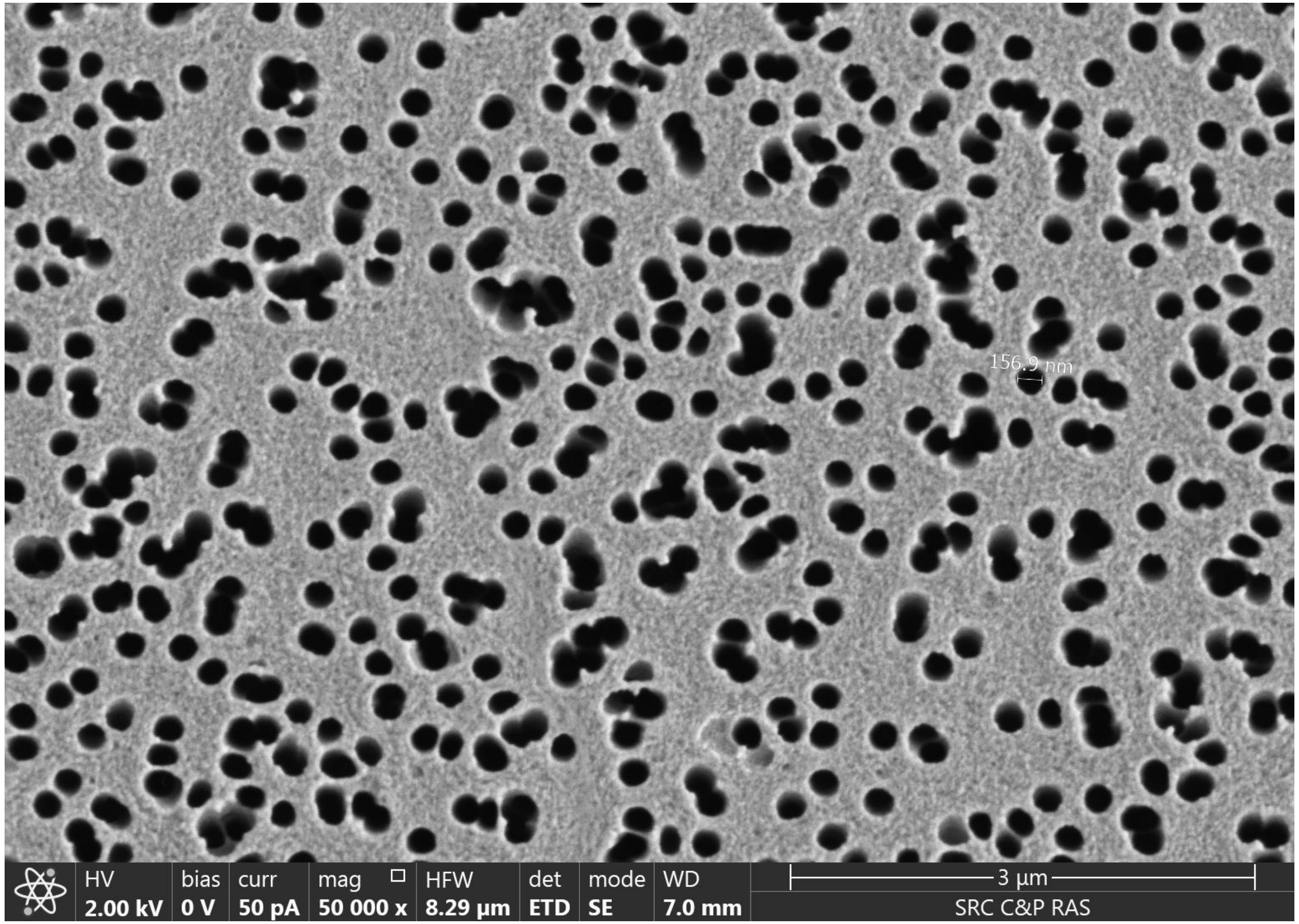
Classical (determined) algorithms

What is track membrane?

- Polymer films
- About 10 μm thick
- Produced by radiation of particle accelerator
- Track etching

Used for:

- Water filters
- Plasmapheresis
- Template synthesis



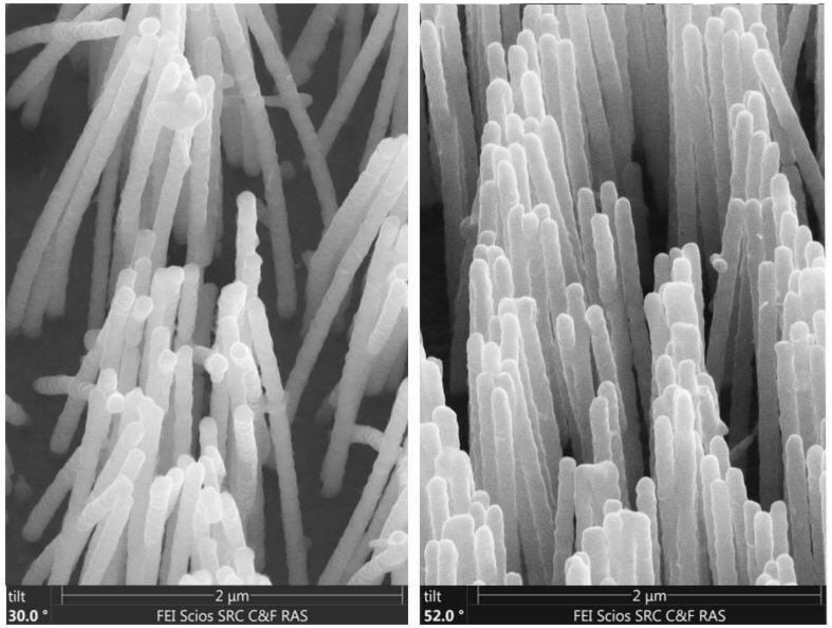
SEM image of track membrane

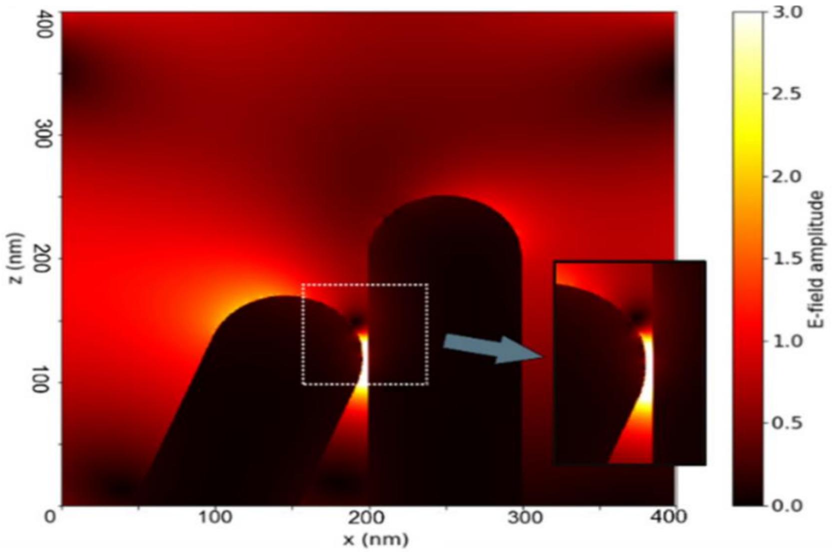
Why characteristics needed?

- Topology of nanomaterial produced by template synthesis

- More accurate calculation of local fields and signal amplification substances in nanoconcentrations

- “Finger-prints” of accelerator

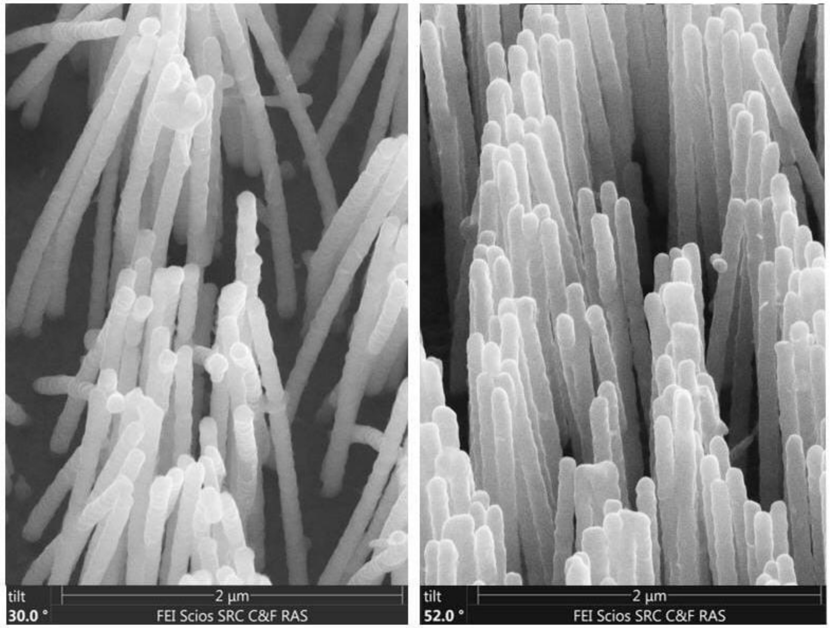


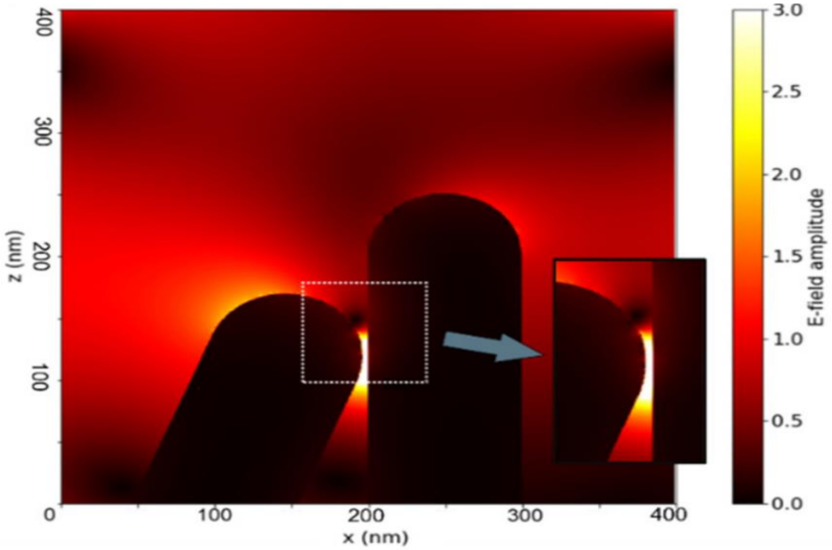


Why characteristics needed?

Fields of interest

- Topology of nanomaterial produced by template synthesis
- More accurate calculation of local fields and signal amplification substances in nanoconcentrations
- “Finger-prints” of accelerator





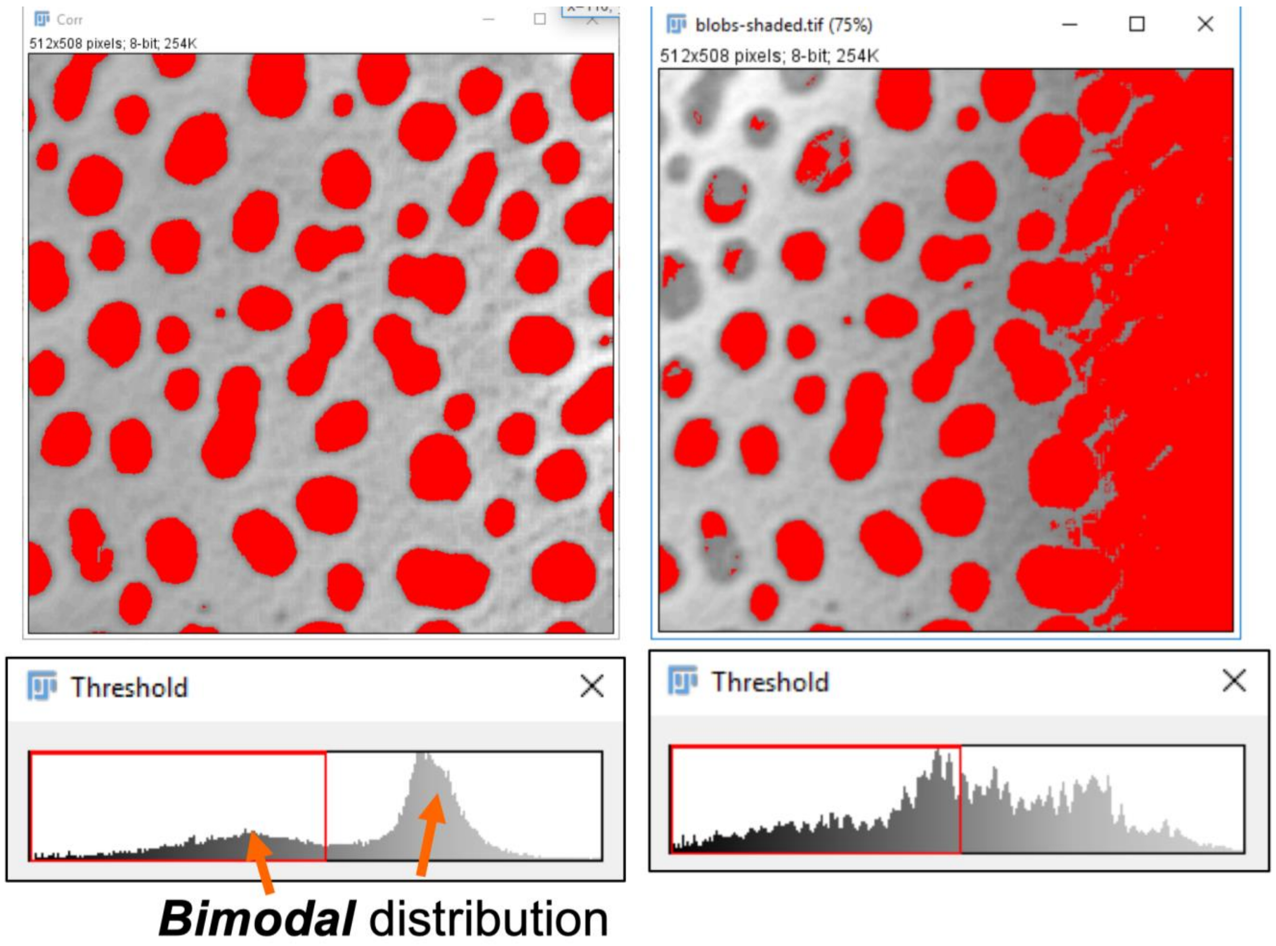
Why machine learning?

Ways to calculate characteristics:

- ImageJ
- Manually

Main disadvantages:

- Dependence on color distribution
- Manual adjustment
- Hard to assemble big statistics
- Takes human-time



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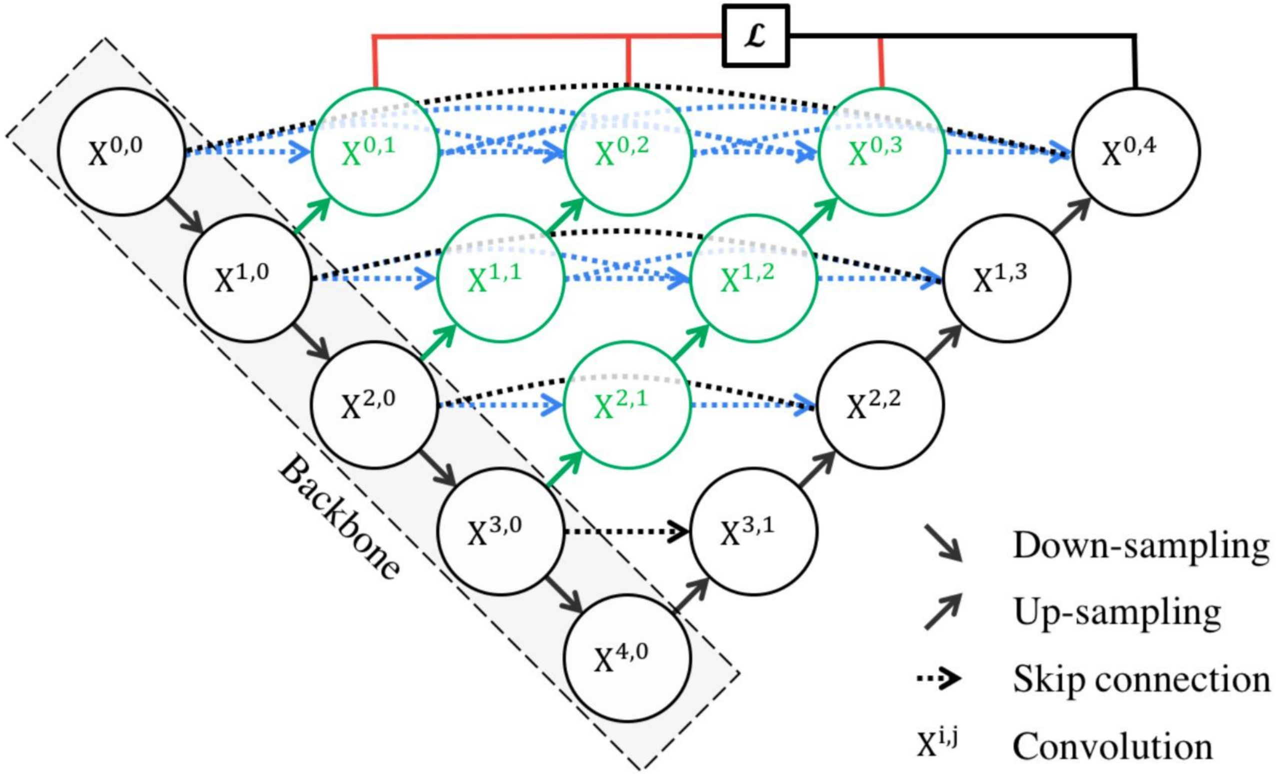
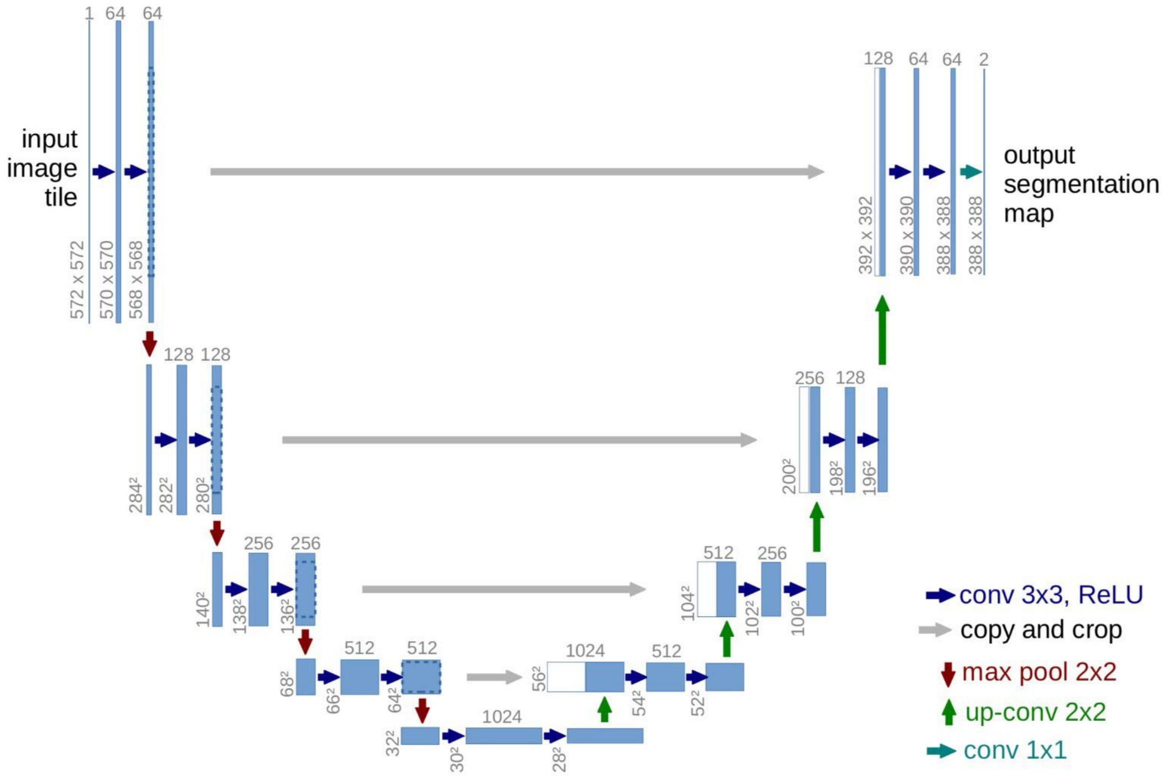
Models

UNet++



U-Net



Zhou Z., Rahman Siddiquee M.M., Tajbakhsh N., Liang J. (2018)
UNet++: A Nested U-Net Architecture for Medical Image Segmentation

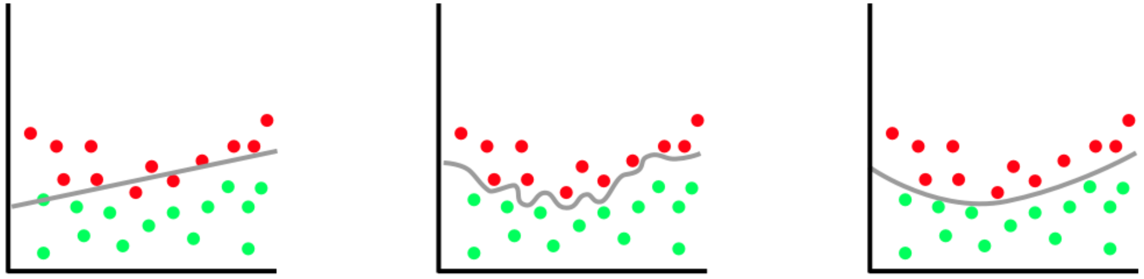
Ronneberger O., Fischer P., Brox T. (2015)
U-Net: Convolutional Networks for Biomedical Image Segmentation

Loss functions

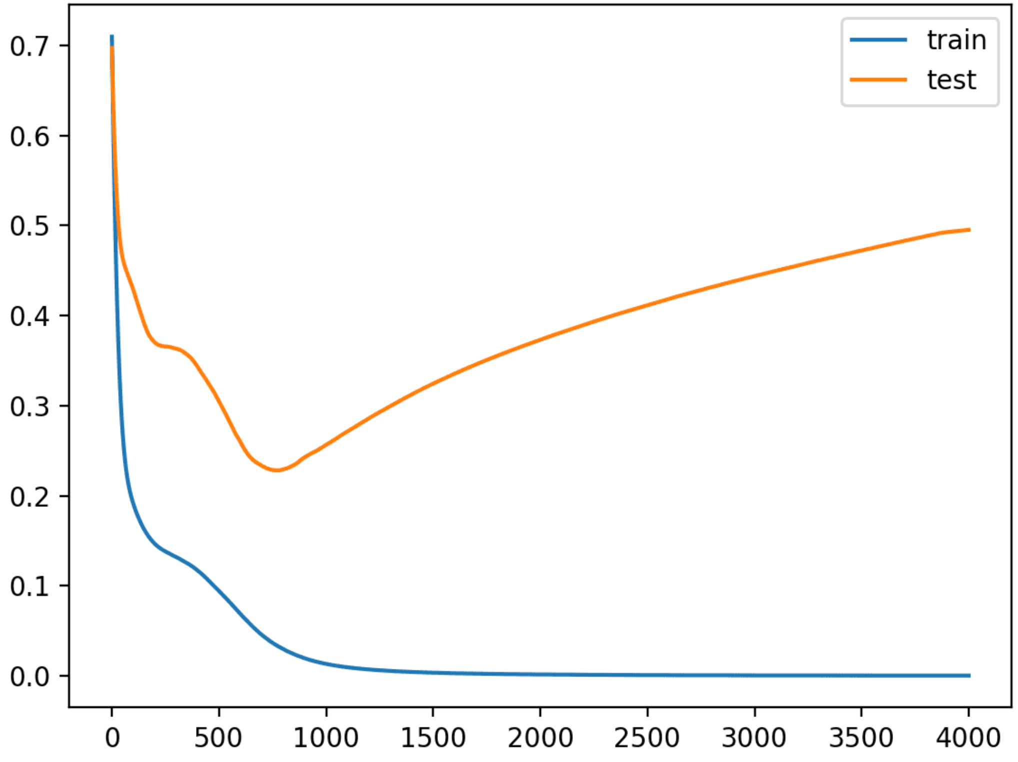
BCE Loss: $l_n = -\frac{1}{N}\sum_{i=0}^{N} y_n \cdot \log x_n + (1 - y_n) \cdot \log(1 - x_n)$

DiceLoss: $D = \frac{2\sum_i^N p_i g_i}{\sum_i^N p_i^2 + \sum_i^N g_i^2}$

FocalLoss: $FL = -(1 - p_t)^{\gamma} \log(p_t)$

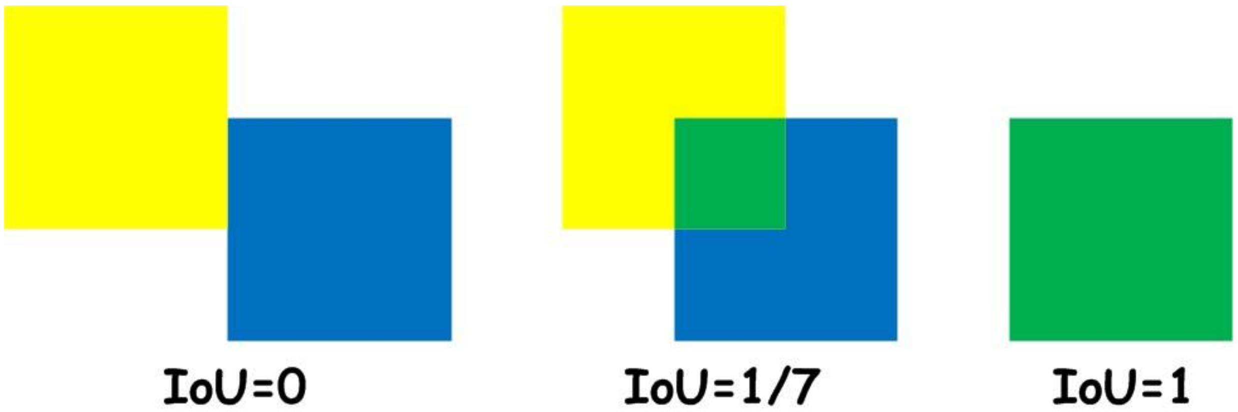


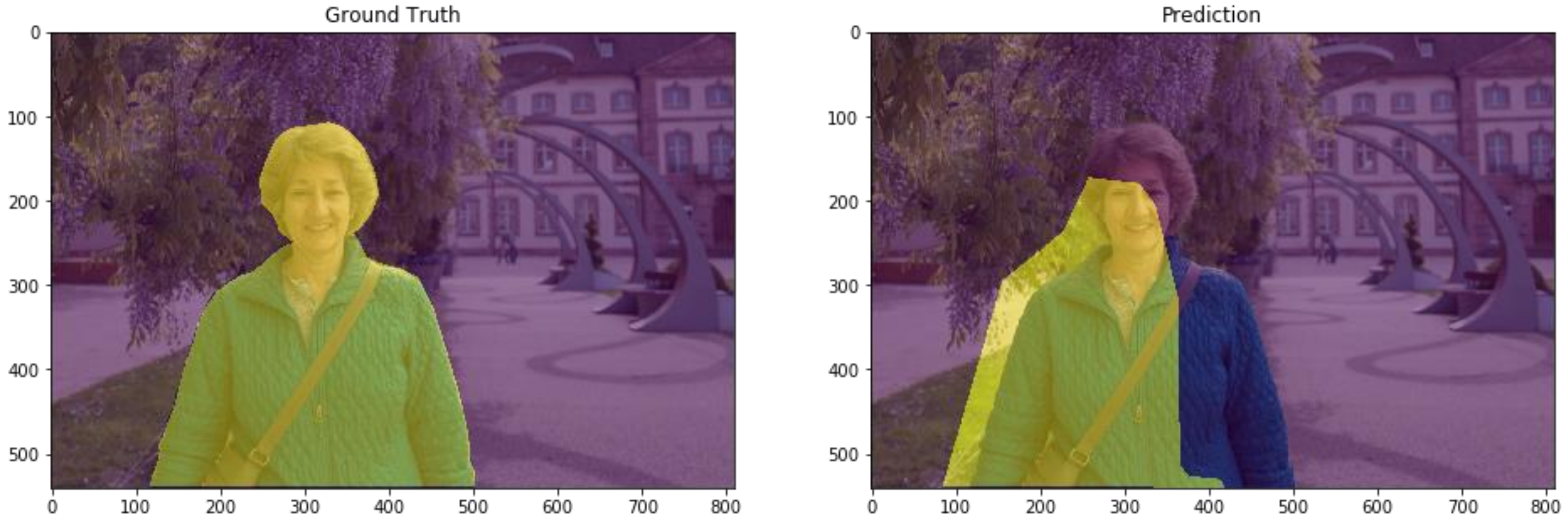
Underfitting Overfitting Balanced



Metrics

$$\text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$

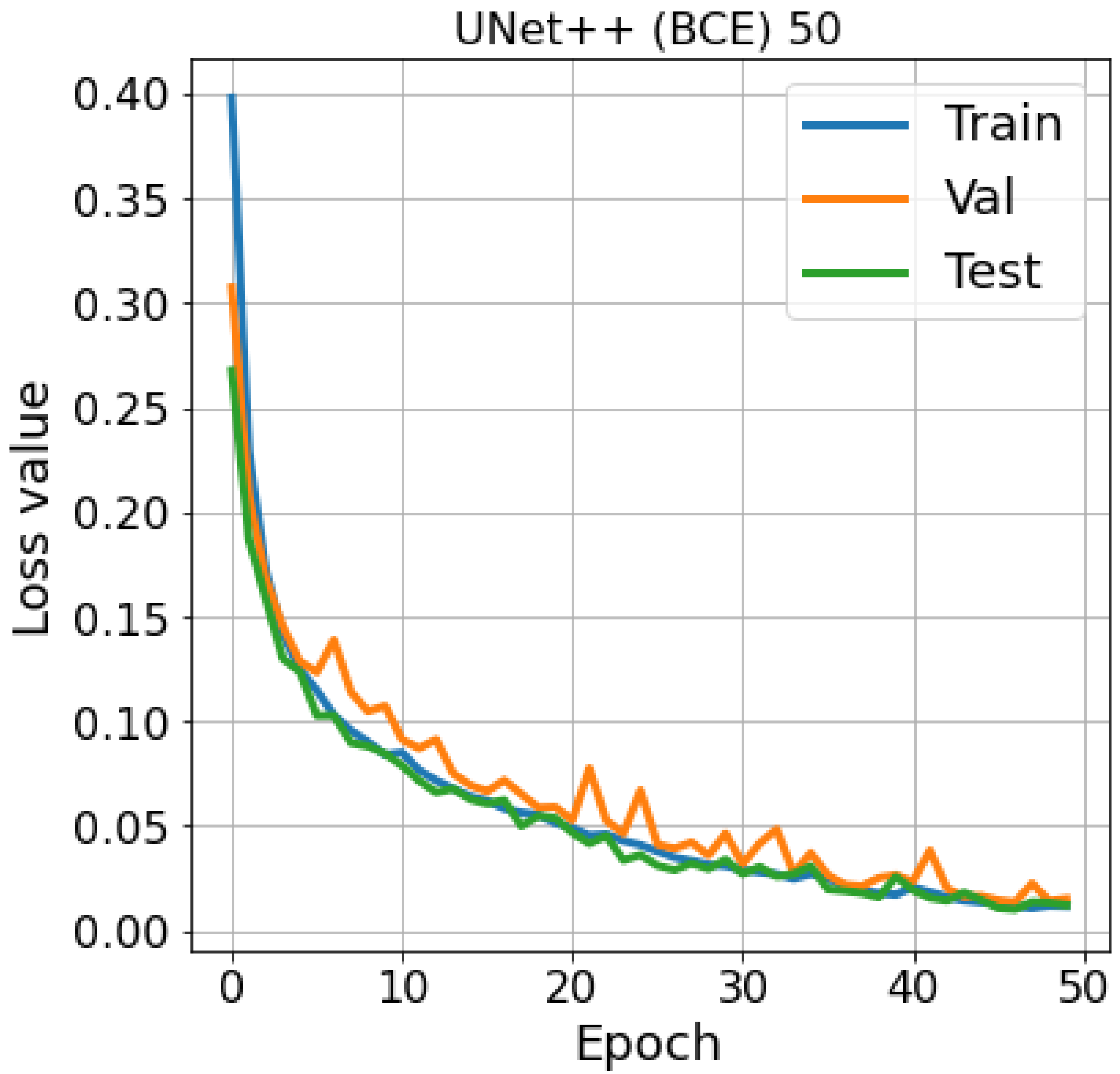


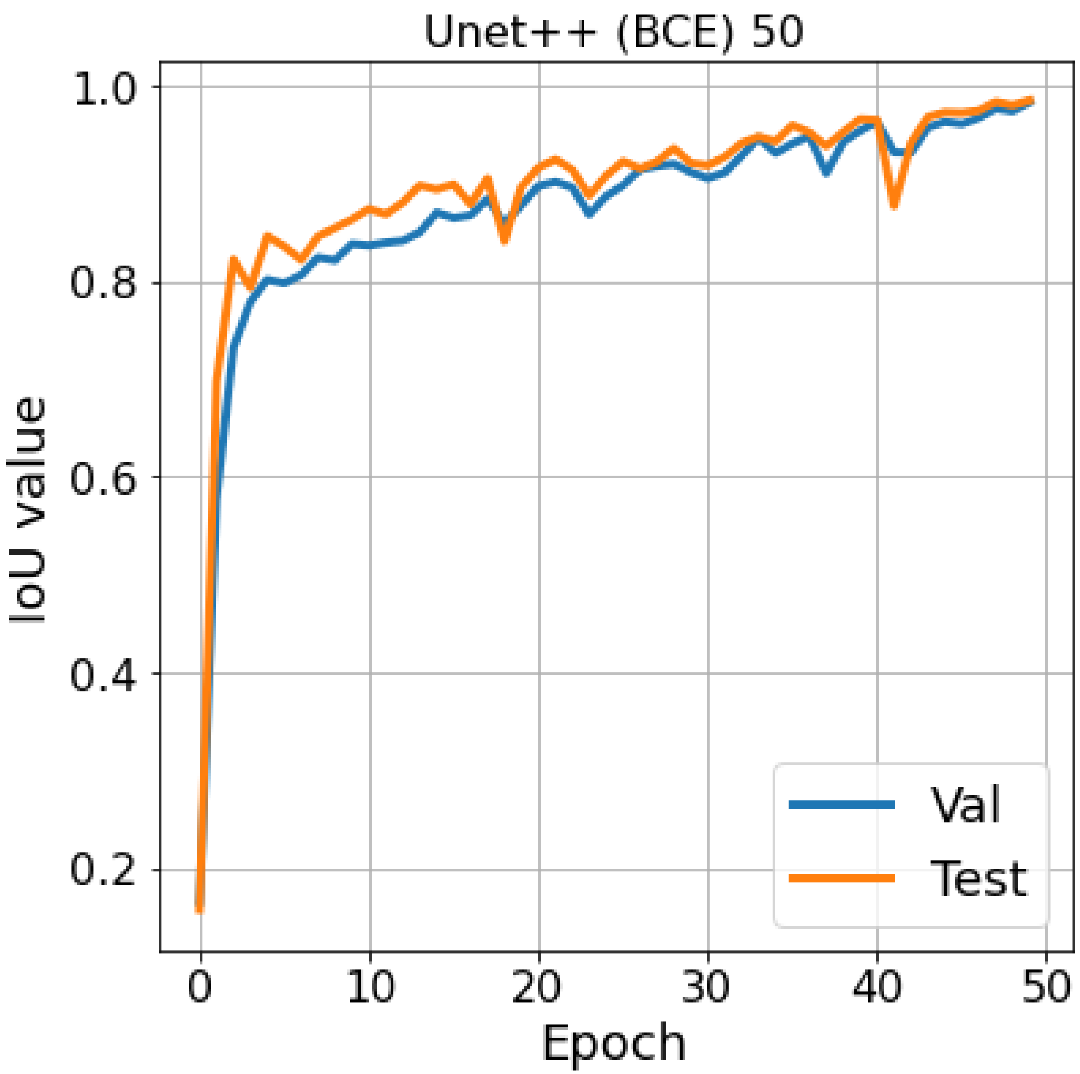


Model comparison

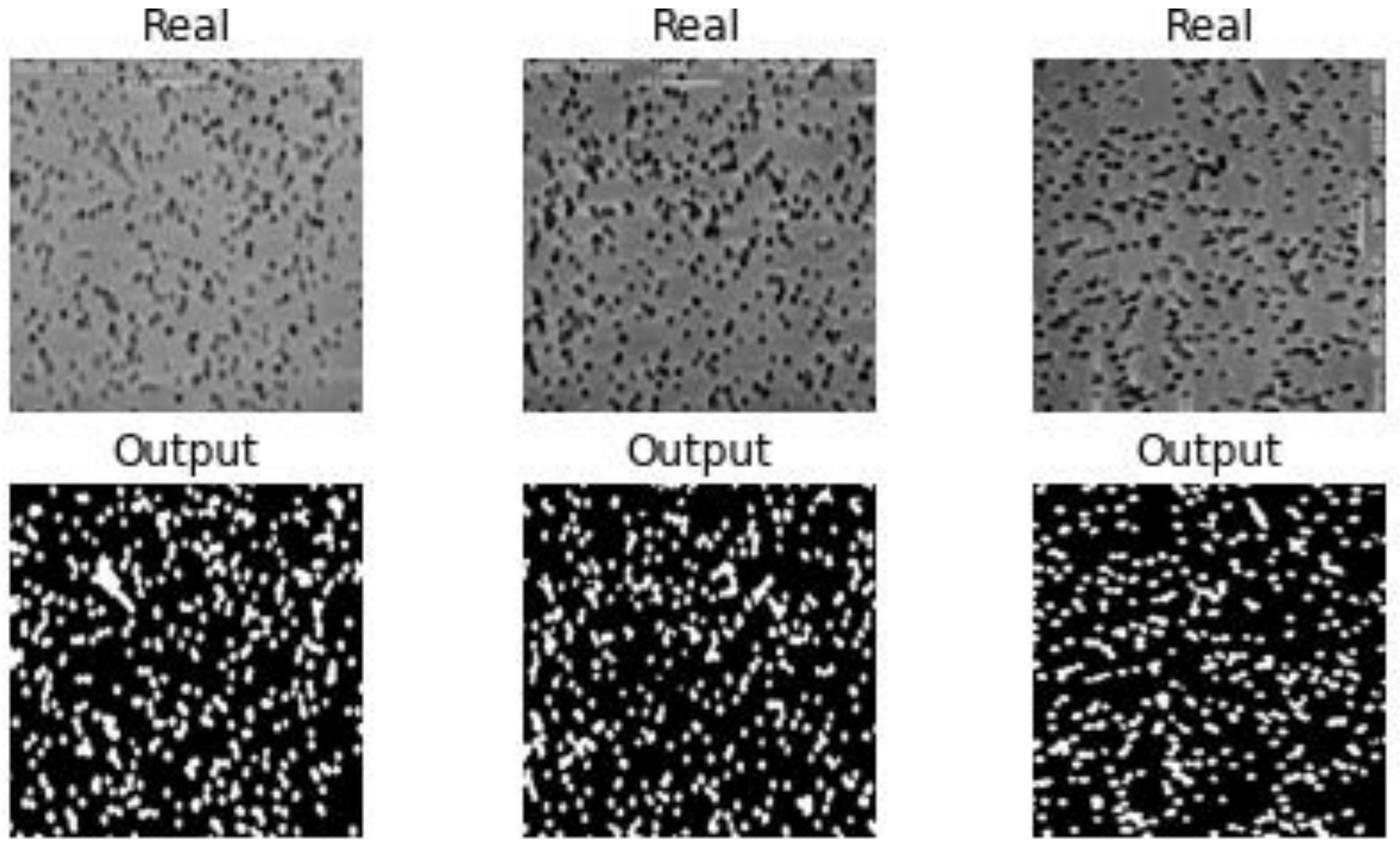
Model	Loss function	Epochs	Metrics value	
			Test score	Val score
U-Net	BCELoss	25	0.86836	0.84576
		50	0.91750	0.91018
	DiceLoss	25	0.92085	0.91542
		50	**0.97154**	**0.95578**
	FocalLoss	25	0.77734	0.78690
		50	0.93594	0.90207
Unet++	BCELoss	25	0.95526	0.93887
		50	**0.99024**	**0.98484**
	DiceLoss	25	0.94966	0.94163
		50	0.98713	0.98378
	FocalLoss	25	0.94630	0.93150
		50	0.97177	0.96680

Training and metric curves





Result of training



Achieved metrics of segmentation

Test metric
0.990

Validation metric
0.985

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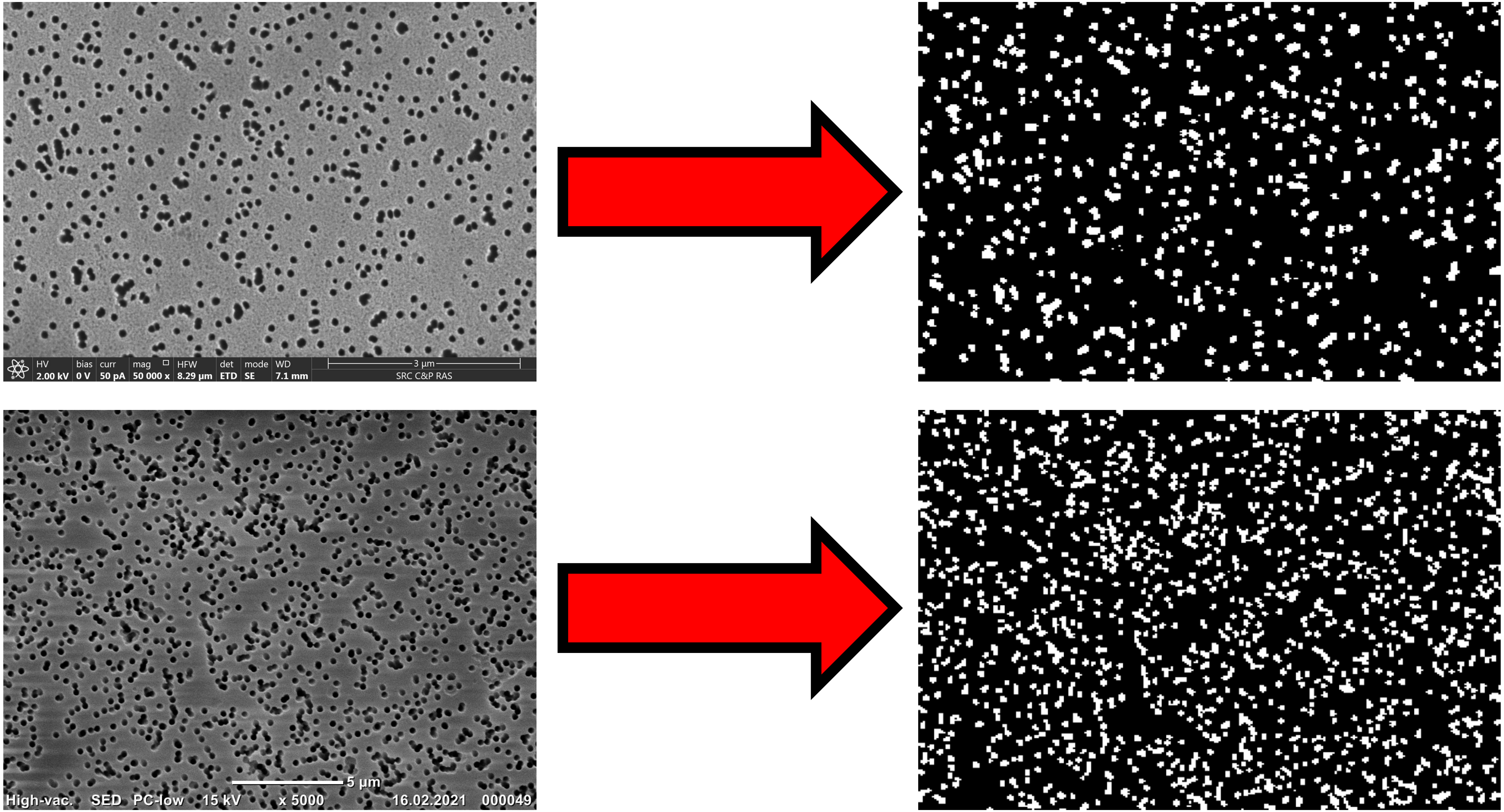
Calculation of characteristics

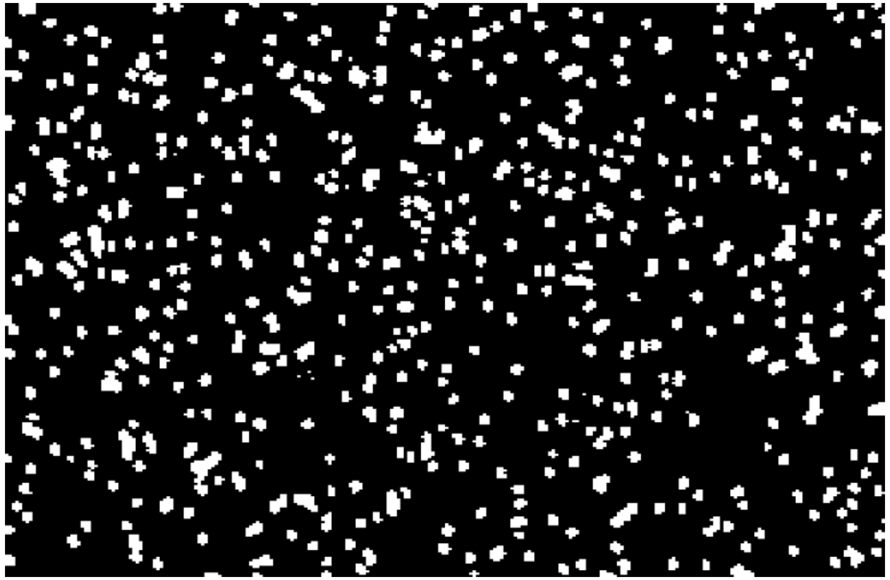


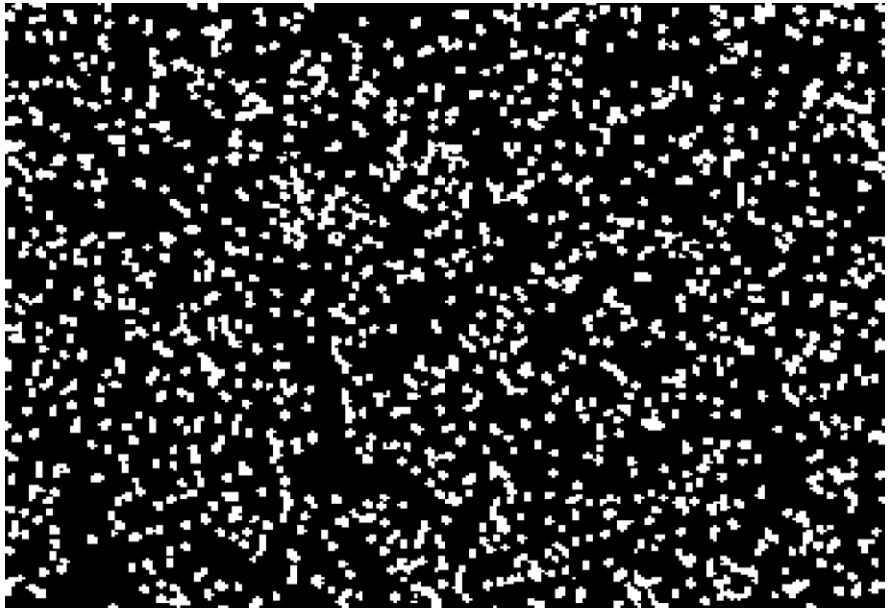
Calculation of characteristics

Porosity [%]

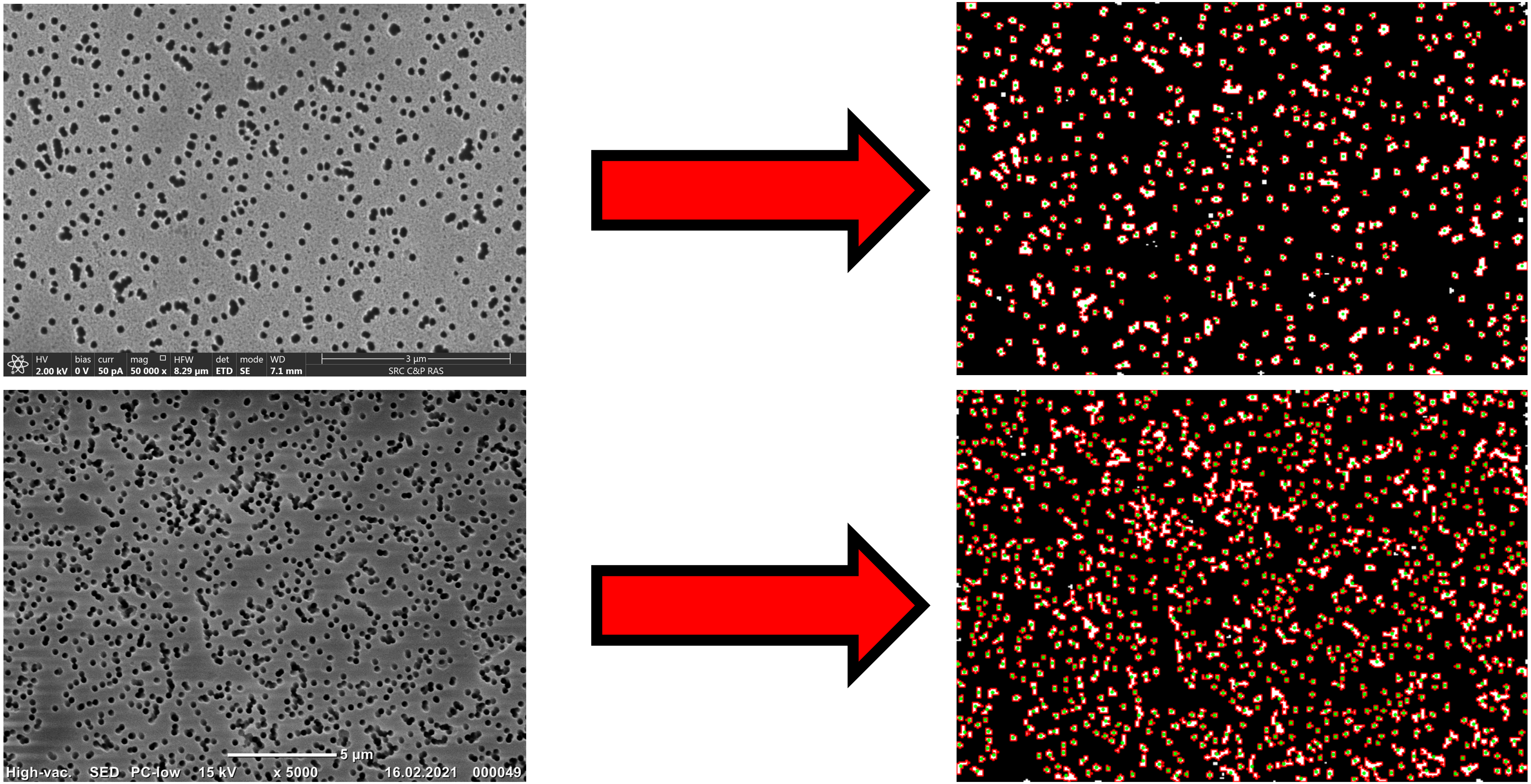
12.14294 (using model)
13.73415 (manually)

19.31616 (using model)
39.79699 (manually)



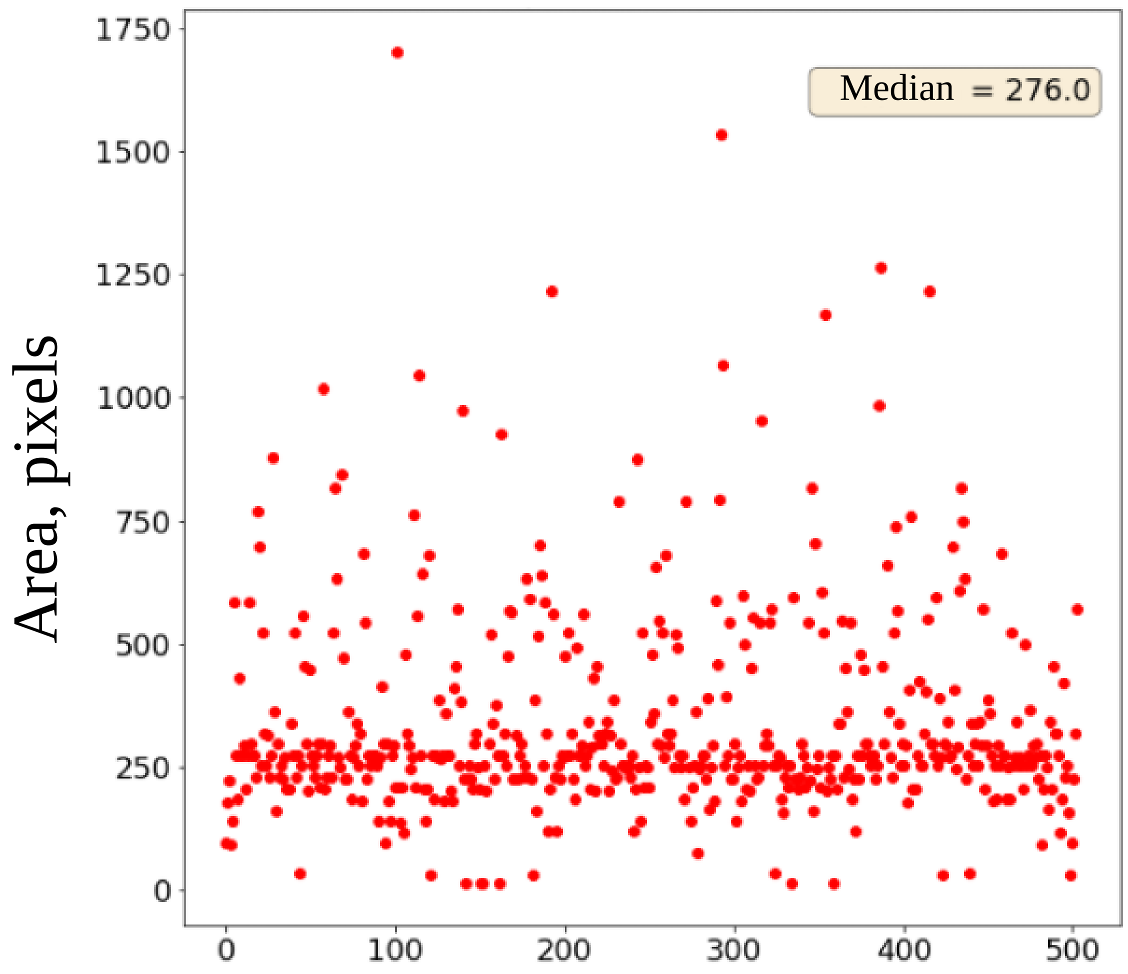


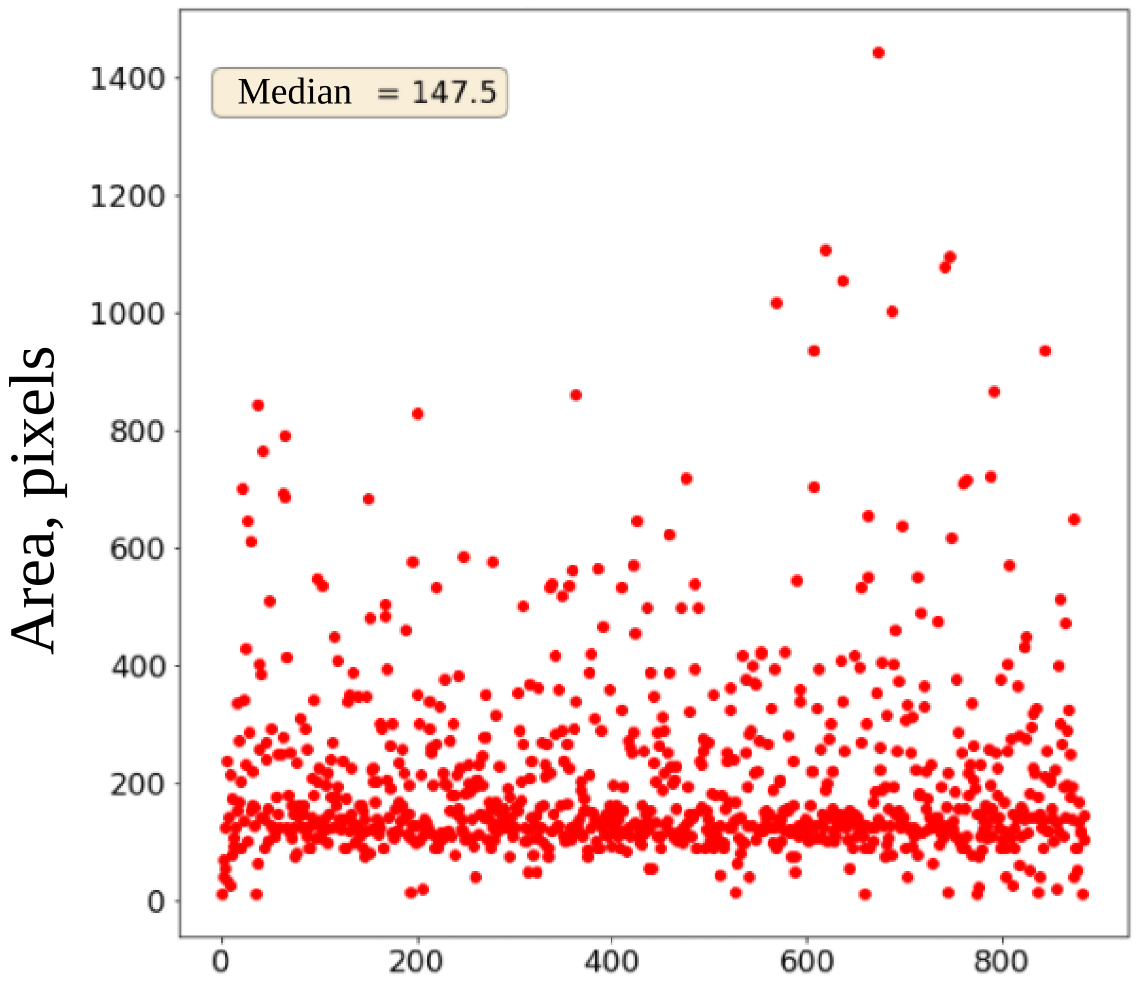
Calculation of characteristics



Pore localization → Area of all white regions and centers of masses

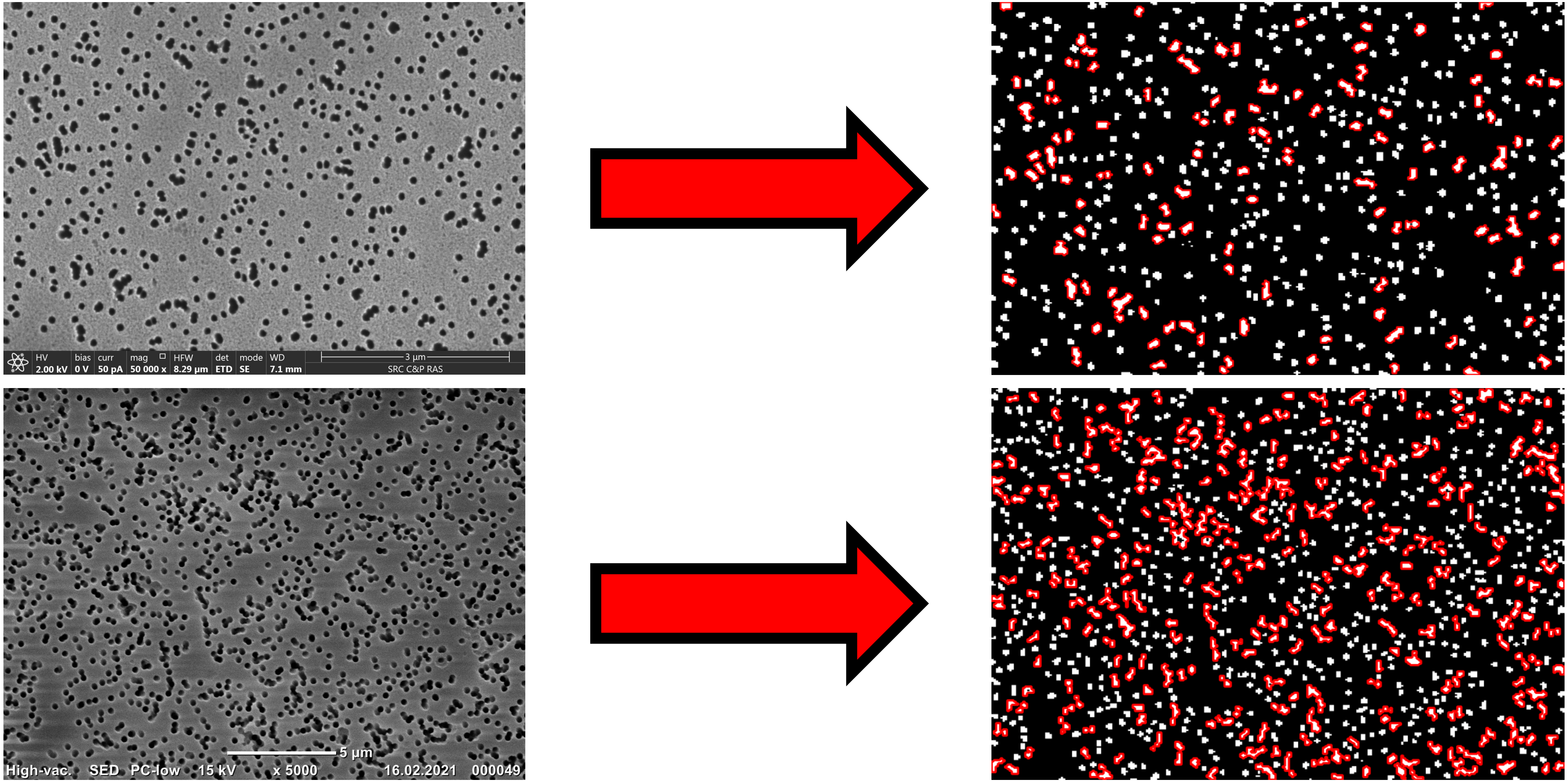
Calculation of characteristics





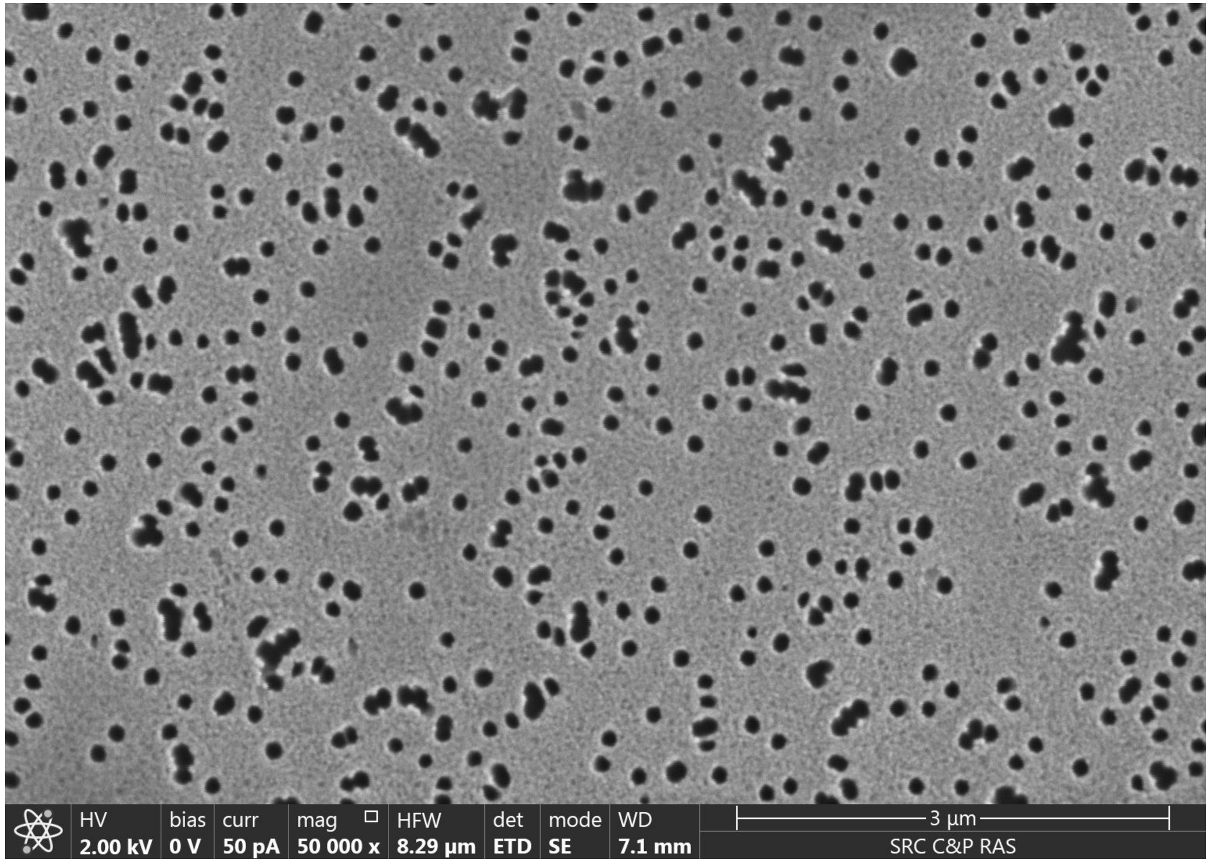
Area distribution of white regions

Calculation of characteristics

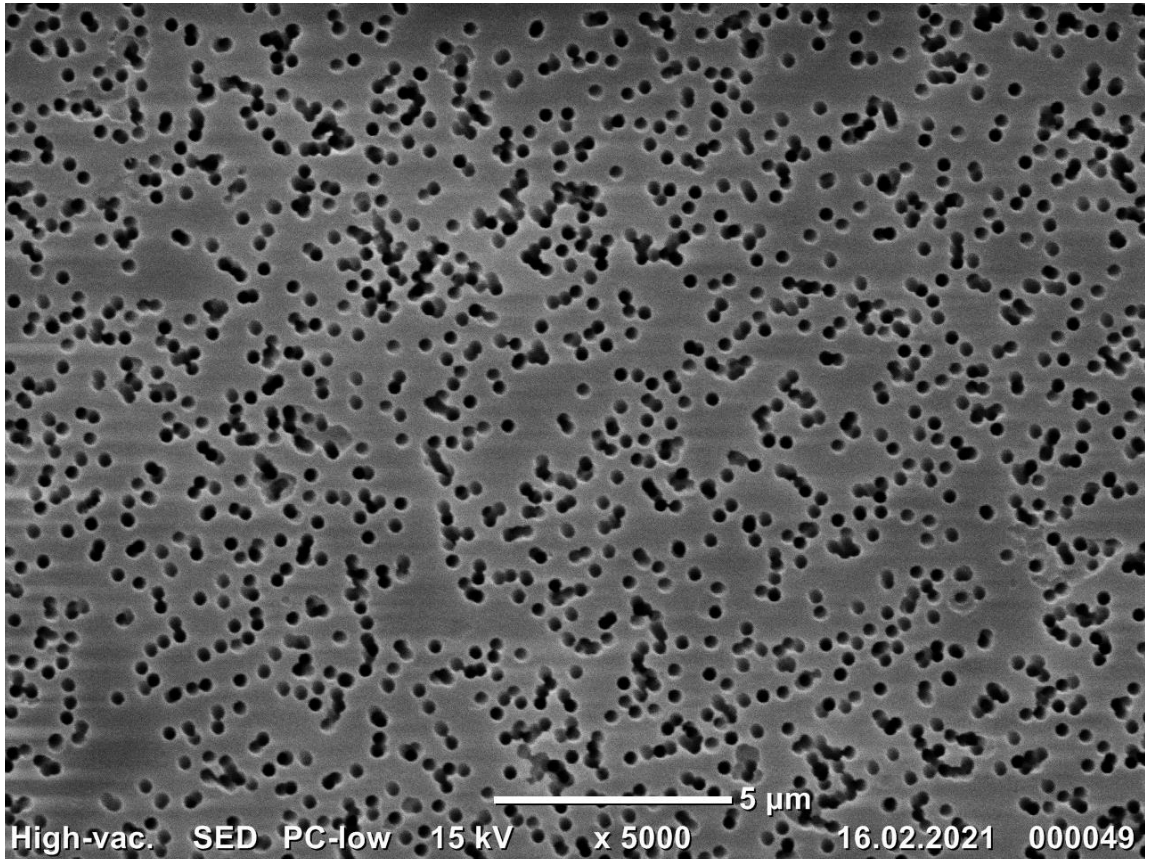


Localization of overlapping pores → Number of pores

Calculation of characteristics



Number of pores:
633 (using model)
624 (manually)



Number of pores:
1257 (using model)
1426 (manually)

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The main results of the work are…

- Implementation of qualitative image segmentation using UNet++ model
- Reached metrics of segmentation: **0.990** (test), **0.985** (validation)
- Application of classical computer vision algorithms to mask analysis
- Shown that suggested calculation approach can be used to calculate track membrane’s characteristics
- A comparison with the manual approach is provided, as well as limitations of the approach

Conferences

- III student conference Higher School of Education “From galaxy nuclei to atomic scales”, winner diploma

- 2-nd conference on condensed matter physics, Chernogolovka, DOI: 10.26201/ISSP.2020/FKS-2.351

- Kuznetsov N. V., Bedin S. A. “Search for pores on the surface of track membranes using machine learning”, Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques (sent to the journal)

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