eli nuclear physics

Tumor segmentation from scattering images obtained with a Talbot-Lau interferometer using Convolutional Neural Networks

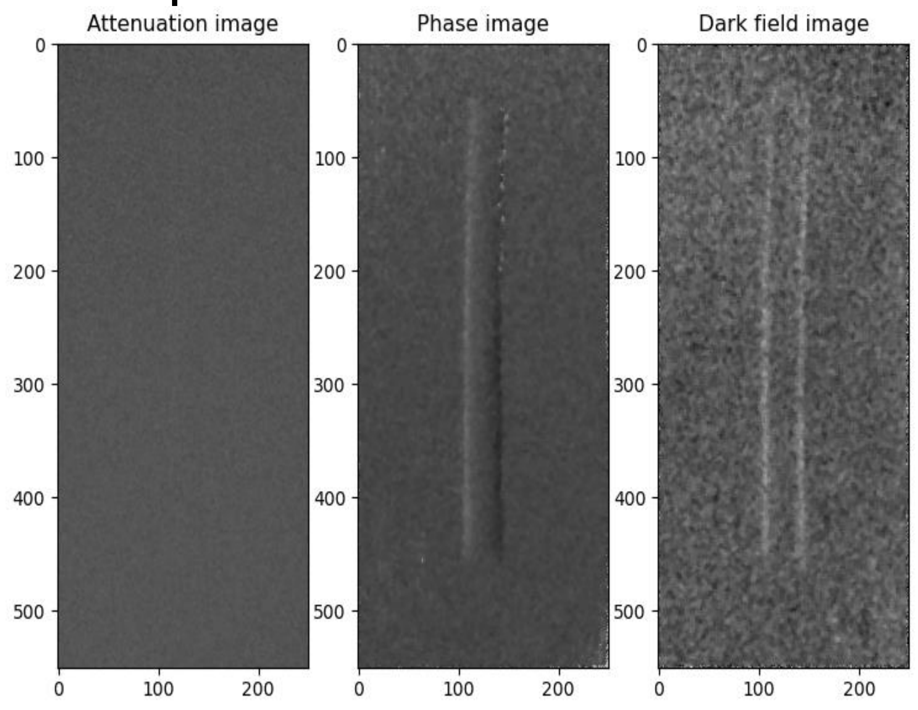
Student:
Ionuț-Cristian Ciobanu

Phase contrast imaging

- Based on refraction, not on absorption;
- Three contrast channels can be obtained (absorption channel, phase channel, and scattering channel).

Advantages of the technique

- Improved contrast in images;
- Good visibility is achieved in soft tissues;
- It has the potential to reduce the dose.

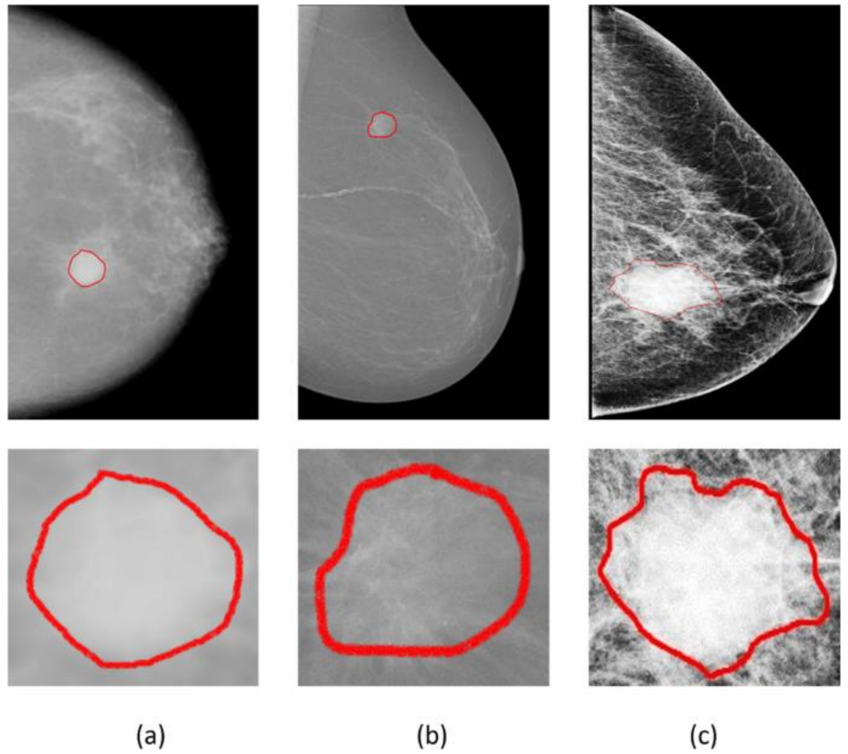


I. Ciobanu et. al., UPB Sci. Bull., 2023

Fig 1. Images that can be obtained.

Convolutional Neural Networks

- Can learn to recognize complex patterns in images and detect abnormalities, like tumors or lesions;
- Using CNNs to analyze medical data can automate tasks that would decrease the time diagnosis and increase the quality of diagnosis;
- CNNs can process large amounts of data and continuously improve the accuracy of diagnoses.



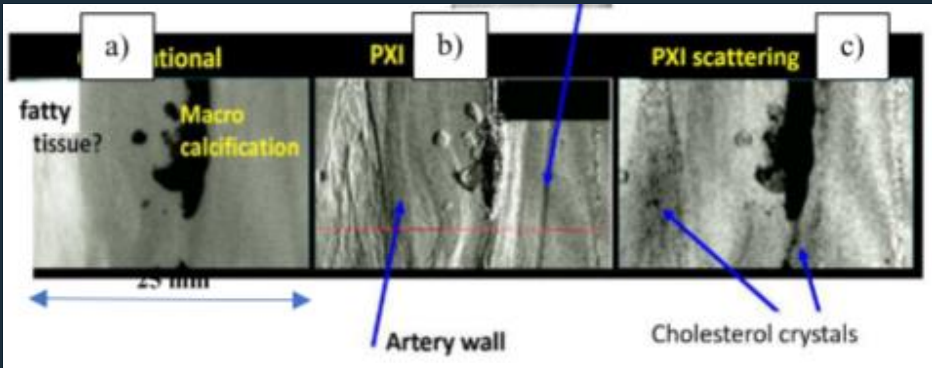
Baccouche, A., et al., npj Breast Cancer, 2021.

Fig 2. Detection of tumors in conventional mammograms using CNNs.

State of the art

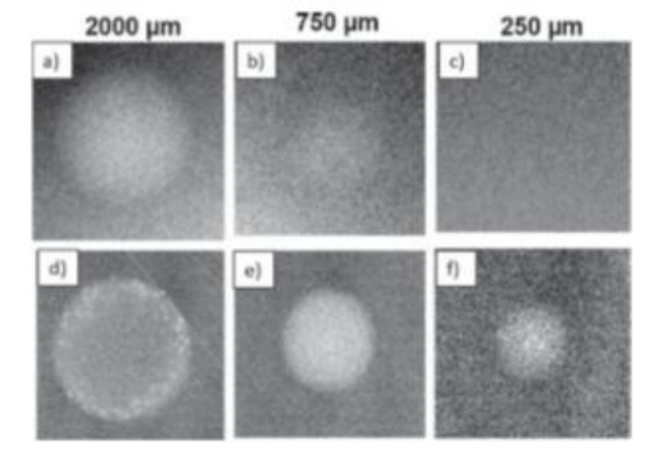
Medical applications of the Talbot-Lau interferometer:

- For cardiovascular applications; 1.8m long interferometer using 2.4 micron gratings;
- For visualizing joints; 3.5m long interferometer using 10 micron gratings (*Dan Ștutman et. al. 2011*);
- X-ray and dark-field CT of the lungs;
- Mammography.



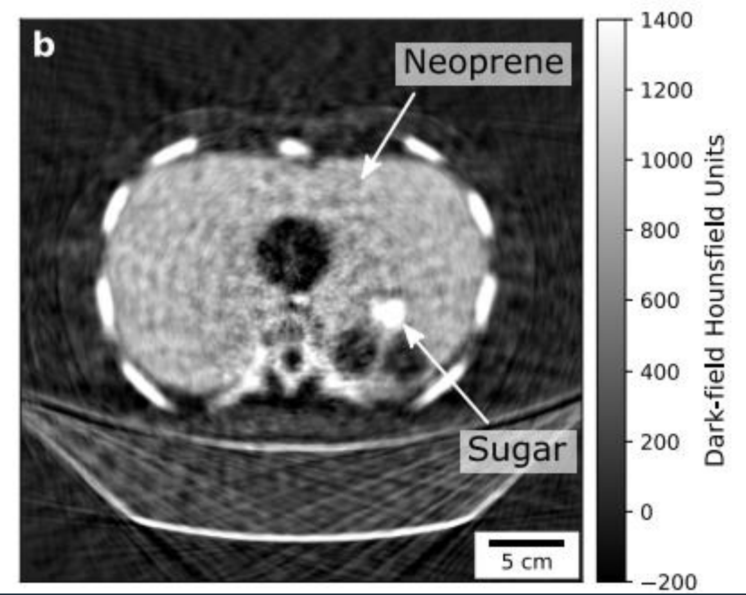
N. Safca el. al. 2021

Fig 3. Atherosclerosis in phase contrast imaging.



N. Safca et. al. 2022

Fig 5. Comparison of conventional and phase contrast mammography



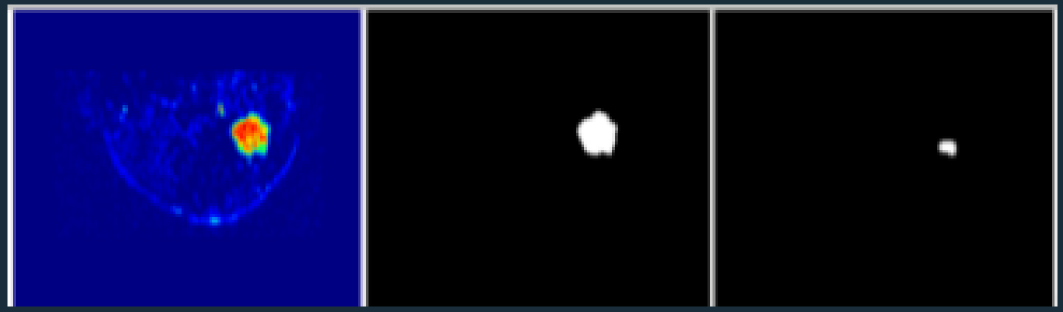
Gassert et. al. 2021, Viermetz et. al. 2022

Fig 4. Dark-field CT of lungs

- The highest sensitivity of a Talbot-Lau interferometer used in medical applications is 0.87 microradians. That interferometer is in X-ray Imaging Laboratory at ELI-NP.

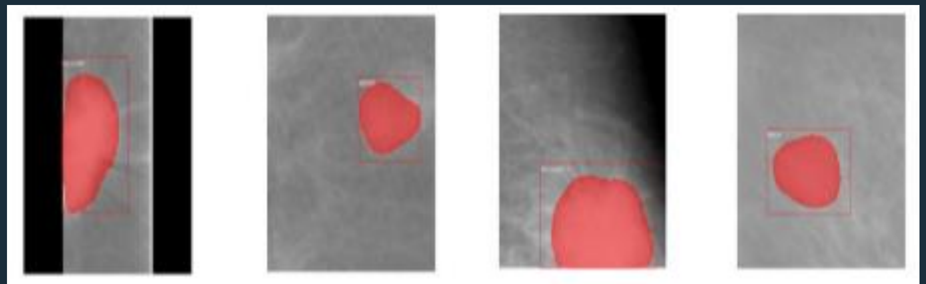
The most used convolutional neural networks for segmenting biomedical images used in the diagnosis of breast cancer(*L.J.H. Leow et. al. 2024, I.N. Anghelache Năstase et. al. 2024, C. B. Goncalves et. al. 2022, T. Alam et. al. 2023*):

- Mask-RCNN; U-net; VGG-16; DeepLabV3; SegNet; PSPNet; ResNet50.



M. El Adoui et. al. 2019

Fig 6. CNNs prediction results in MRI images



S.K Raza et. al. 2023

Fig 7. CNNs prediction results in mammograms.

The CNNs in phase contrast imaging were used only in the filtration of phase images and to detect threat objects from scattering images (*T. Partridge et. al. 2022; Y. Ge et. al. 2021*).

Materials and methods

Set-up

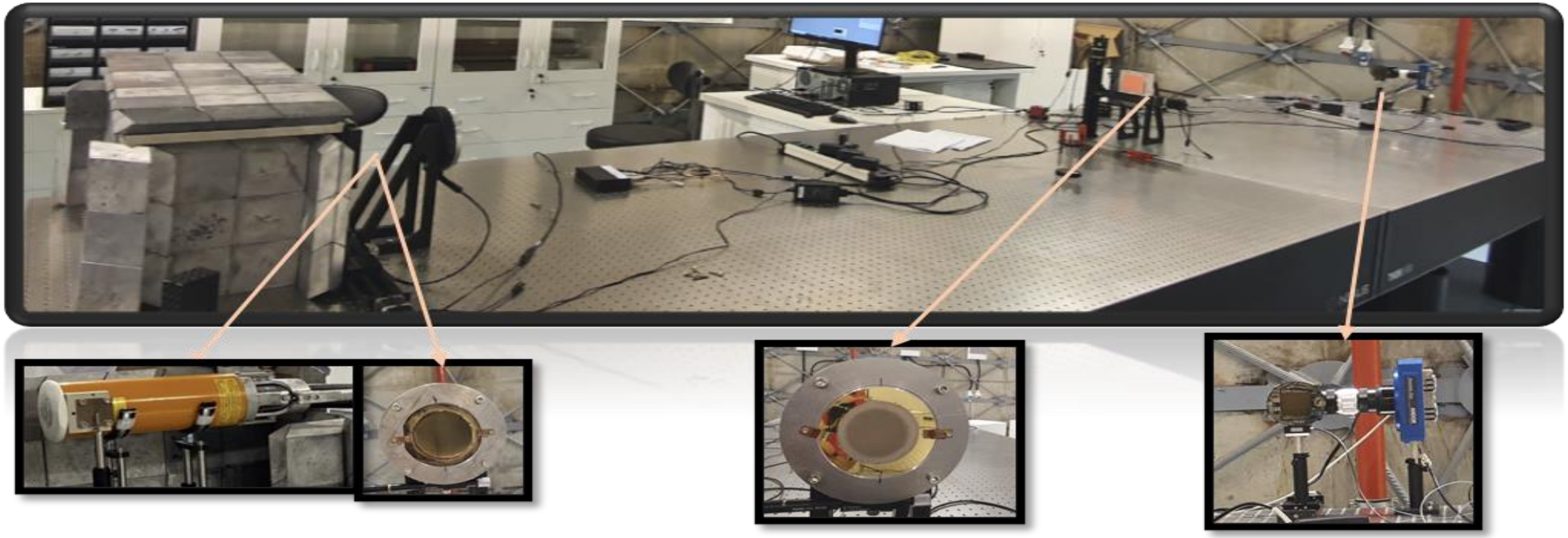


Table 1. Parameters of the interferometer used

Parameter	Value
Sensitivity [μrad]	0.87
Contrast [%]	15
Length [m]	6

Fig 8. Talbot-Lau Ultrahigh Sensitivity Interferometer

Materials and methods

The sample

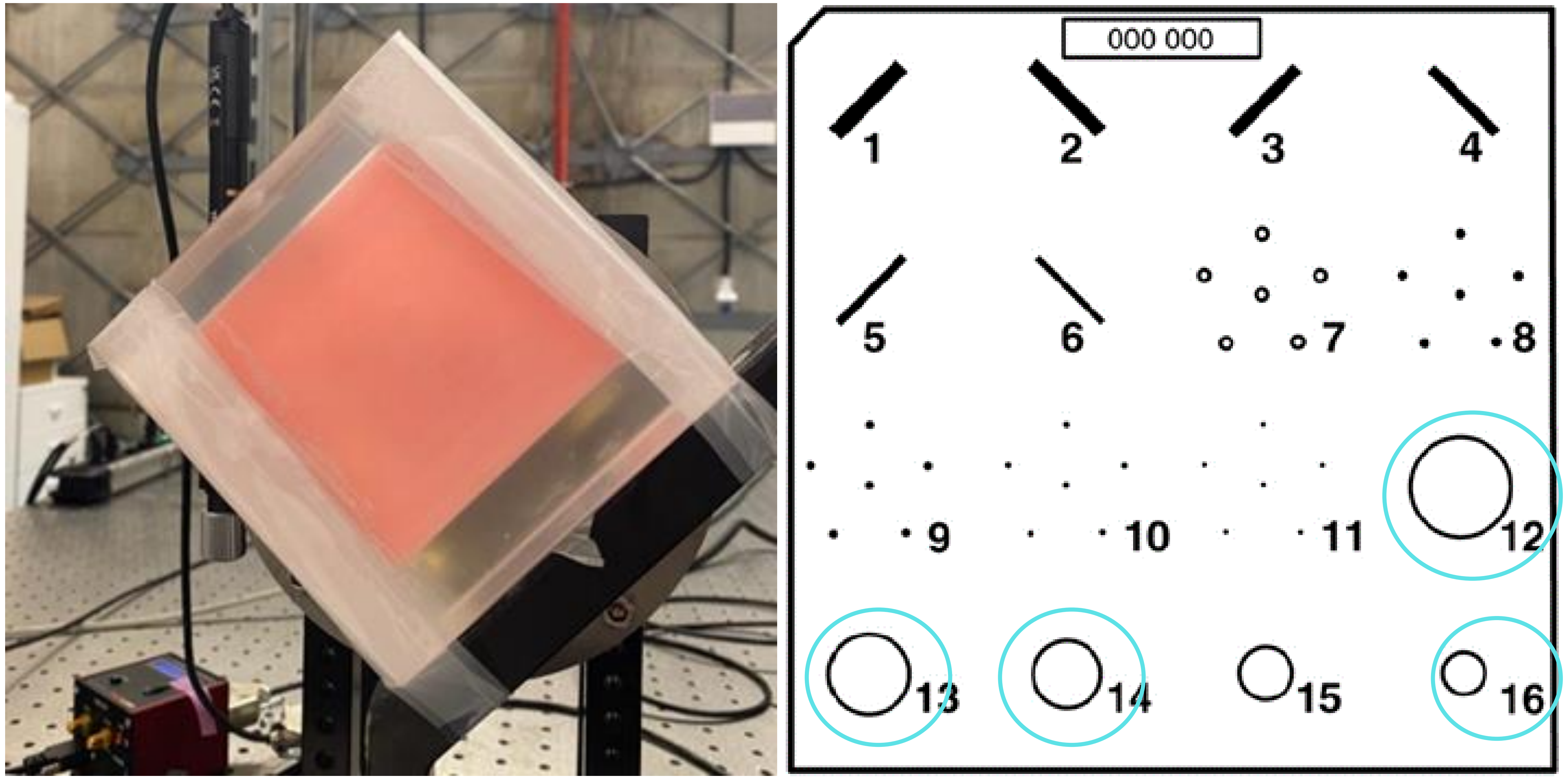


Fig 9. The analyzed sample and its structure

- Breast phantom that mimics a compressed breast composed of 50% glandular tissue and 50% adipose tissue.
- Tumors analyzed:
  1. Tumor 12: 2 mm;
  2. Tumor 13: 1 mm;
  3. Tumor 14: 0.75 mm;
  4. Tumor 16: 0.25 mm.

Materials and methods

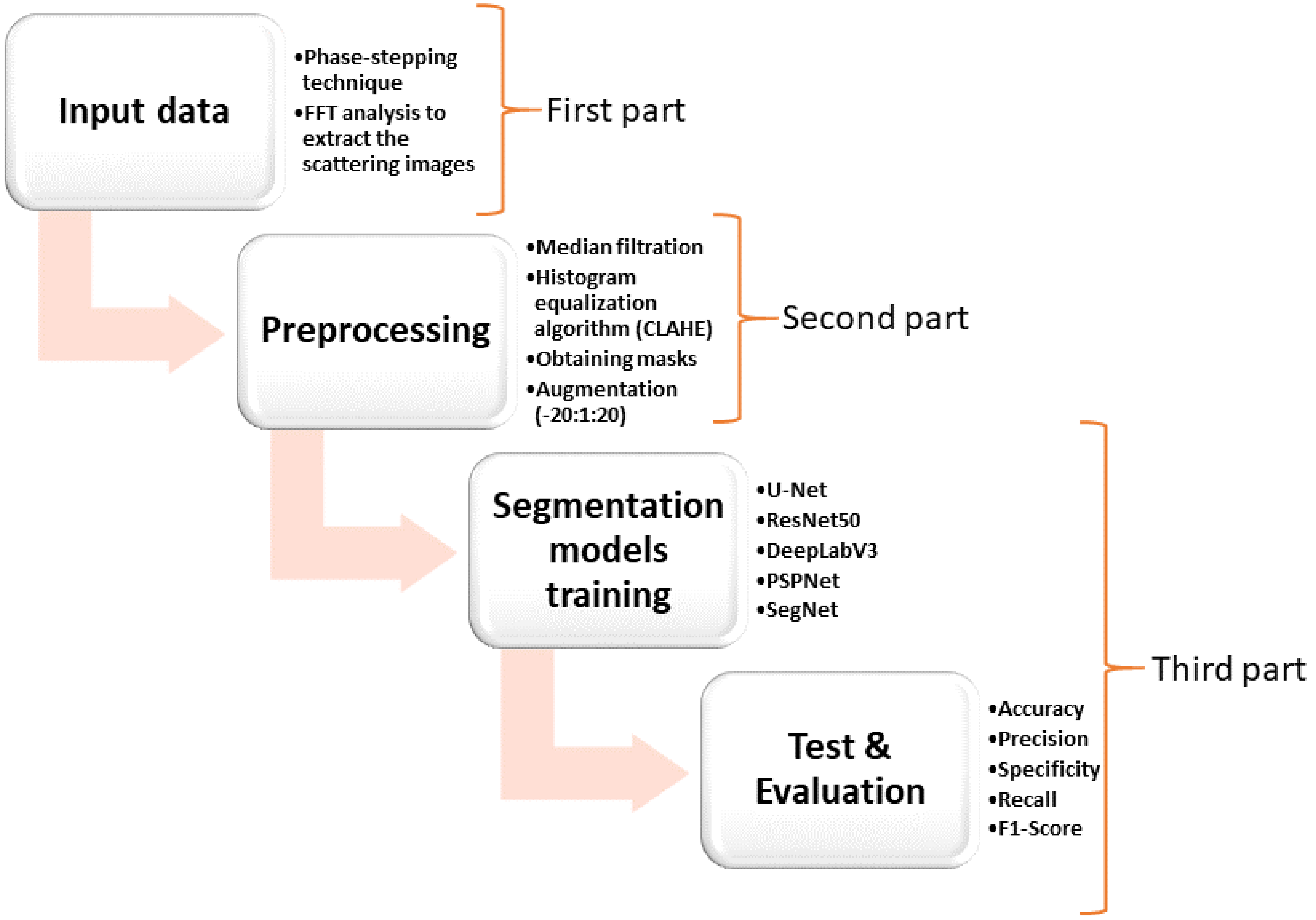


Fig 10. Diagram flow of the algorithm

Algorithm used

Conclusions

- ResNet50 has the worst performance for scattering image segmentation obtained with the high-sensitivity Talbot-Lau interferometer.
- The highest accuracy is achieved in the case of DeepLabV3, and precision and specificity have the highest values in the case of PSPNet, but these CNNs present overfitting, which means that are not suitable for our task.
- Also, SegNet present overfitting.
- U-Net performs in terms of recall, and has the most stable variation of loss and accuracy. U-net accuracy is 1% lower than DeepLabV3 accuracy, which is not a big difference. All that fact makes U-Net the most suitable CNN for scattering image segmentation.
- Even the dataset is small (320 images) we obtained good results and we expect that by increasing the dataset we will obtain even better results.
- Also, we expect the dataset to be as large as datasets used in conventional techniques, because of the good characteristics of images.

Future work

- Increasing the volume of the dataset to obtain higher values of performance parameters.
- Testing the CNNs on a dataset with tumors from real tissue.
- Optimization of CNNs structures.

Thank you!