European Commission
Horizon 2020
European Union funding
for Research & Innovation

Three dimensional breast cancer models
for X-ray imaging research

MaXIMA

H2020-TWINN-2015, Grant Agreement 692097

Development of breast tumours models database

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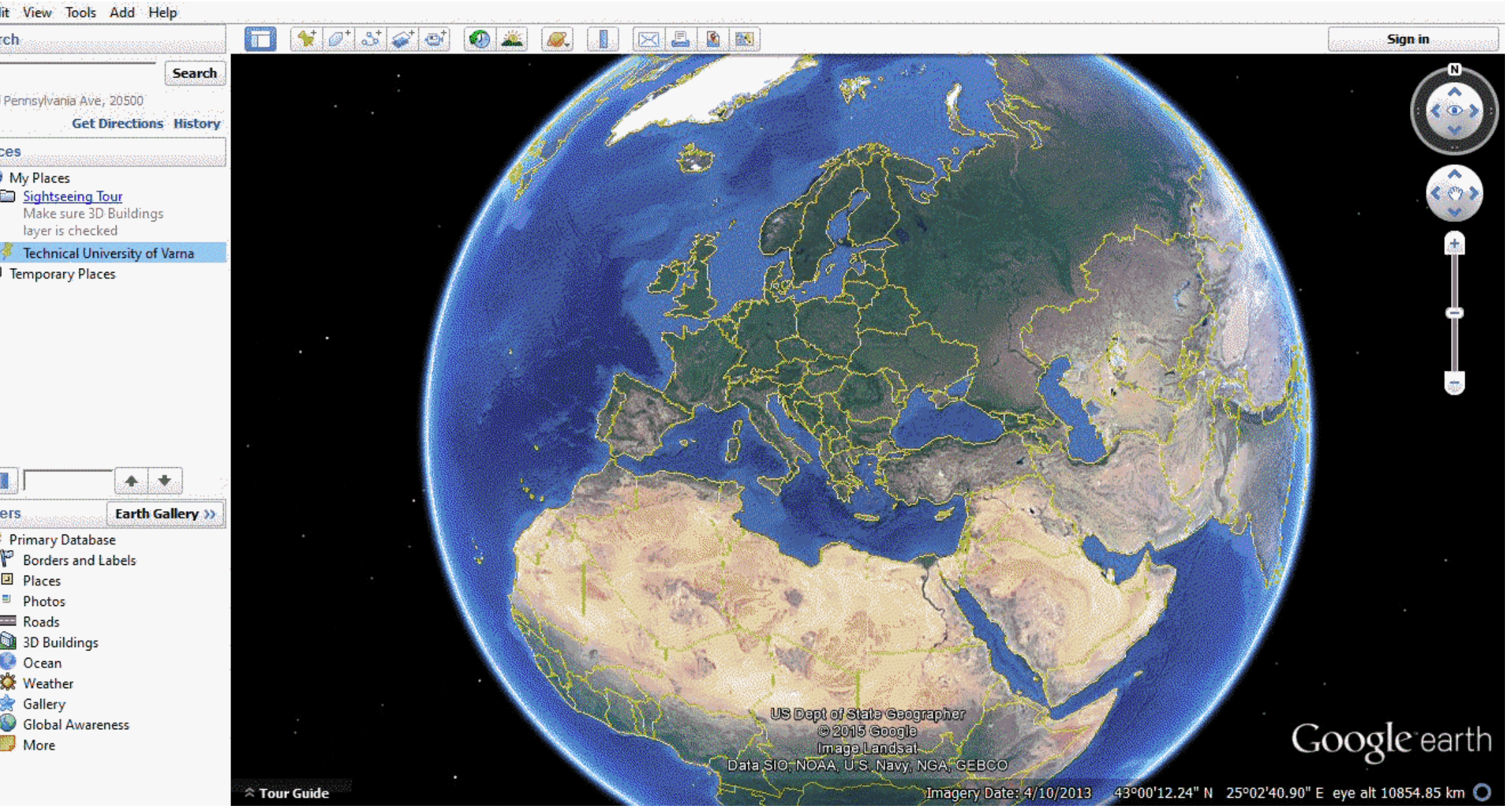
Laboratory of Computer Simulations in Medicine

Maxima team

location ☺

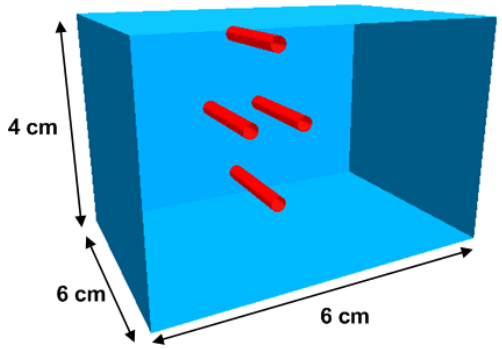

View Tools Add Help
Search
Pennsylvania Ave, 20500
Get Directions History
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Technical University of Varna
Temporary Places
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
Sign in
US Dept of State Geographer
© 2015 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Tour Guide
Imagery Date: 4/10/2013 43°00'12.24" N 25°02'40.90" E eye alt 10854.85 km

The place

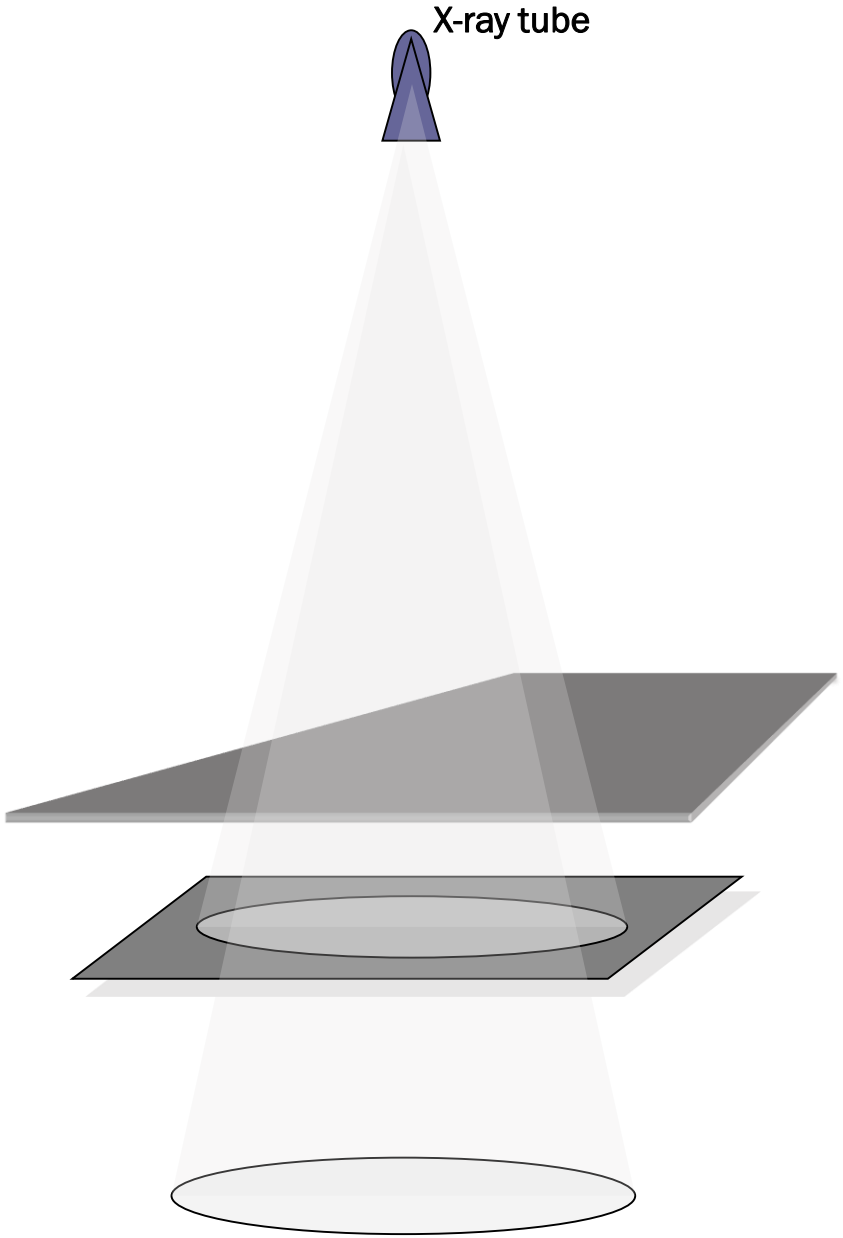
Outline

- Why realistic models of abnormalities?
- Our approach and advances
- Exploitation of results in practice

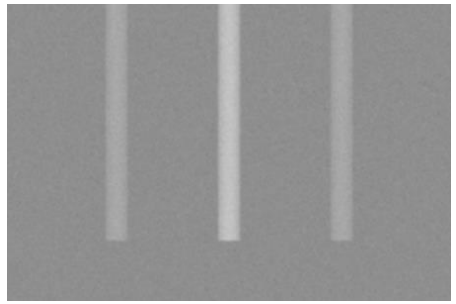
Simulation

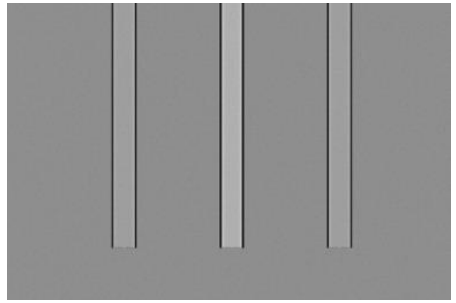


Mathematical phantom



Projection images

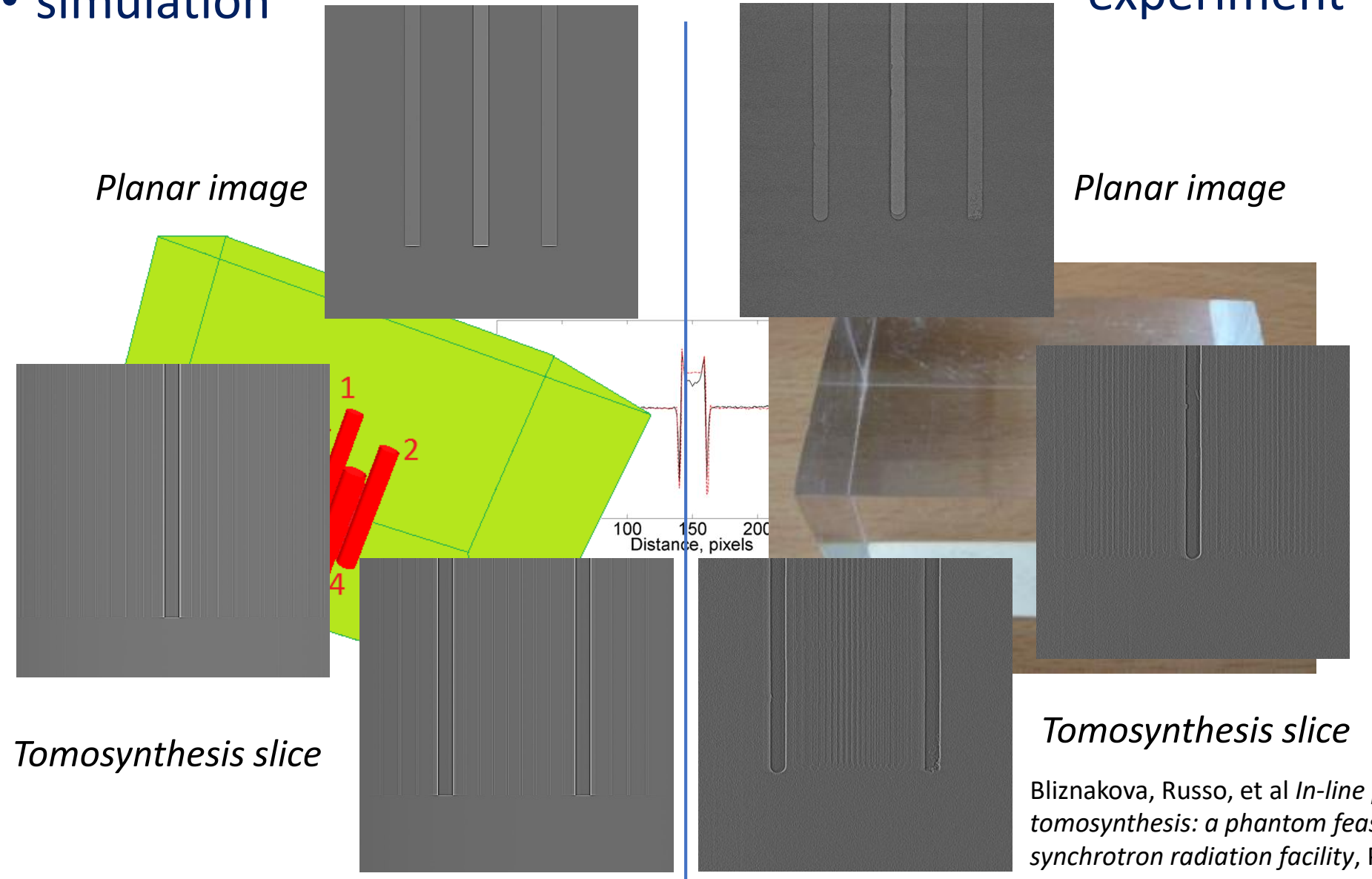




Earlier validation studies

- simulation

Planar image



Tomosynthesis slice

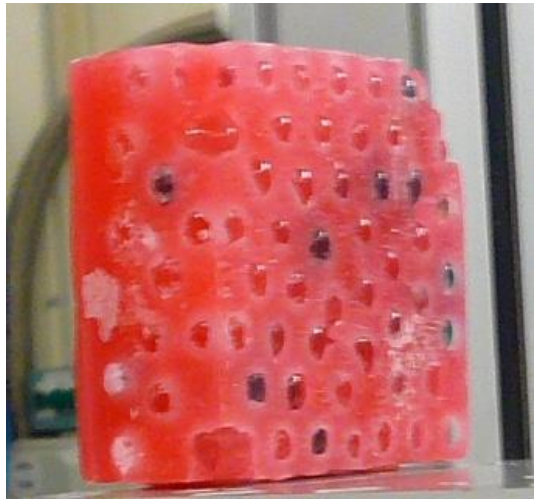
- experiment

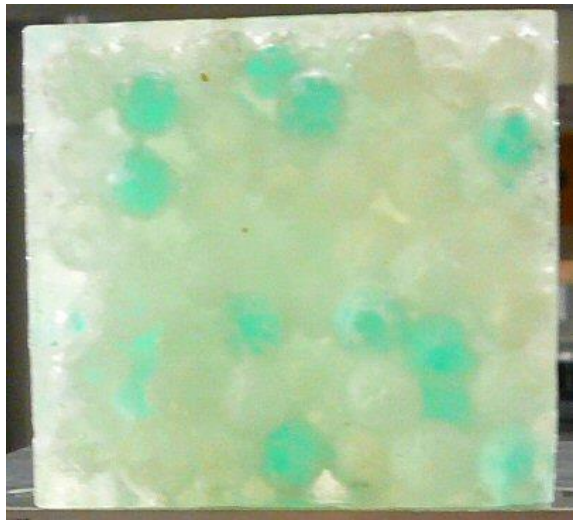
Planar image

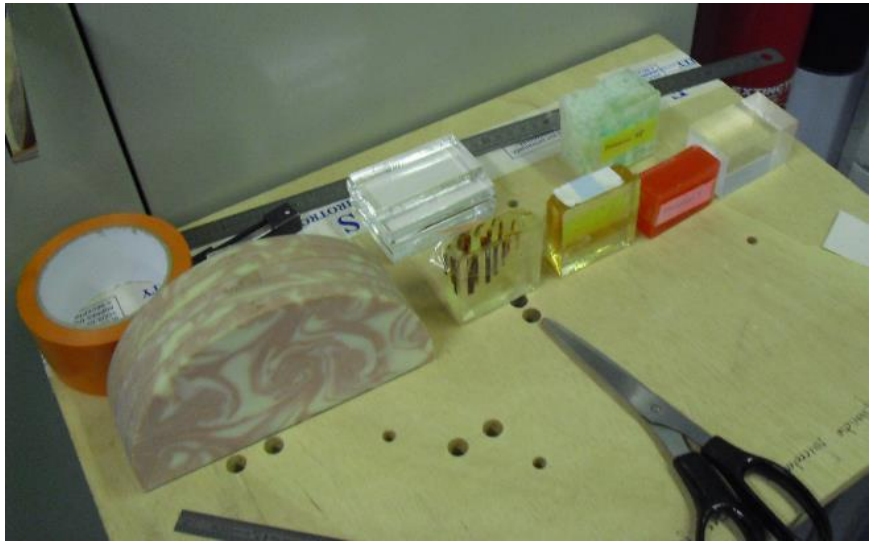
Tomosynthesis slice

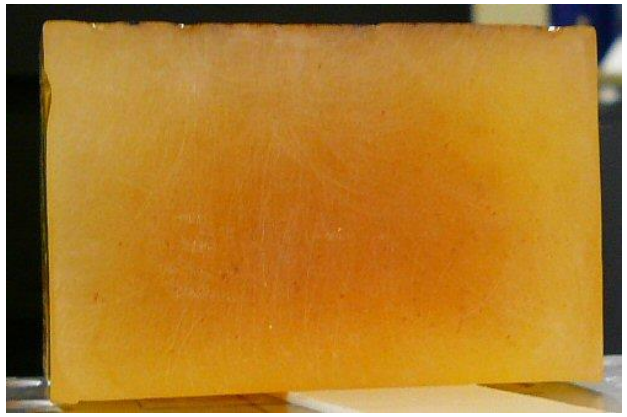
Bliznakova, Russo, et al *In-line phase-contrast breast tomosynthesis: a phantom feasibility study at a synchrotron radiation facility*, PMB, 61(16):6243-63

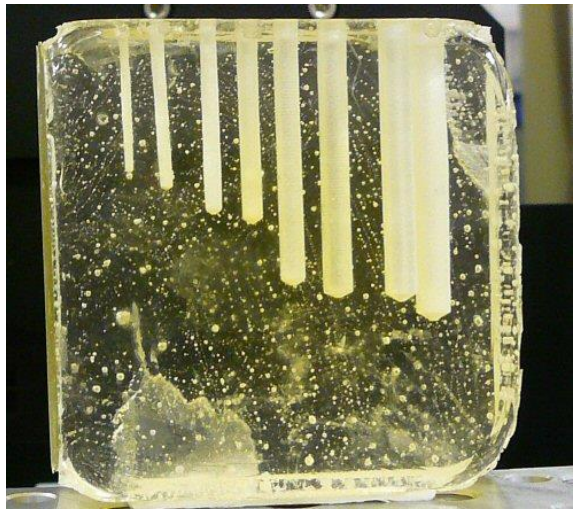
Earlier validations









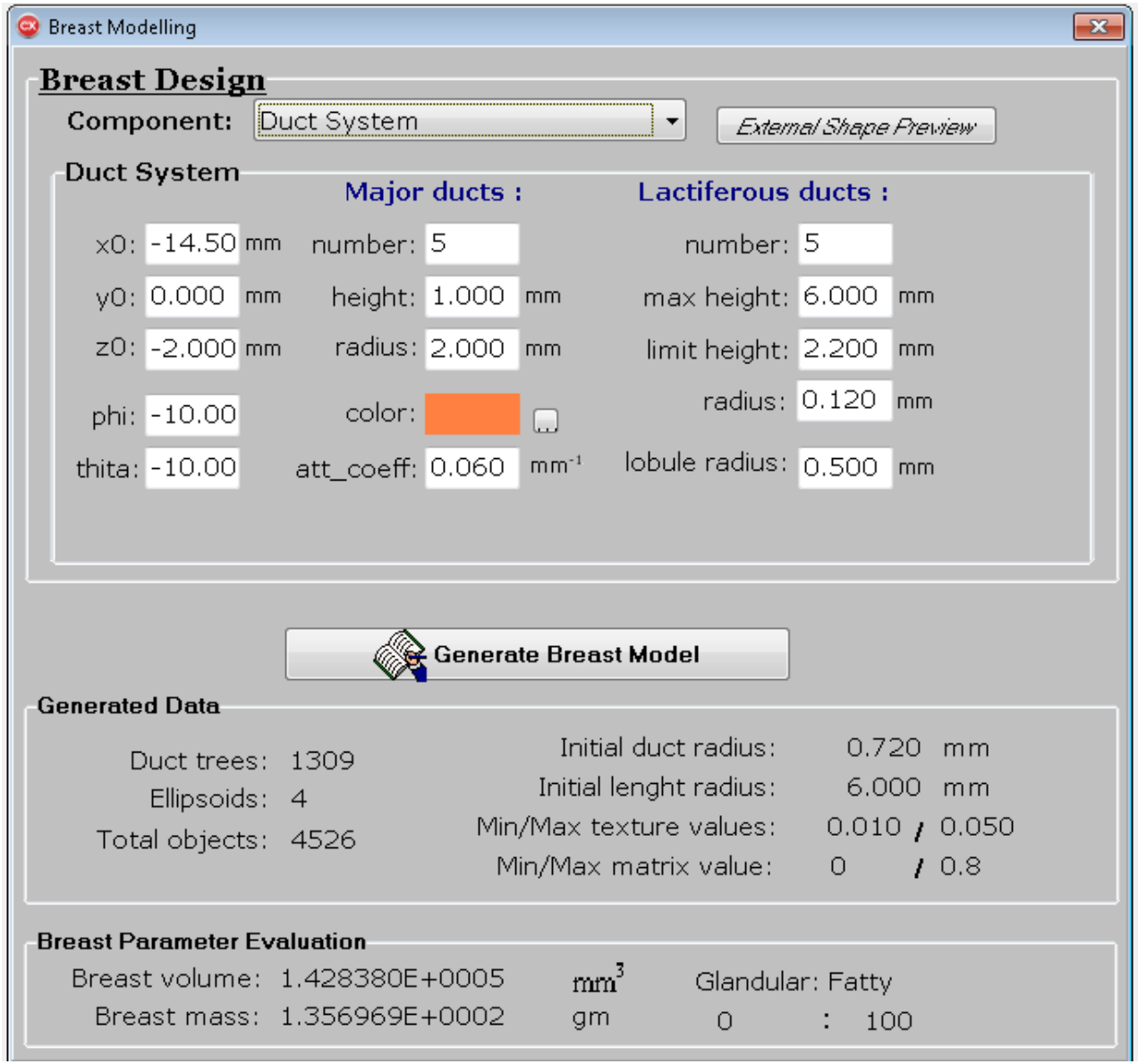


? Anthropomorphic breast phantoms ?

Creation of a Breast Model

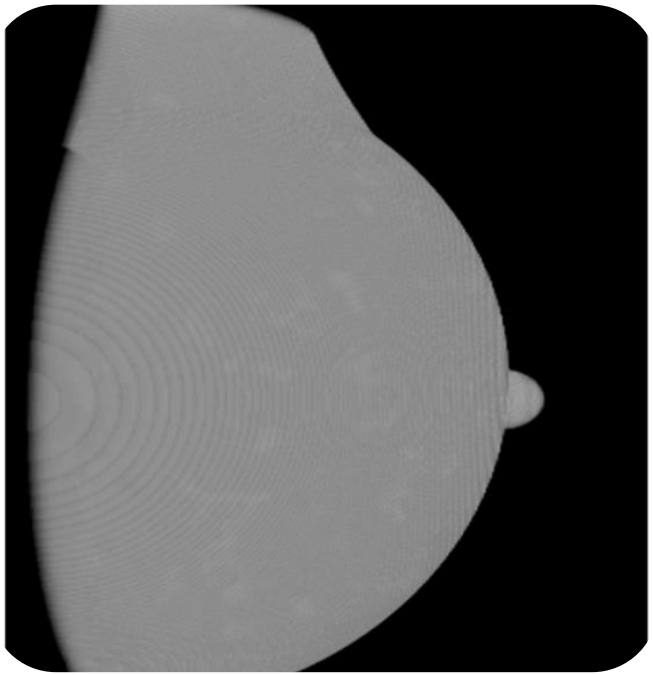
- Tool for creation of breast models.

  - ✓ Shape
  - ✓ Size
  - ✓ Glandular tissues
  - ✓ Adipose tissue
  - ✓ Skin
  - ✓ Abnormalities

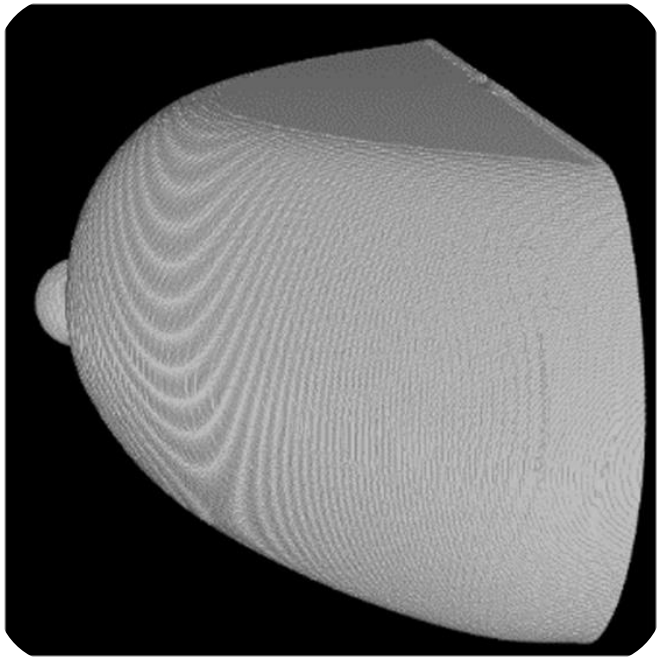


BreastSimulator

Anthropomorphic phantom

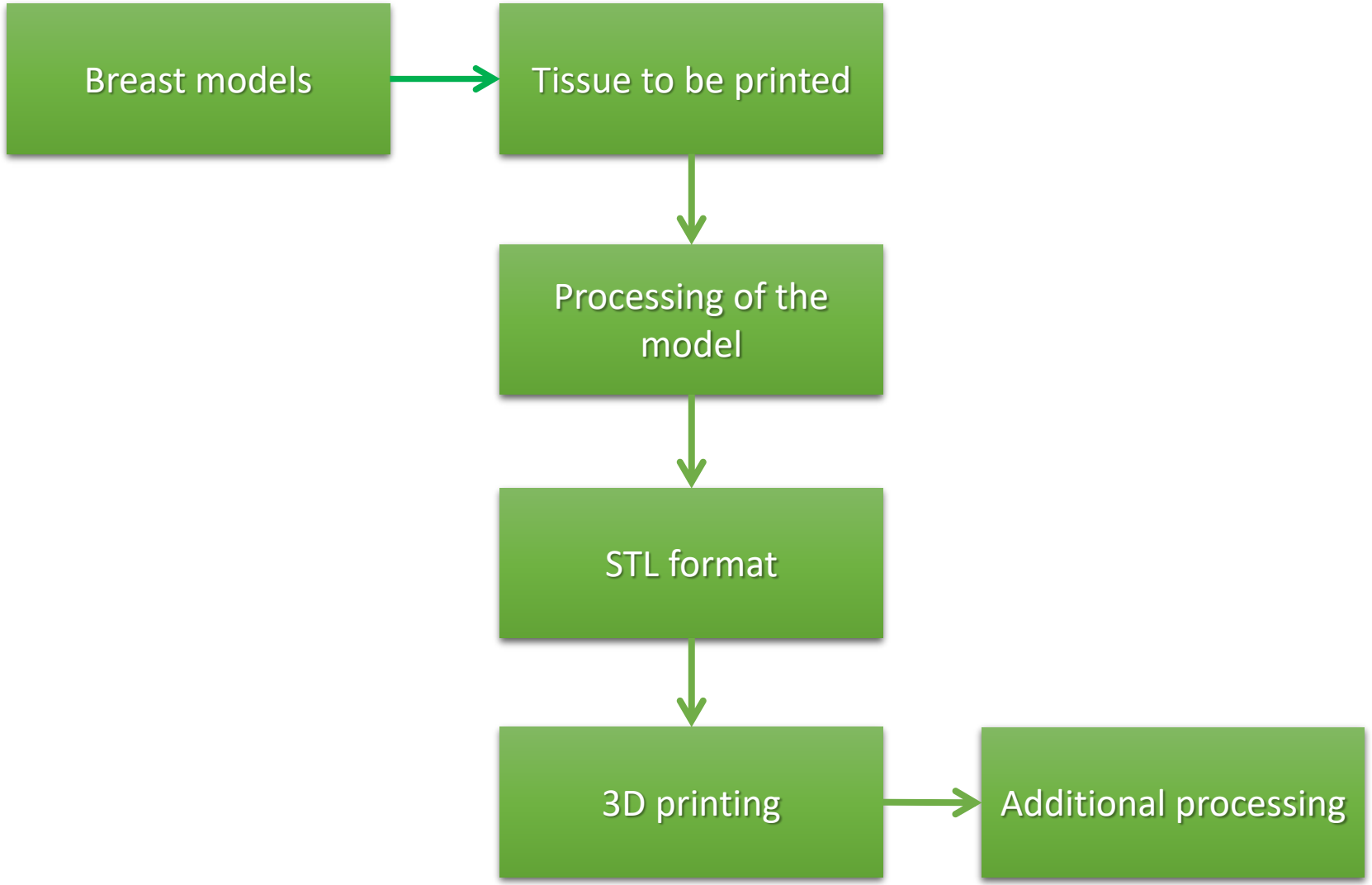


Modeled breast phantom

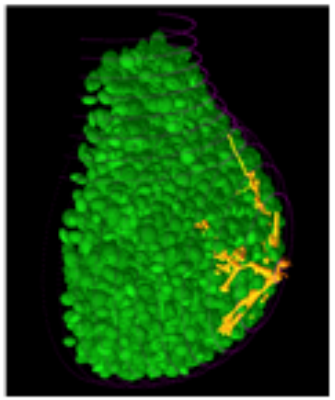


Compressed breast phantom

Development of physical breast phantoms for phase contrast imaging

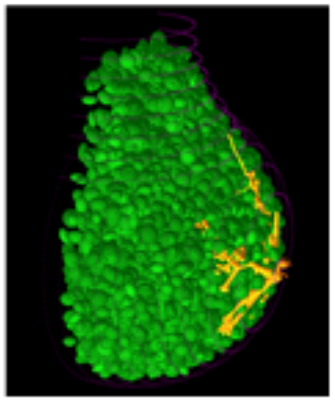


Development of physical breast phantoms for phase contrast imaging



Breast models → Tissue to be printed → Processing of the model → STL format → 3D printing → Additional processing

Development of physical breast phantoms for phase contrast imaging



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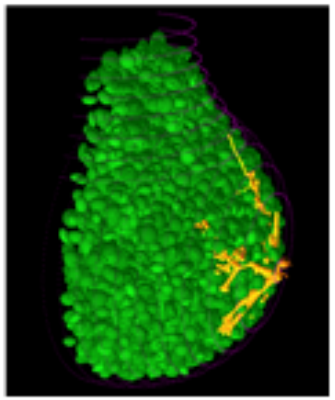

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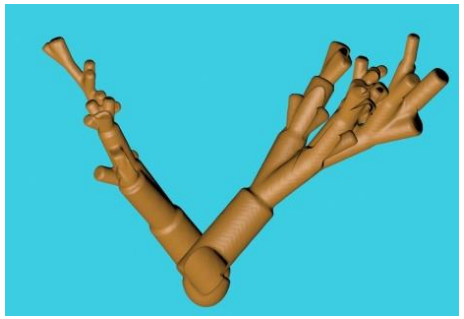
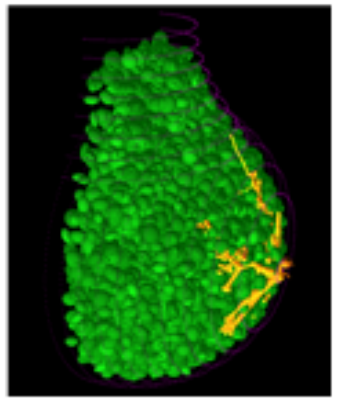
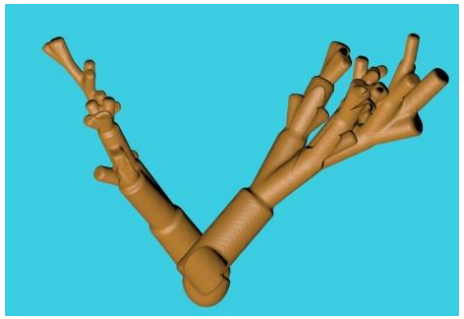


Development of physical breast phantoms for phase contrast imaging



Breast models → Tissue to be printed

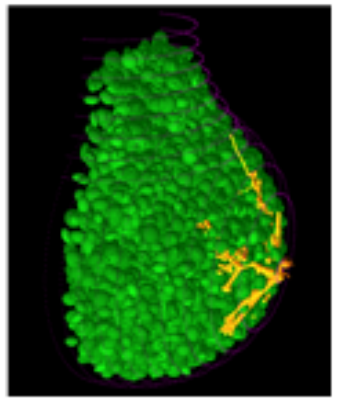


Processing of the model

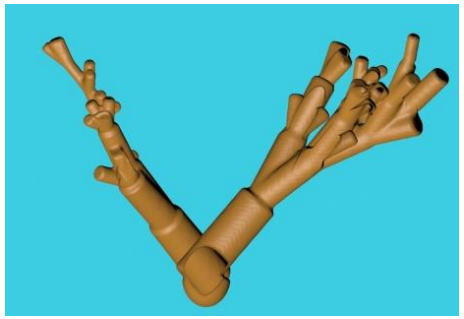
STL format

3D printing → Additional processing

Development of physical breast phantoms for phase contrast imaging



Breast models → Tissue to be printed



Processing of the model

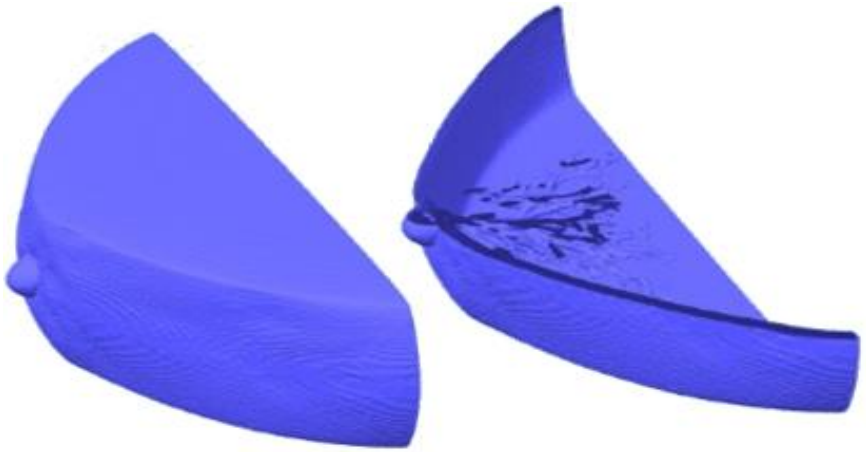
STL format

3D printing → Additional processing

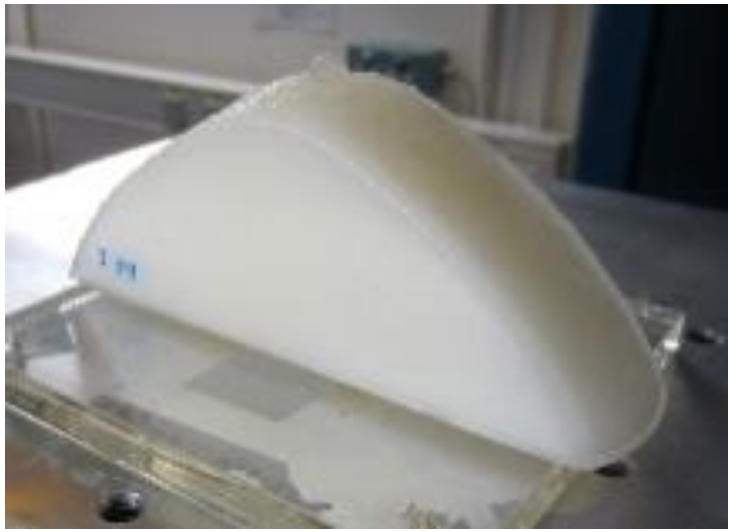

BreastSimulator - D:\BreastSimulator\Win64\Debug
Phantom
Analytical Image Simulation
Visualization
Tools
Window
Help

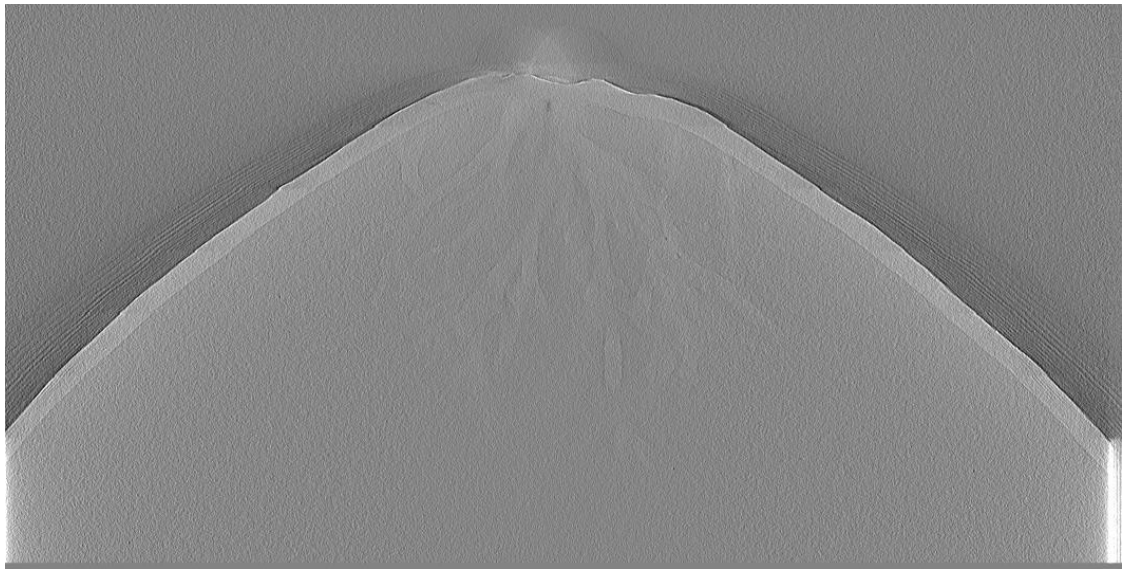
Anthropomorphic phantoms

- Breast shape – Clear resin;
- Glandular tree – Clear resin;



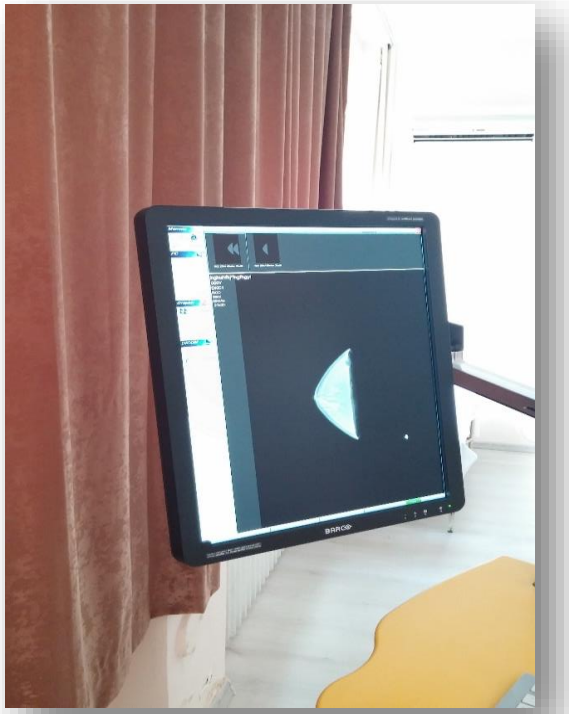
- Animal fat;
- Thickness – 31 mm;
- Wall thickness – 1.7 mm.

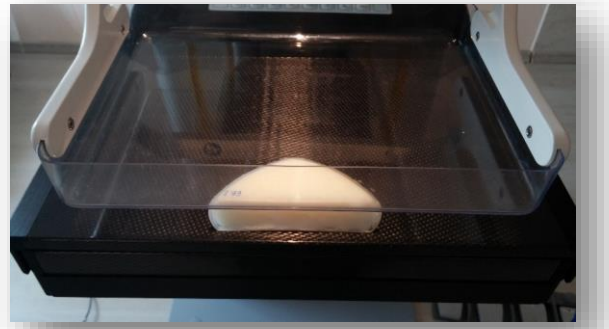


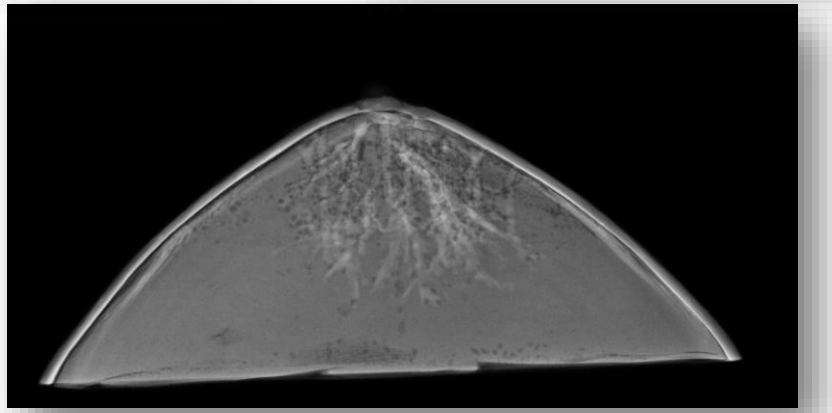


Development of physical breast phantoms for phase contrast imaging

Physical phantoms







Courtesy Danail Ivanov et al, FOCHOS, 2016

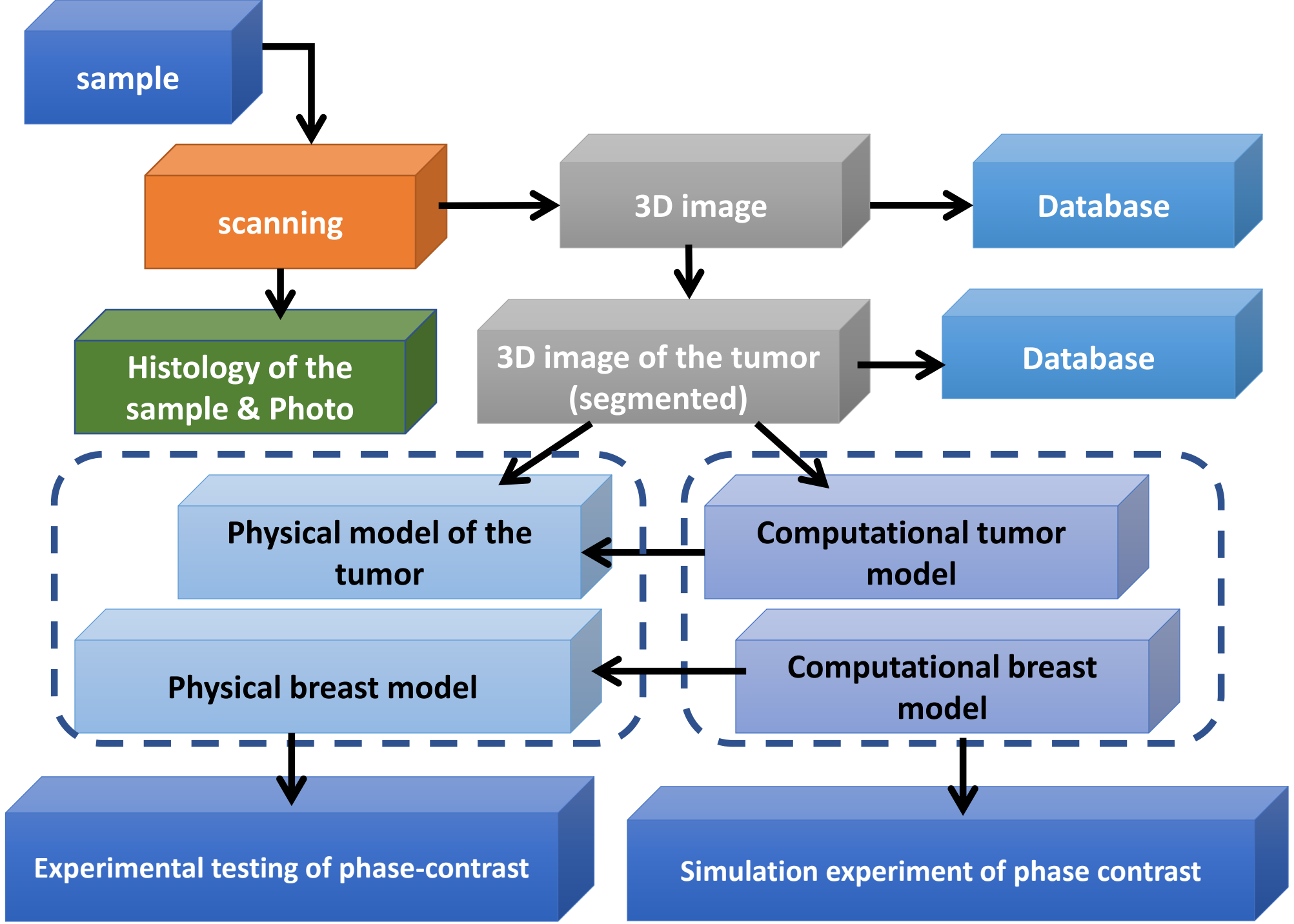
? Realistic in shape, size and absorption properties tumors

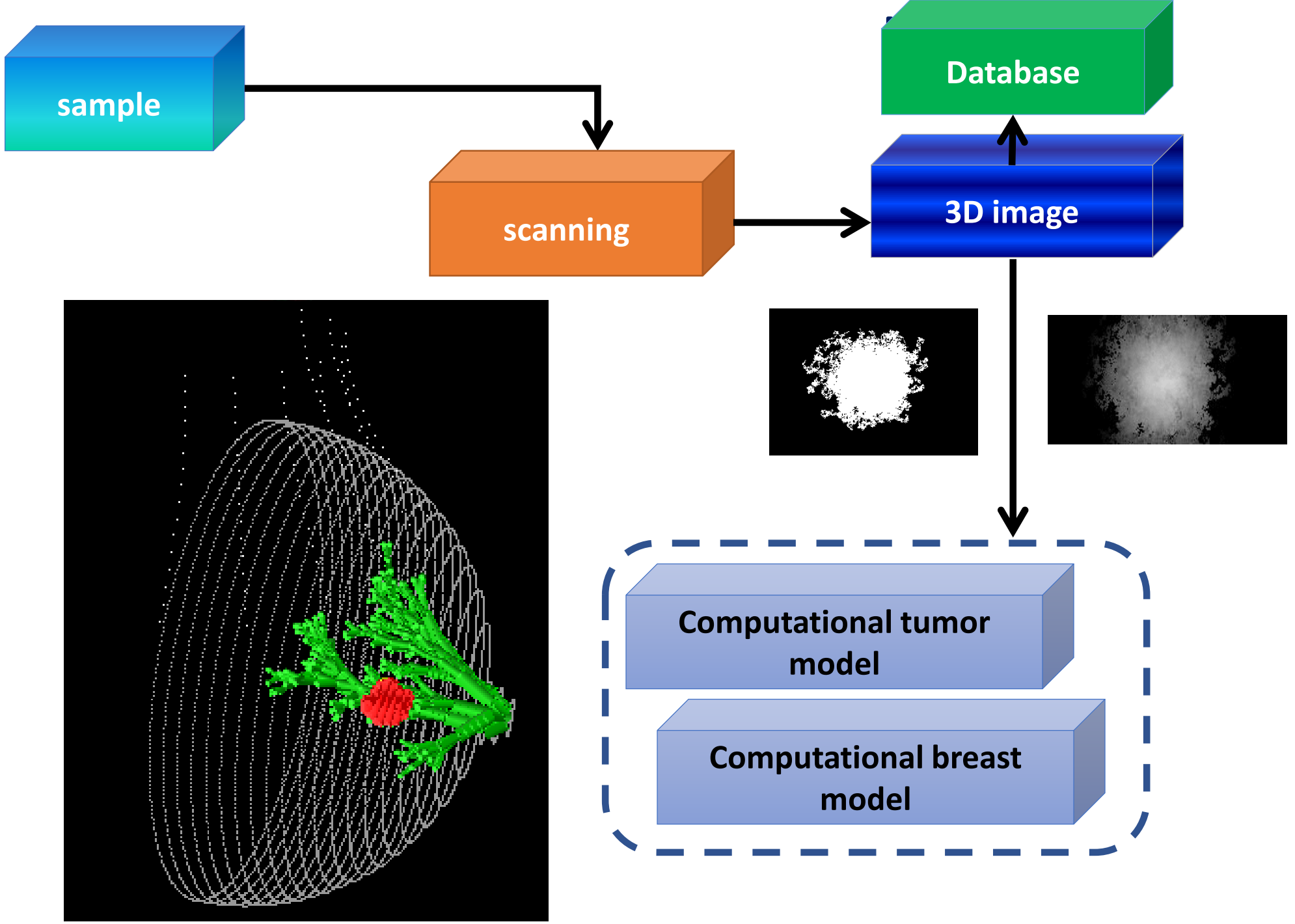
Outline

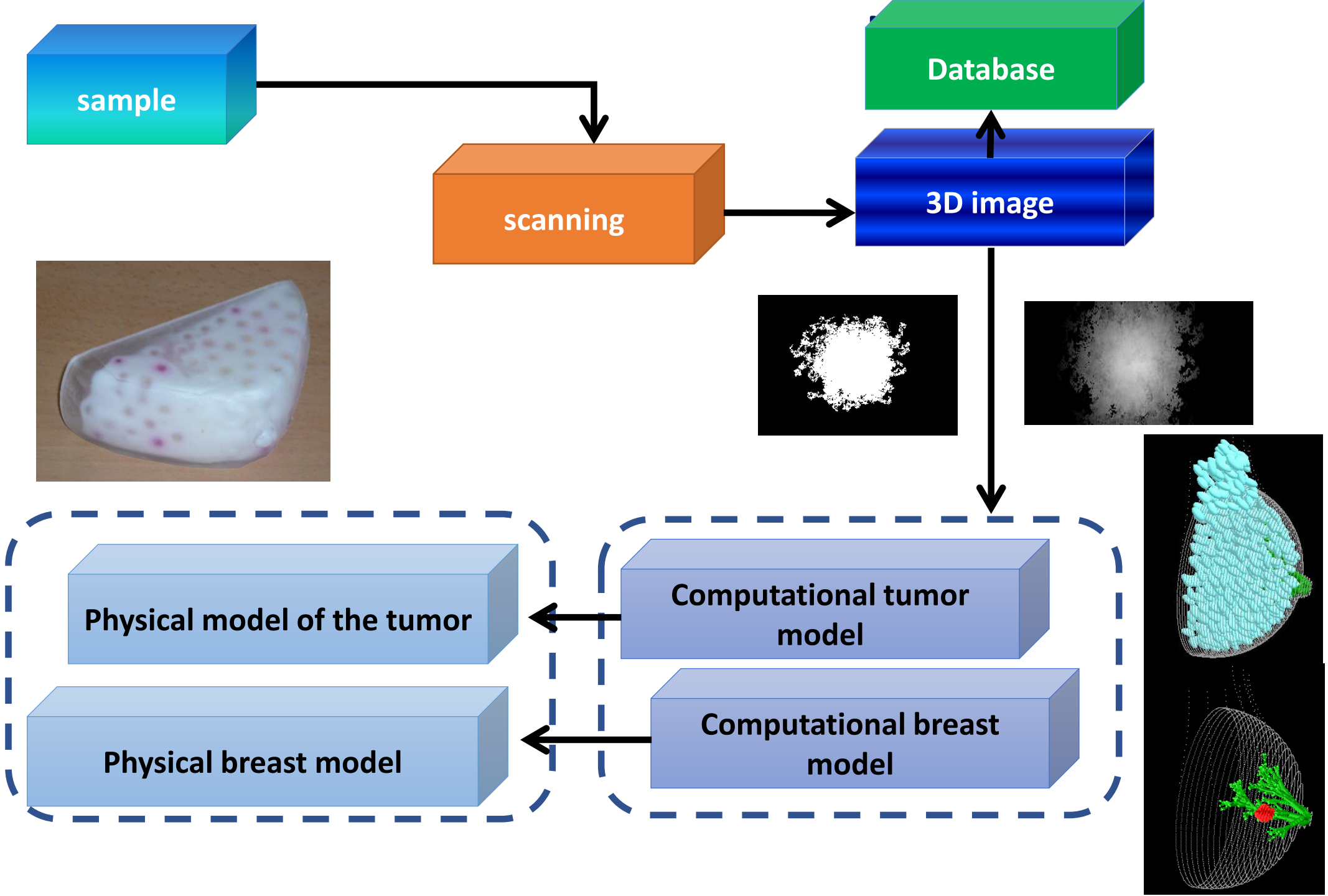
- Why realistic models of abnormalities?
- Our approach and advances
- Exploitation of results in practice

The Maxima objective

- *The **main objective** of the project is to increase the research and innovation capacity of the host organisation in the field of computational modelling of breast tumours and their use in studies of advanced x-ray breast imaging techniques such as breast tomosynthesis and phase contrast imaging.*


sample
scanning
3D image
Database
Histology of the sample & Photo
3D image of the tumor (segmented)
Database
Physical model of the tumor
Computational tumor model
Physical breast model
Computational breast model
Experimental testing of phase-contrast
Simulation experiment of phase contrast


sample
scanning
Database
3D image
Computational tumor model
Computational breast model


sample
scanning
Database
3D image
Physical model of the tumor
Physical breast model
Computational tumor model
Computational breast model

Aim

To develop
the MaXIMA Breast Tumours Models' Database, which is intended to provide researchers with computer-based breast tumours models, both:

- Segmented from Patient data
- Mathematically modelled realistic in shape

Methods

Segmented lesions

- Sources
- Algorithms
- Evaluation
- Storage

Modelled lesions

- Mathematical algorithms
- Evaluation
- Storage

Methods

Segmented lesions

- Sources
- Algorithms
- Evaluation
- Storage

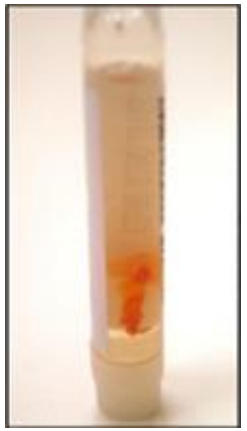
Modelled lesions

- Mathematical algorithms
- Evaluation
- Storage

Segmented lesions

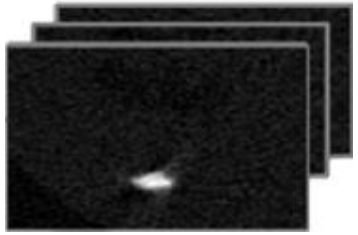
Initial idea ……

Biopsy specimen



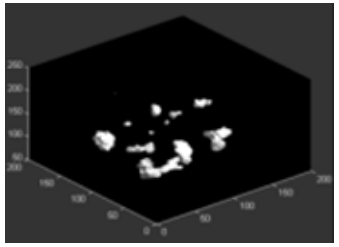
Tube containing tissue in CH_20

Micro CT scanner



Reconstructed images from micro CT

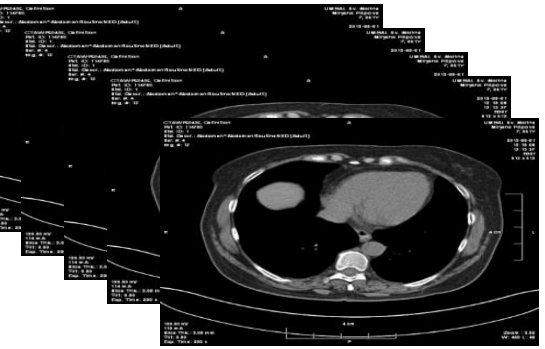
Segmented images

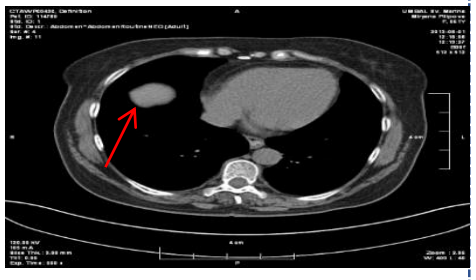


3D model of microcalcification

Courtesy of Prof Hilde Bosmans, KU Leuven

Idea





Input Data

Non contrast abdominal CT scans ✓

Defining the slide where the liver appears initially ✓

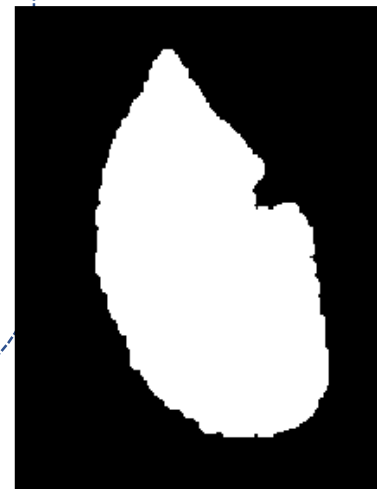
Click in the region of the liver ✓

For each slice

Region Growing within the slice ✓

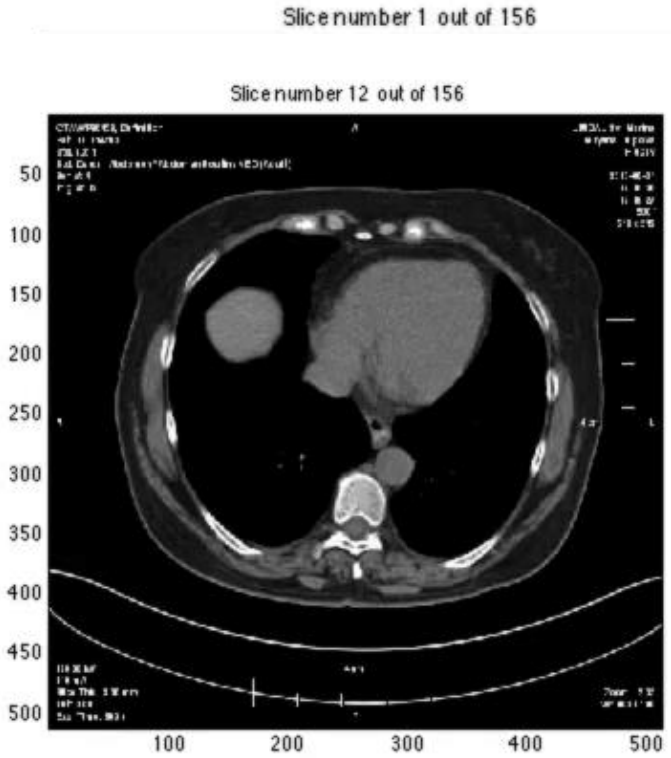
Verify the segmented area ✓

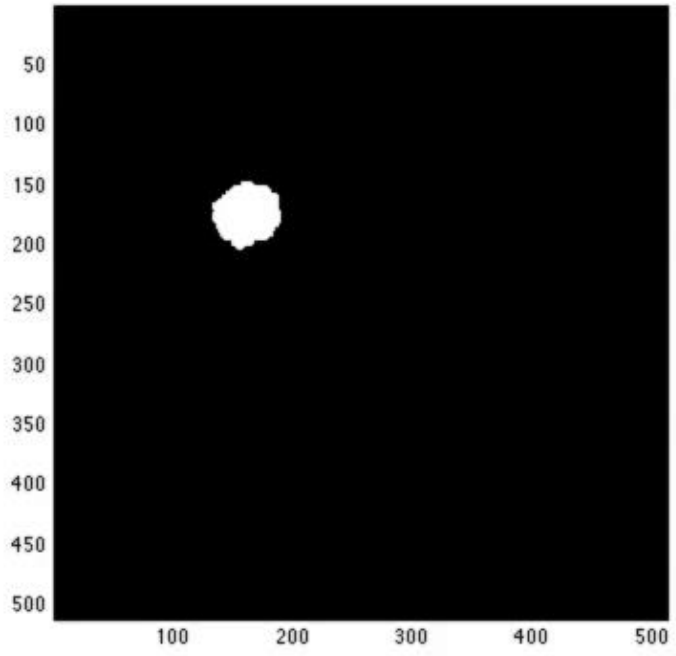
Post-processing the segmented region ✓



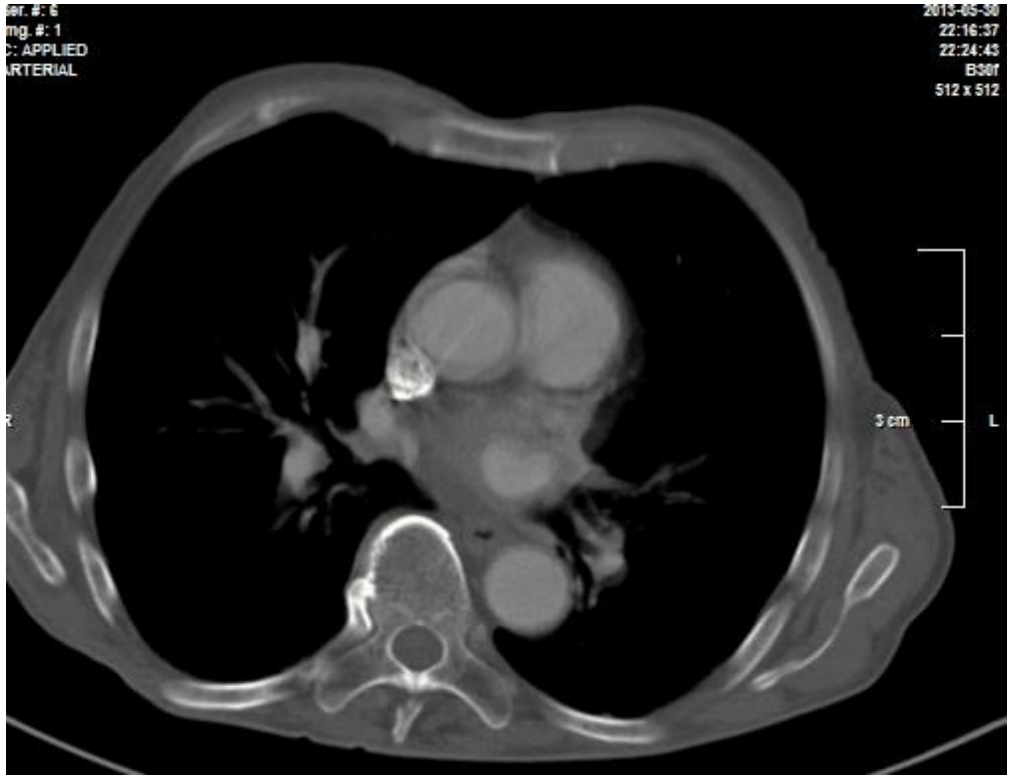
Liver volume ✓

Outlining the tumor by the algorithm example

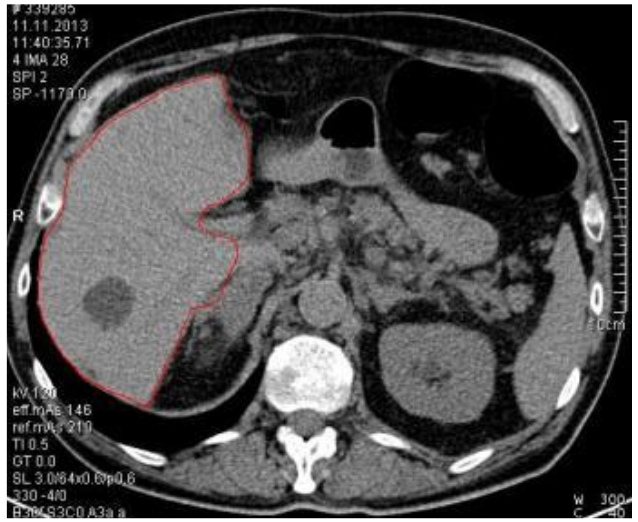
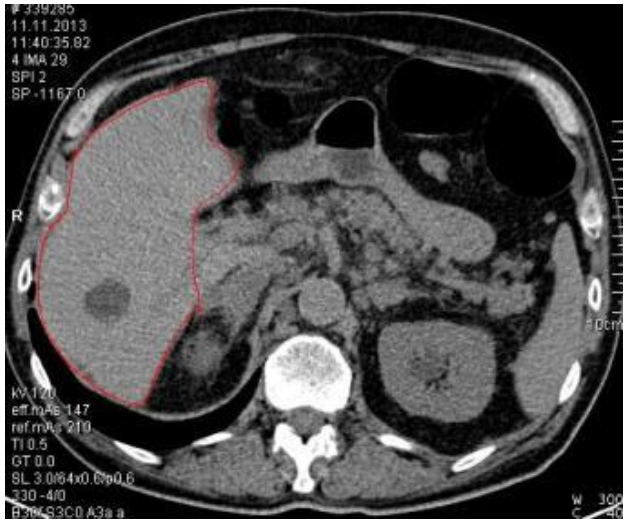
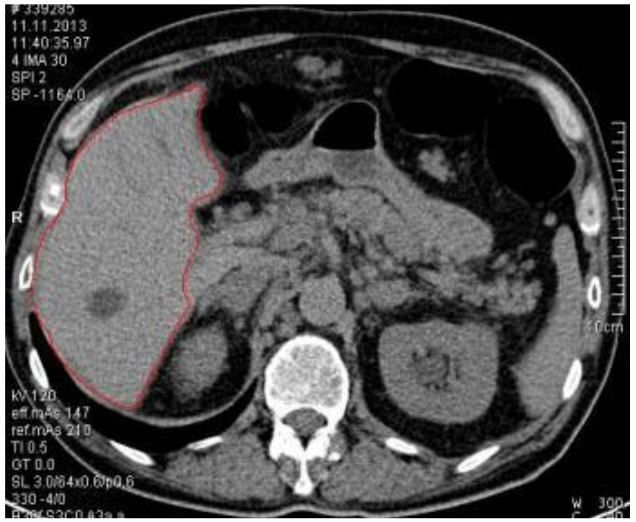


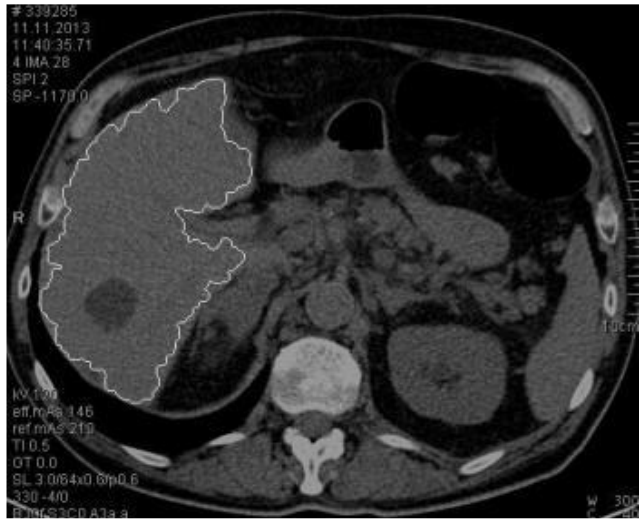
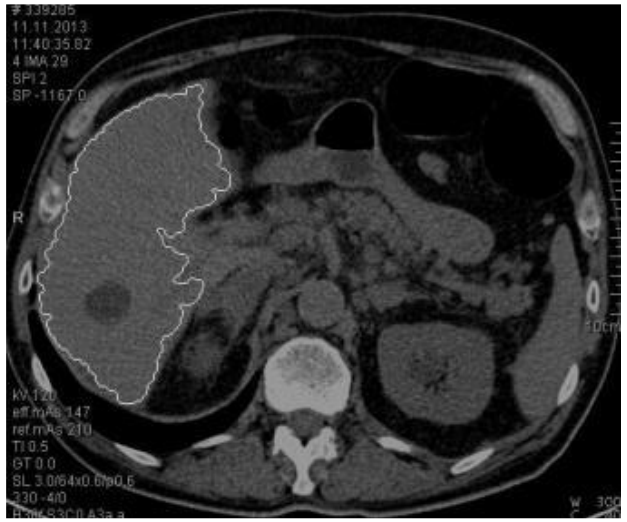
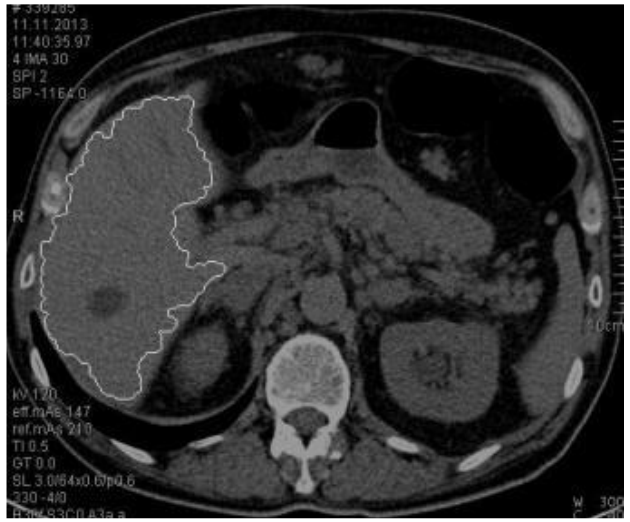


Outlining the tumor by a doctor



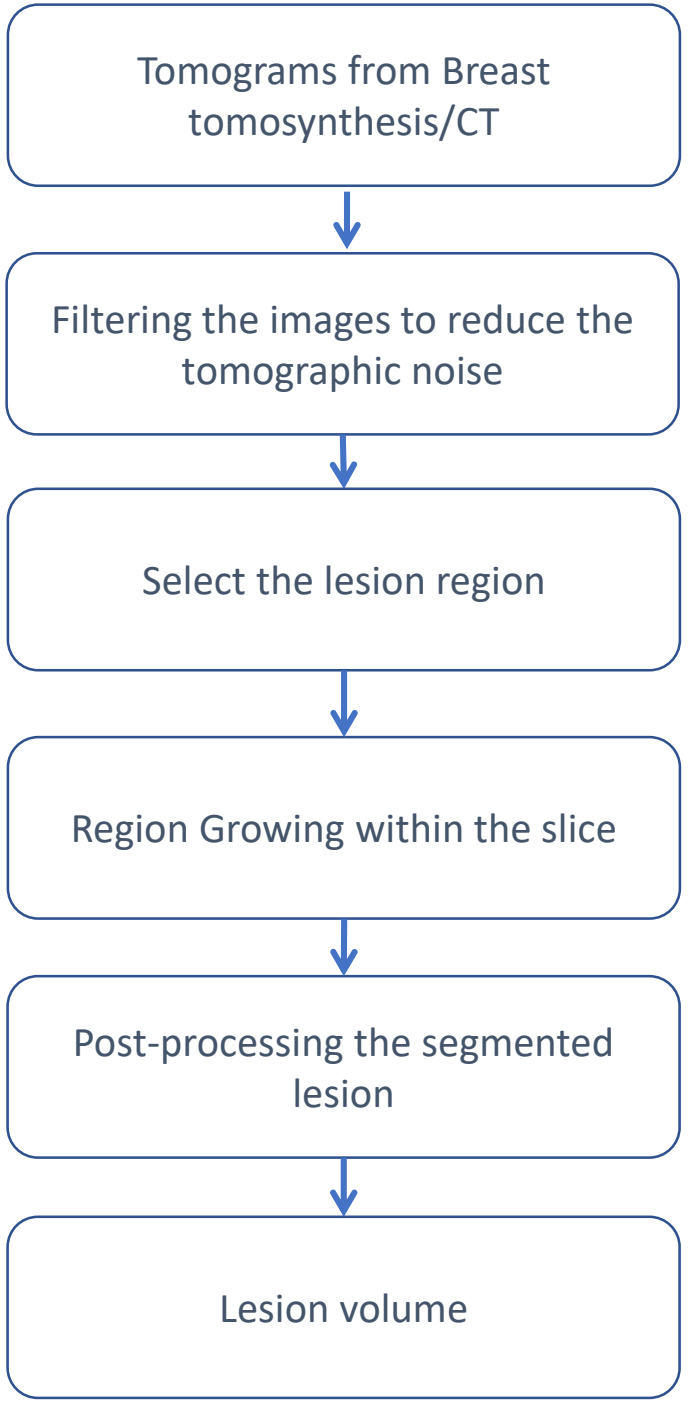
Comparison

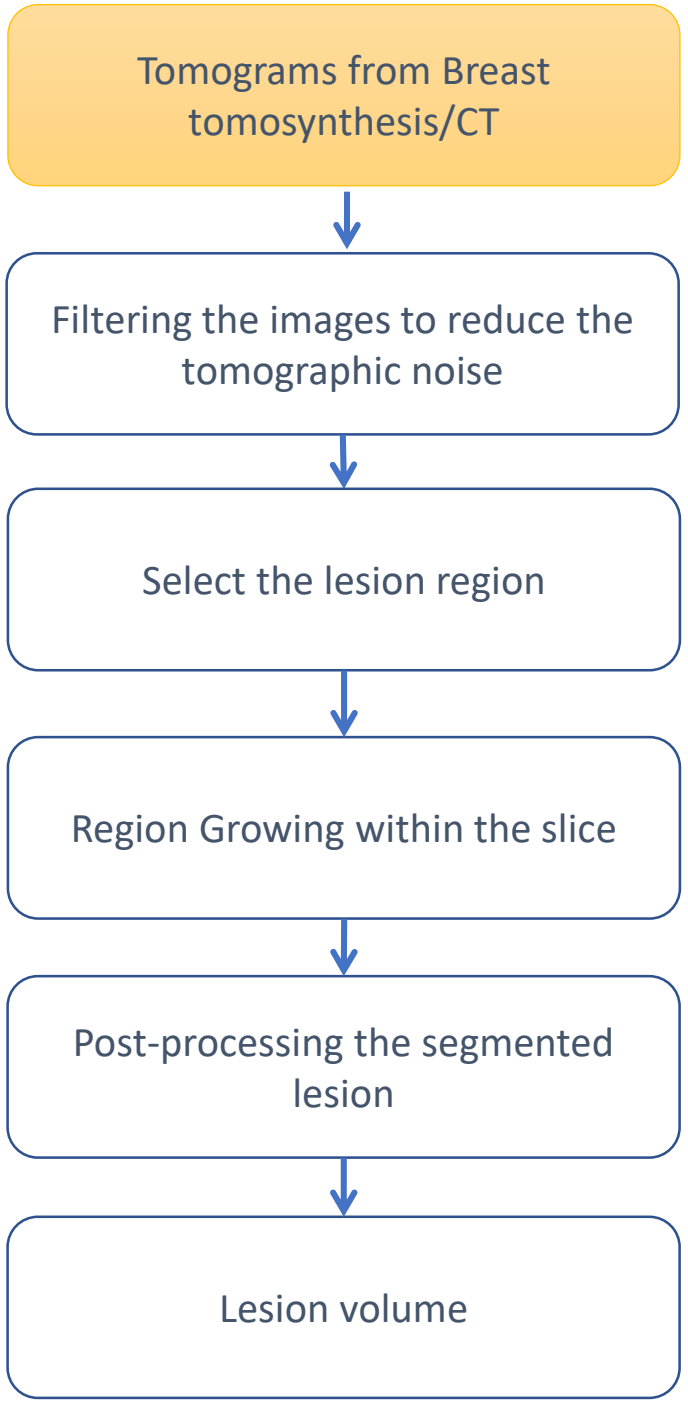





Bliznakova et al :Computer-aided pre-operative evaluation of the residual liver volume using Computed Tomography images J Digit Imaging. 2015 Apr; 28(2): 231–239.

Segmentation of lesions from patient data



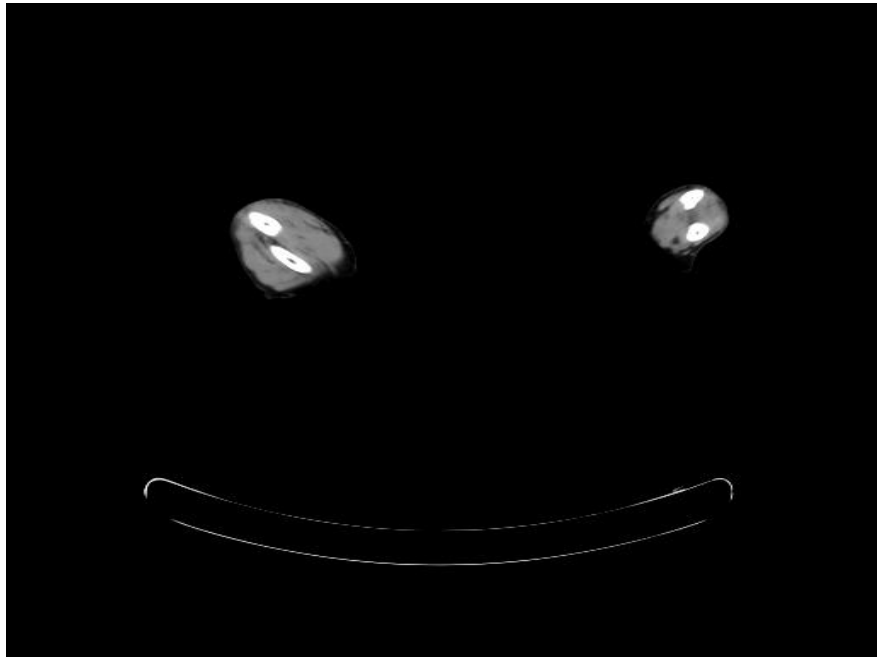
Segmentation of lesions from patient data



Sources of data

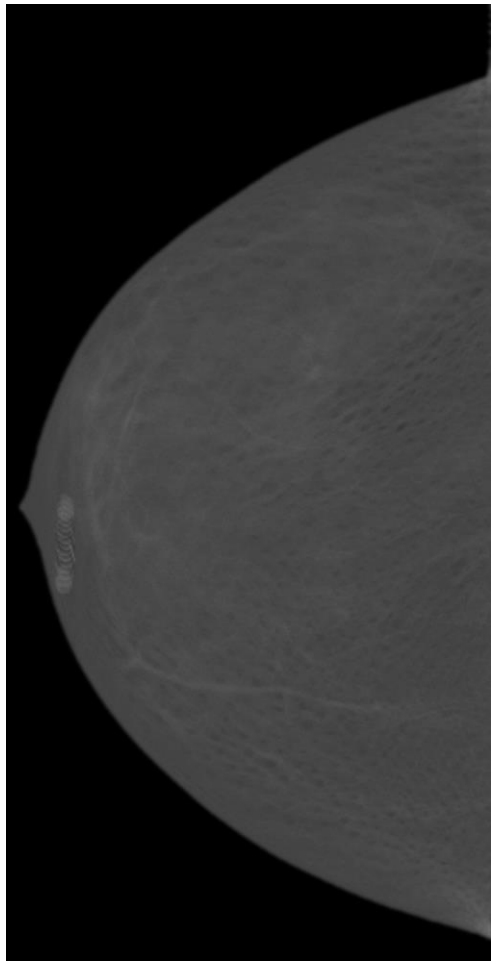
✓CT patient data from radiotherapy department

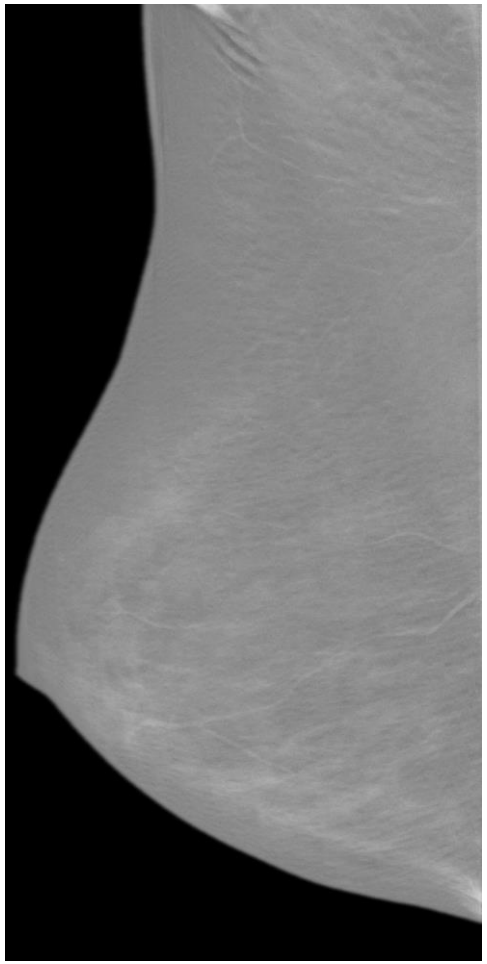
- Image size 512 x 512 pixels, 1.17mm x 1.17mm
- Slice thickness – 5 mm
- 188 slices of the whole body
- Philips GEMINI TF TOF 16



Courtesy: Nikolay Dukov, Fochos 2016

Sources of data

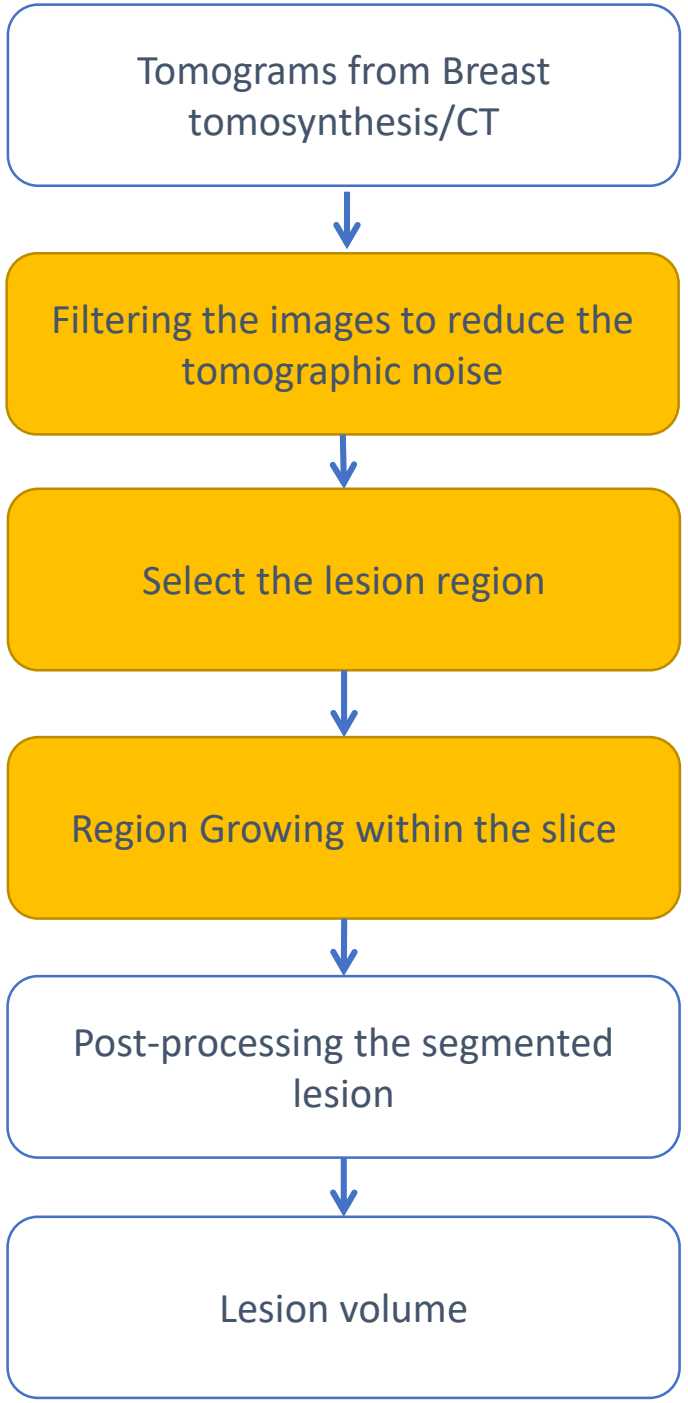




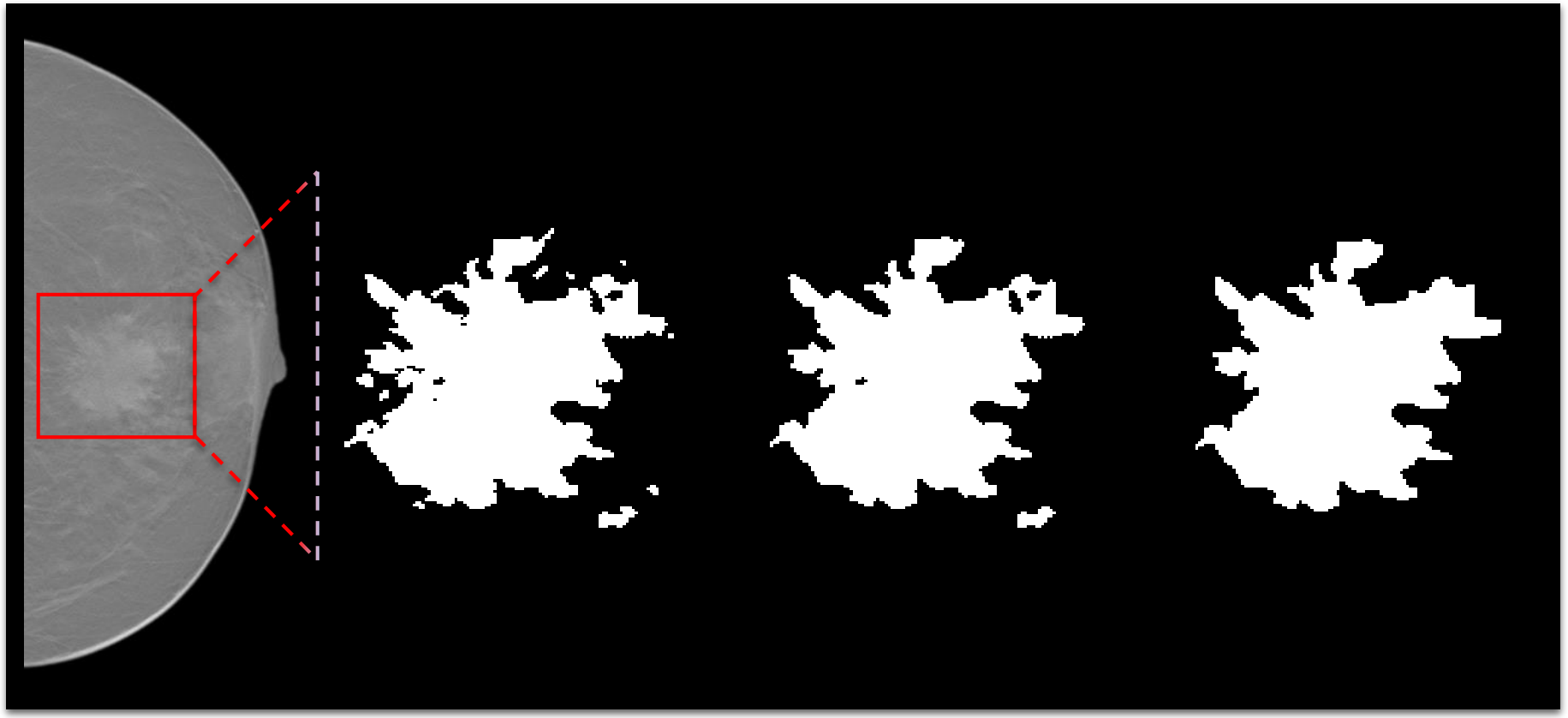
✓ Tomosynthesis – Alexandrovska Hospital, Sofia
University Hospital, Leuven

✓CT - mastectomy University Hospital of Varna

Segmentation of lesions from patient data



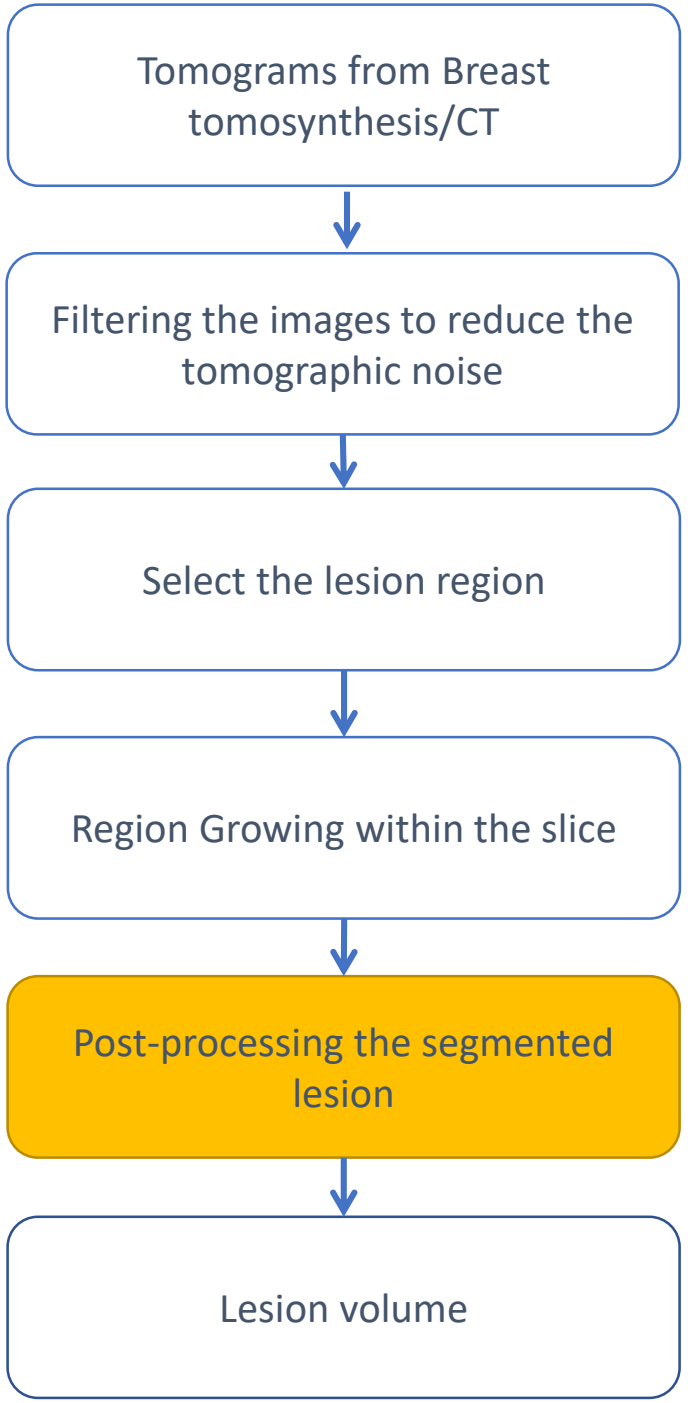
Segmenting the tumour area



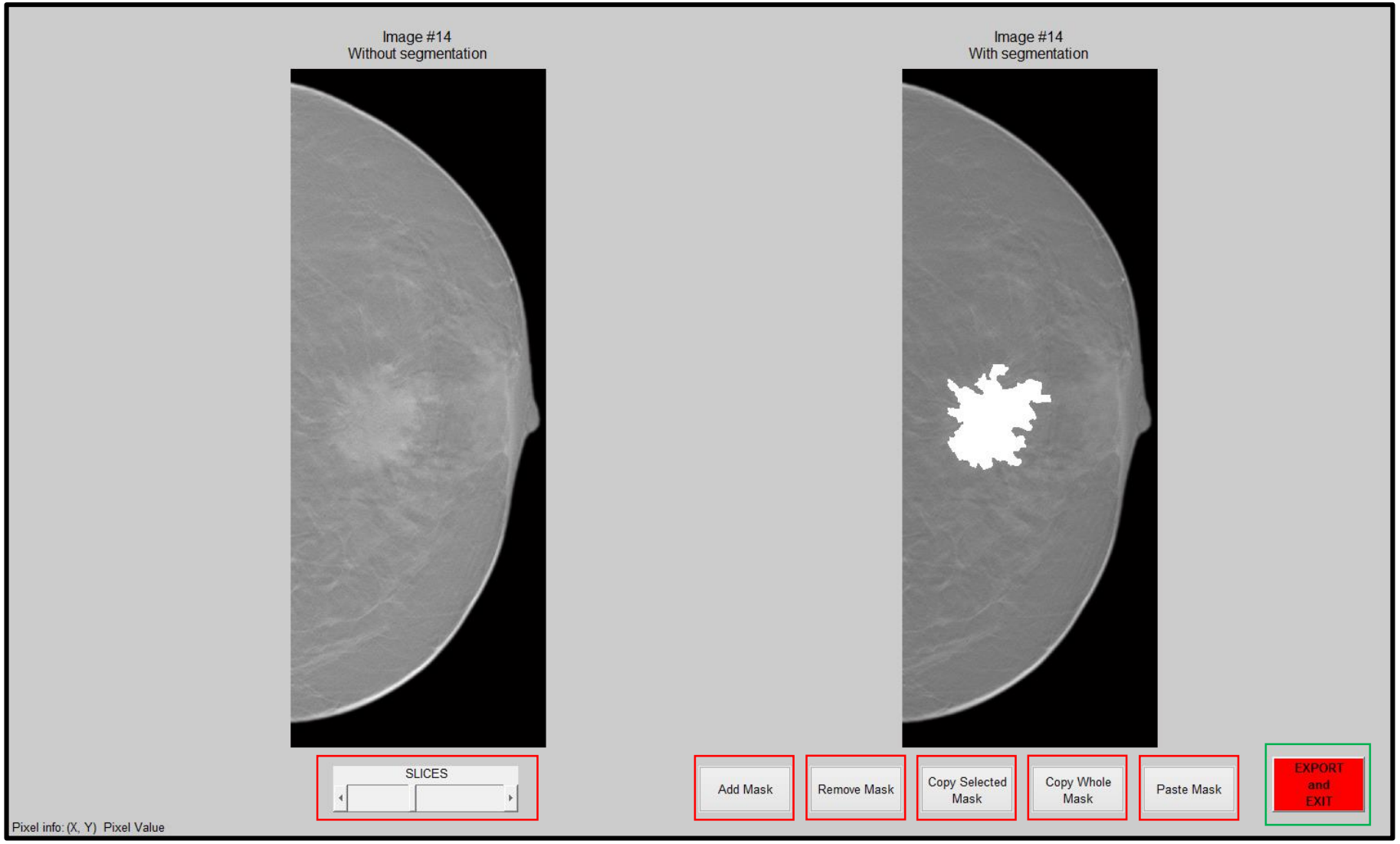
Choosing ROI | **Obtaining binary image** | **Artefact reduction** | **Tumor segmentation**

Dukov et al , RAD, 2017

Segmentation of lesions from patient data

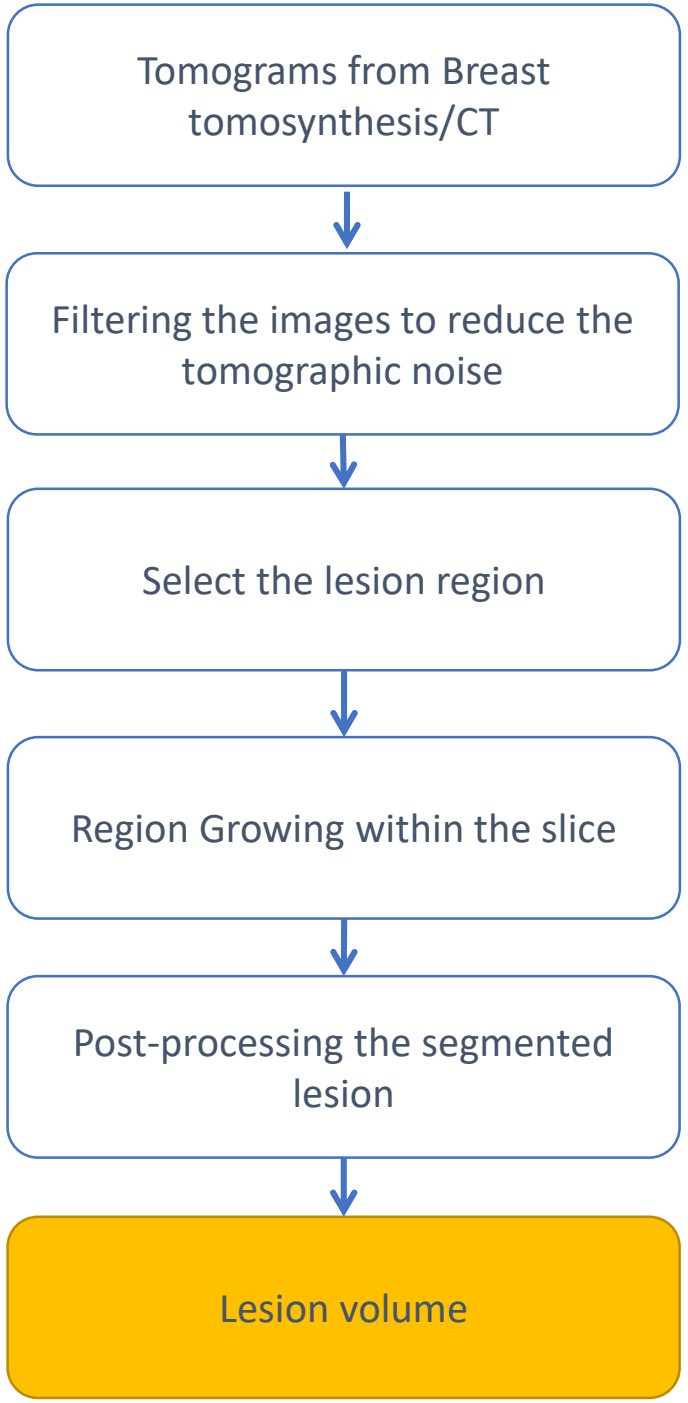


Manual post-processing



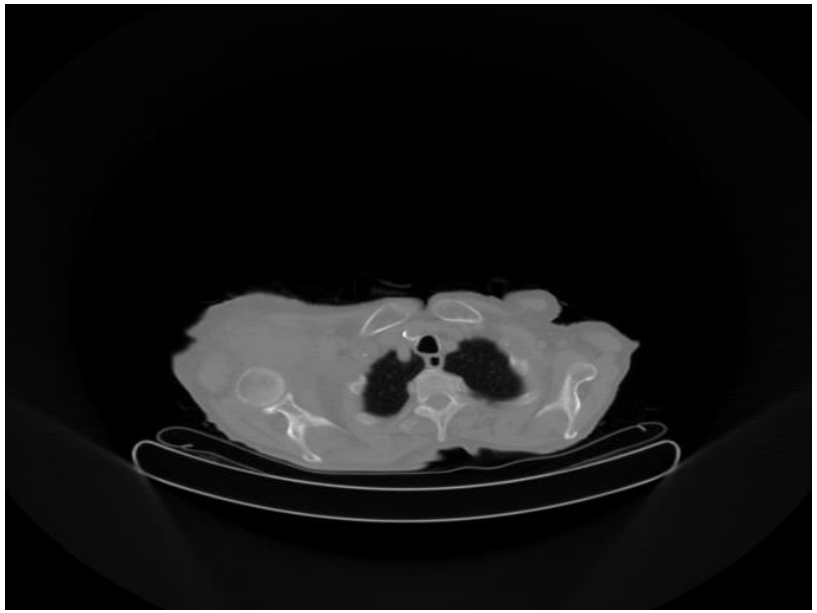
Dukov et al , RAD, 2017

Segmentation of lesions from patient data



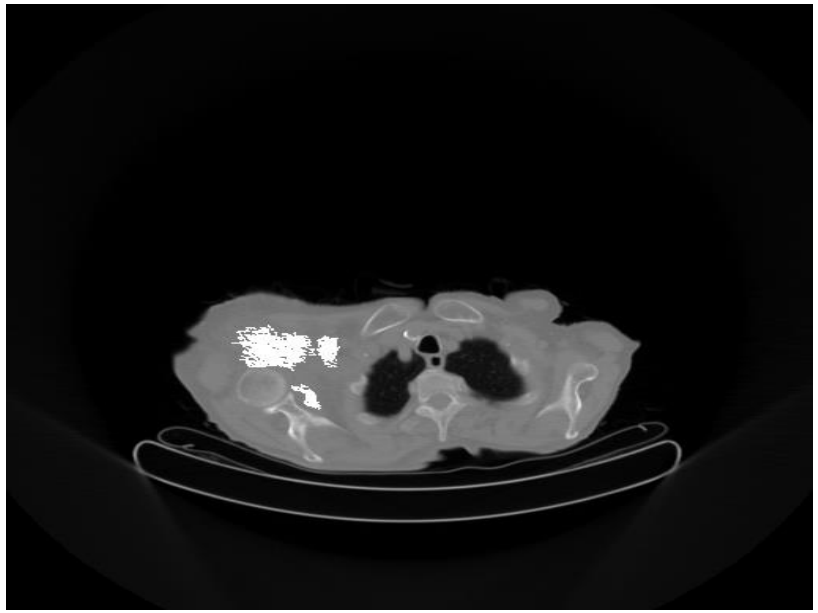
Example

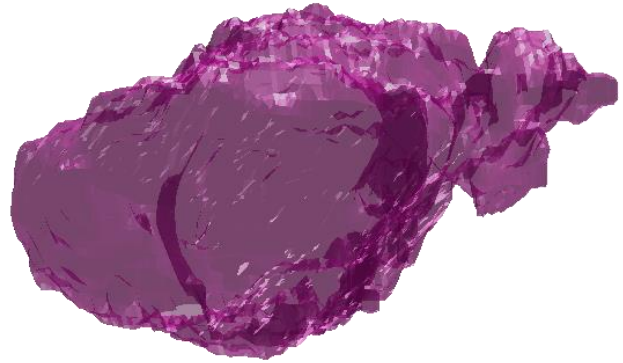
Unprocessed Images



Segmented images

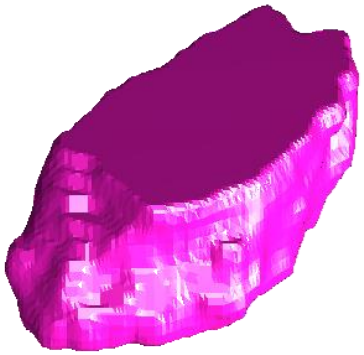
Combined Images

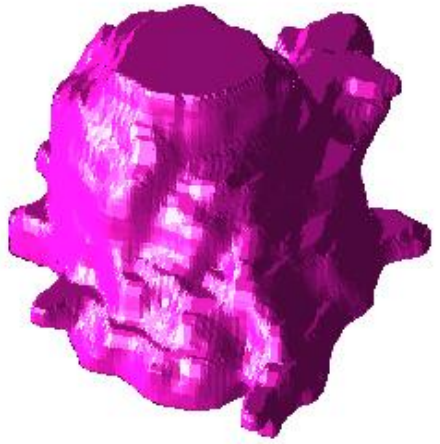




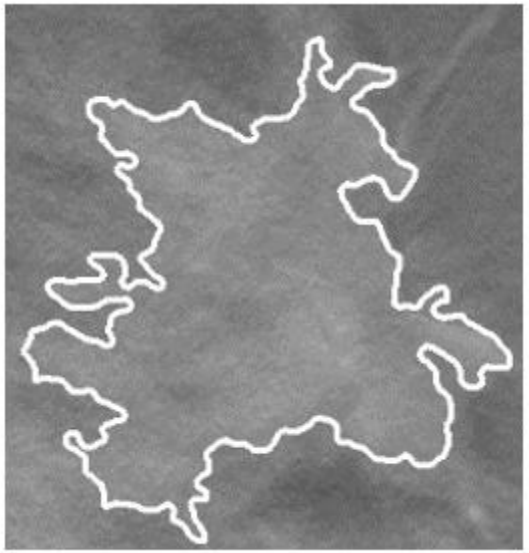
Segmented tumors

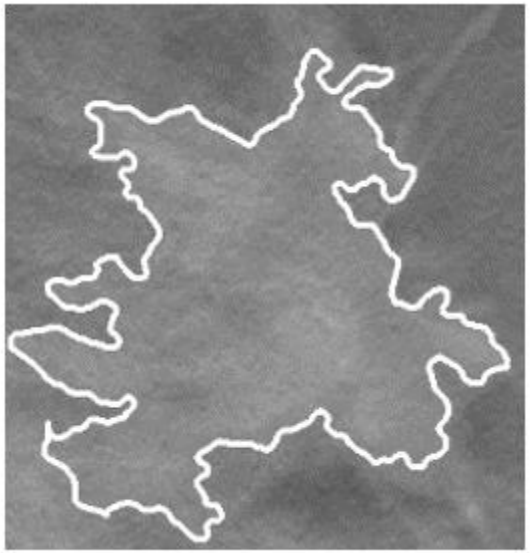
- ✓ More than sixty different 3D models of lesions with irregular shapes were created.
- ✓ Evaluated by experienced radiologists.

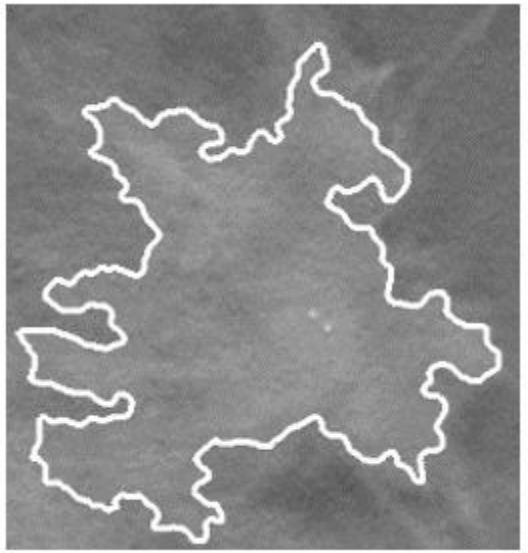


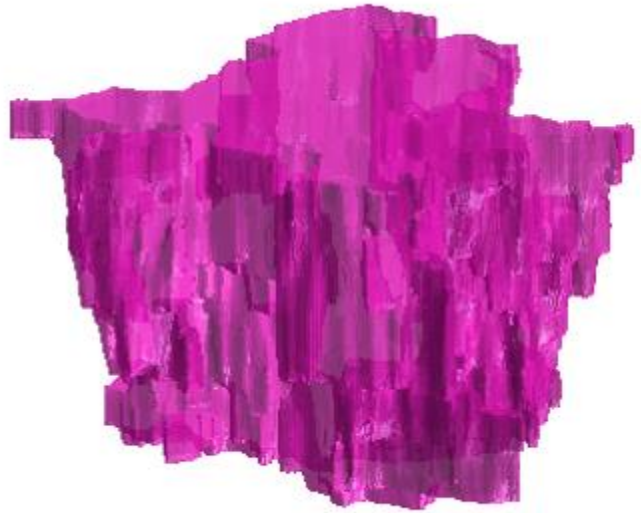


Segmentations



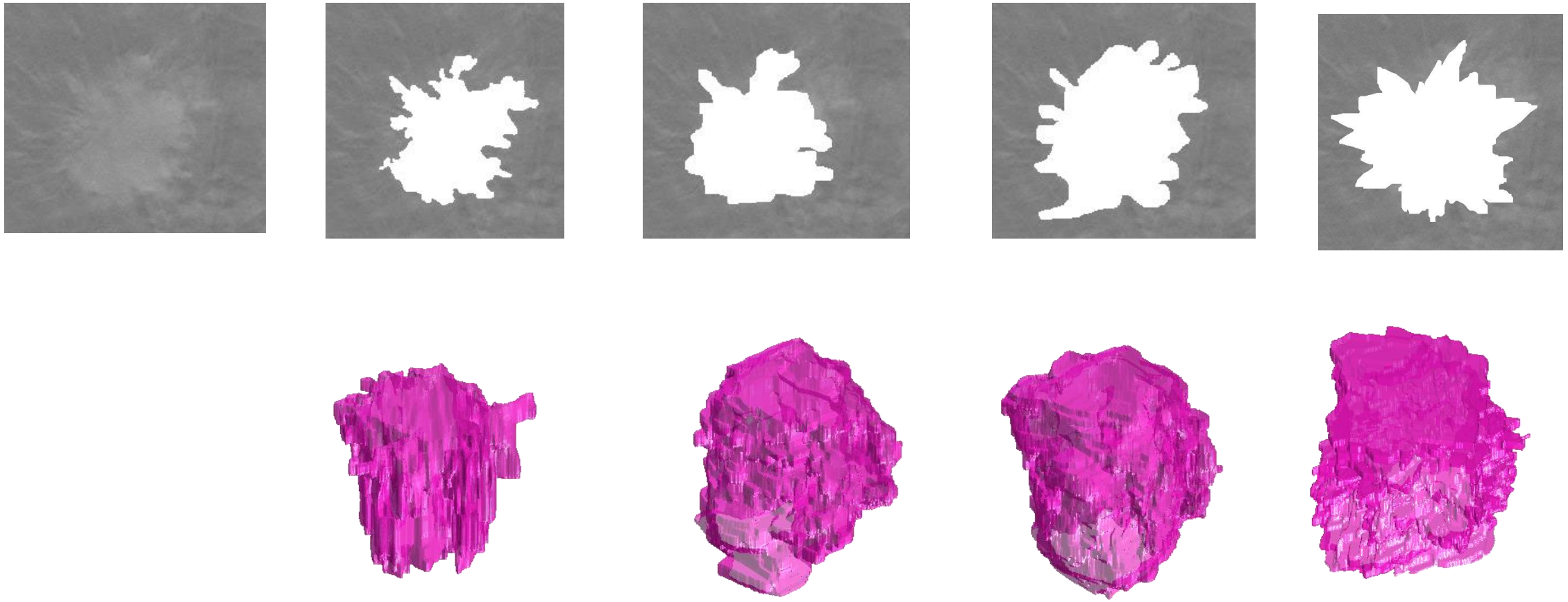






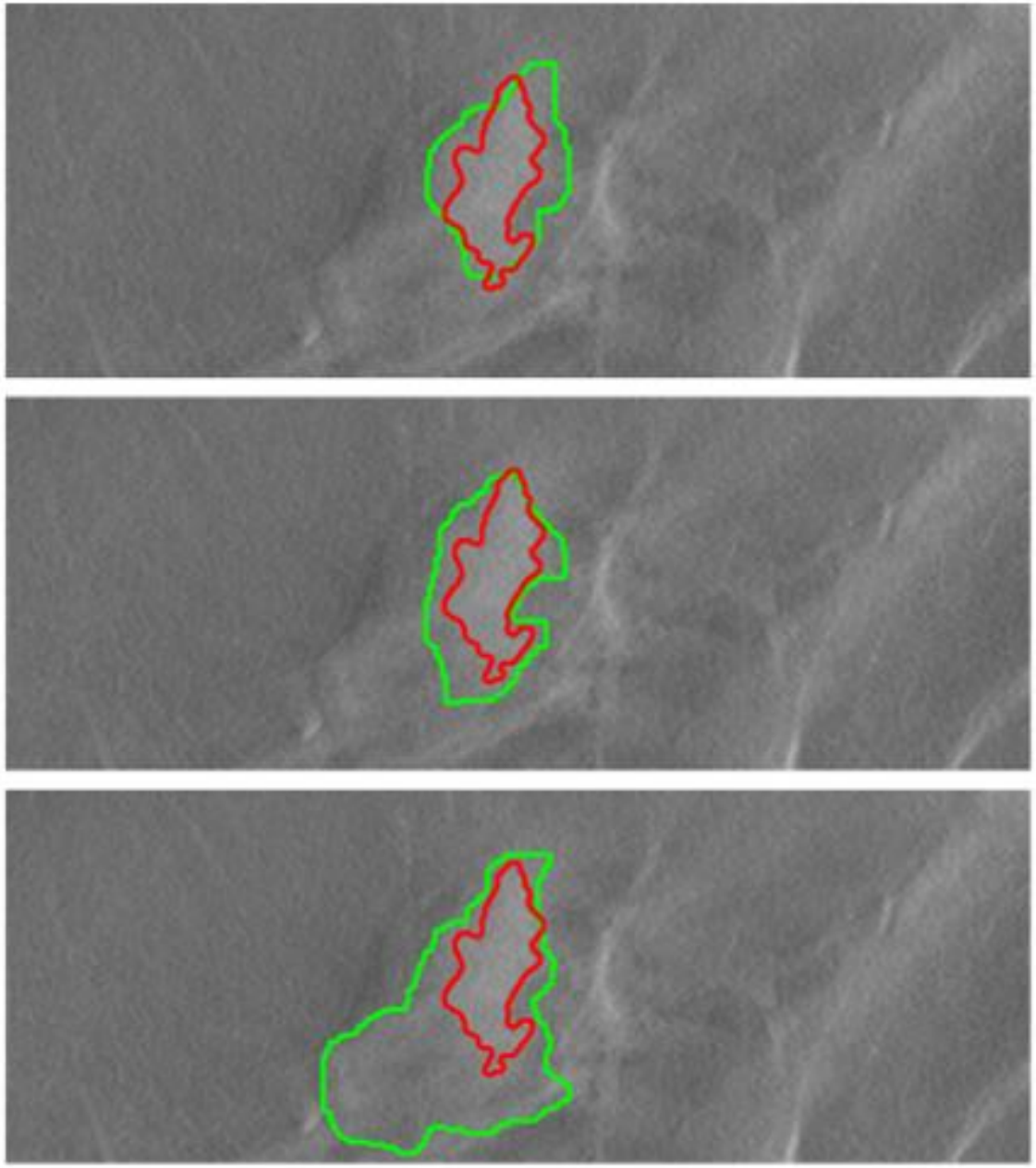
Dukov et al Models of breast abnormalities based on three-dimensional medical x-ray breast images, under revision in Physica Medica

Comparison of segmented slices obtained by using the algorithm and outlined by three radiologists and the corresponding volumes



Dukov et al Models of breast abnormalities based on three-dimensional medical x-ray breast images, under revision in Physica Medica

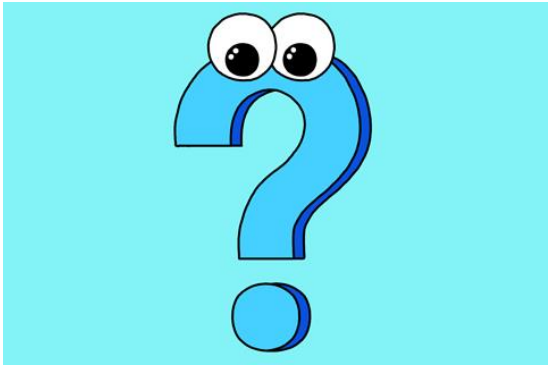
A comparison of segmented (on tomographic slices) shapes obtained with the algorithm (in red) and the three radiologists (green) who participated in the study



Dukov et al Models of breast abnormalities based on three-dimensional medical x-ray breast images, under revision in Physica Medica

Future work

- Correct the shape in z direction
- Classification and full characterization of segmented abnormalities
- Generation of more spiculated in shape abnormalities
- Radiomics with the use of deep learning combined with machine learning
- Generation of new abnormality types from the existing models



Paolo

Methods

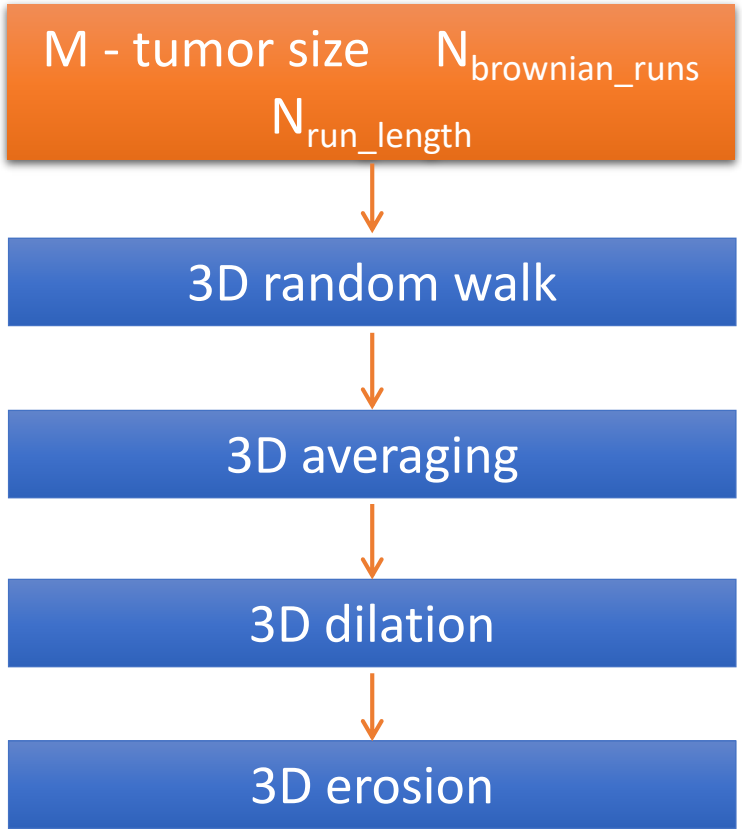
Segmented lesions

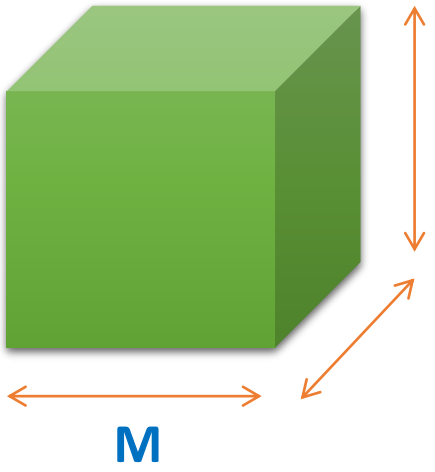
- Sources
- Algorithms
- Evaluation
- Storage

Modelled lesions

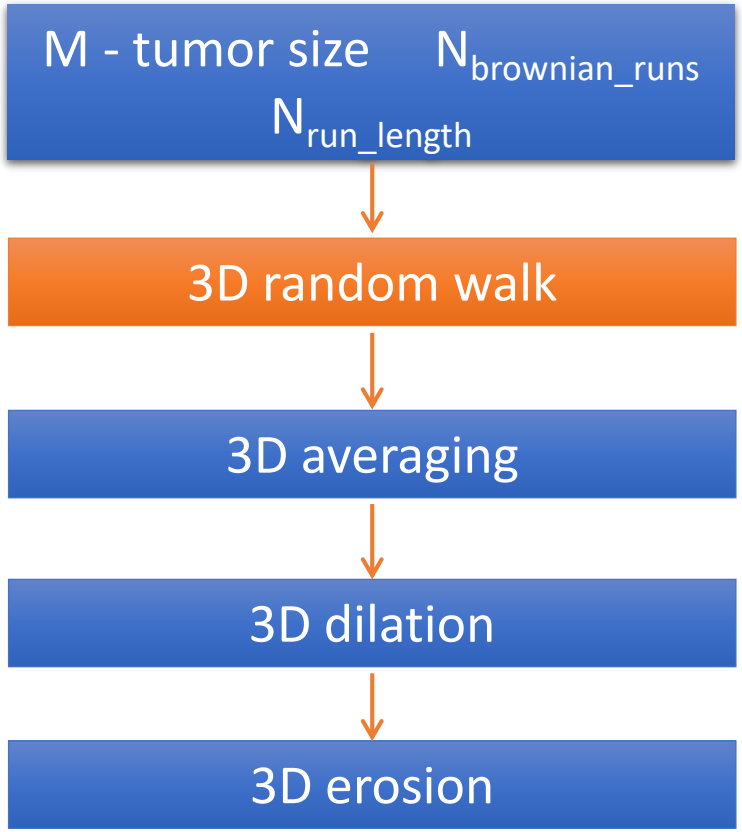
- Mathematical algorithms
- Evaluation
- Storage

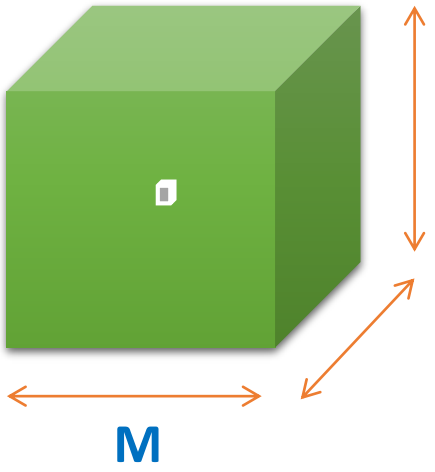
Mathematically modelled lesions - irregular masses





Mathematically modelled lesions - irregular masses

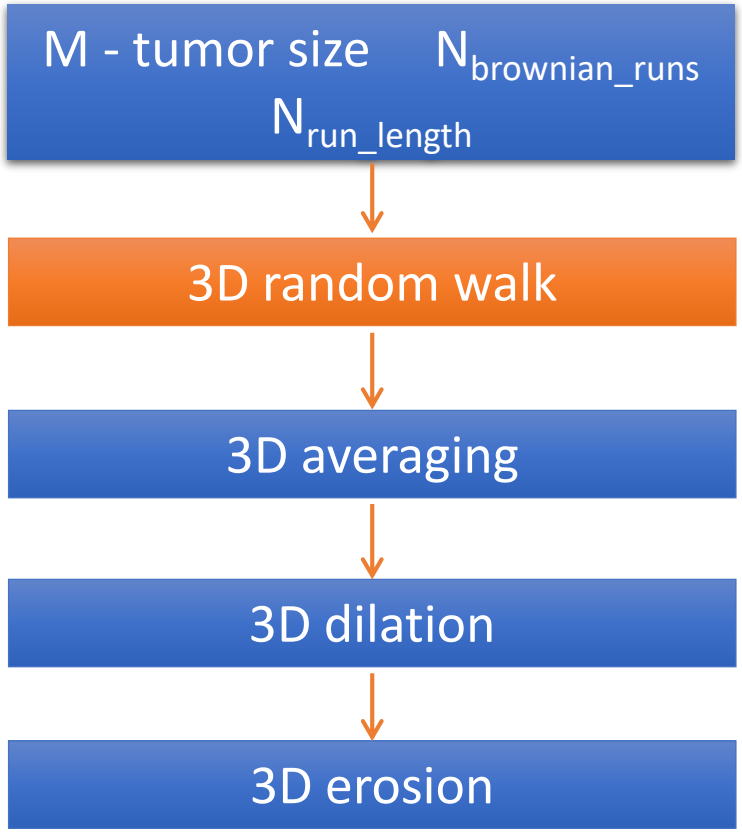


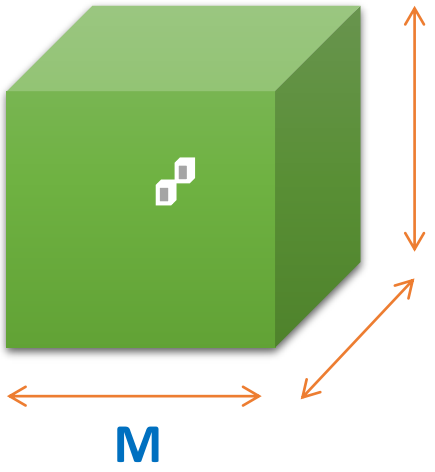


Modelling is based on random walk is a random process consisting of a sequence of discrete steps of fixed length.

At each step, the walk goes randomly a unit distance along one of the neighbor pixels.

Mathematically modelled lesions - irregular masses





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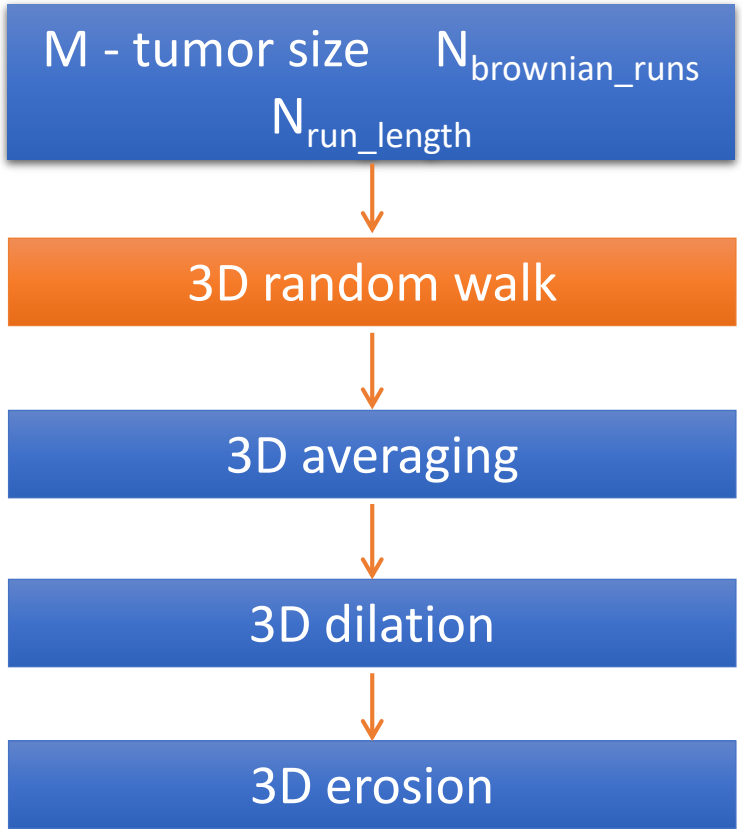
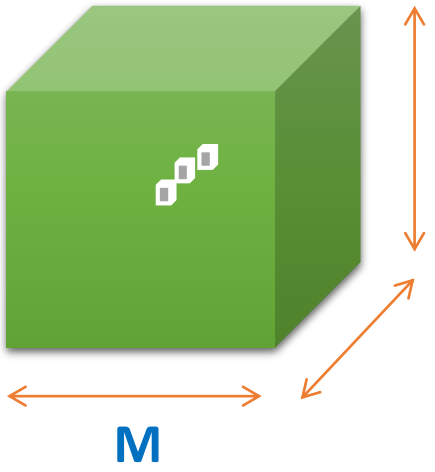
Mathematically modelled lesions - irregular masses





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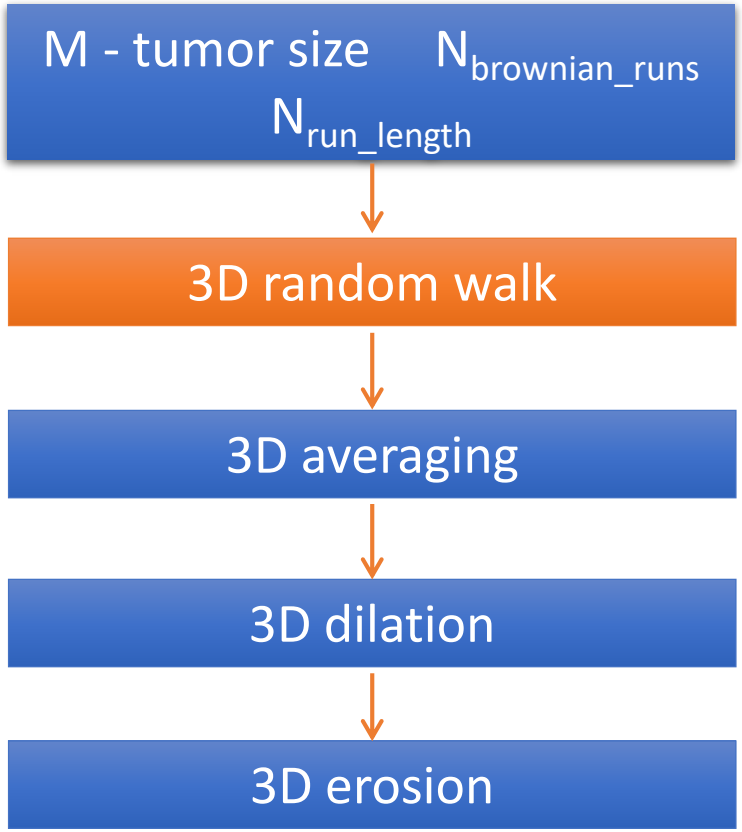
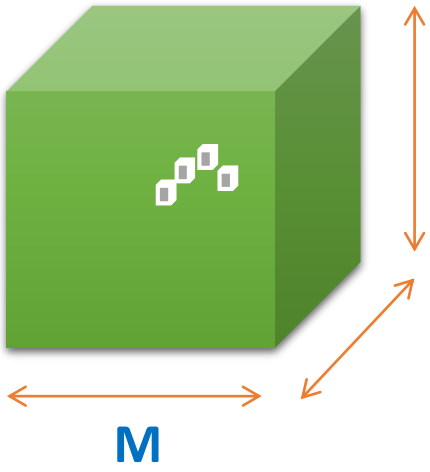
Mathematically modelled lesions - irregular masses





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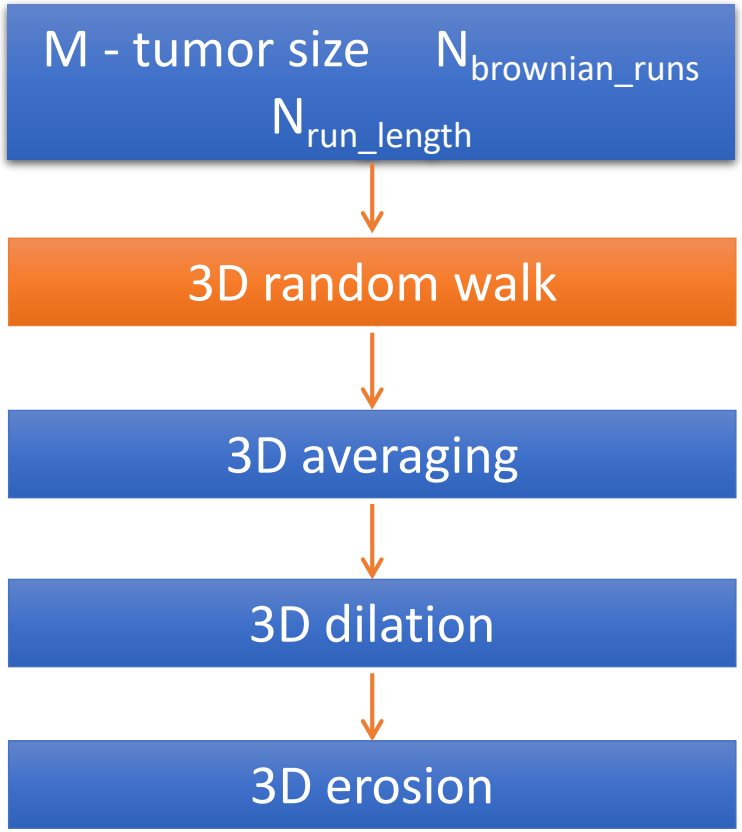
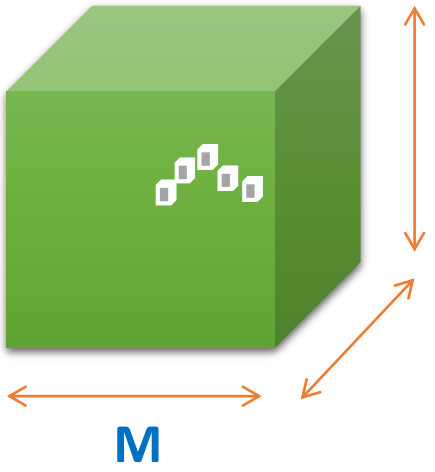
Mathematically modelled lesions - irregular masses





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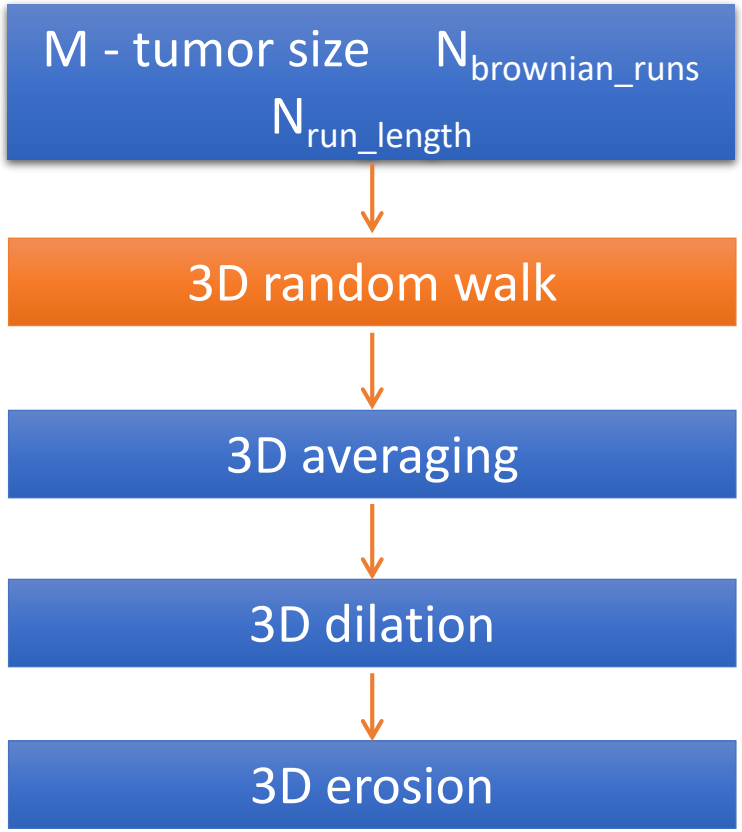
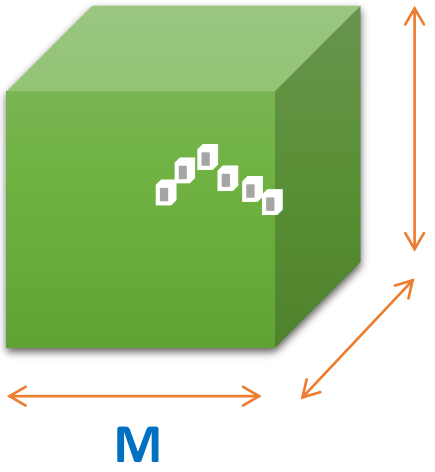
Mathematically modelled lesions - irregular masses





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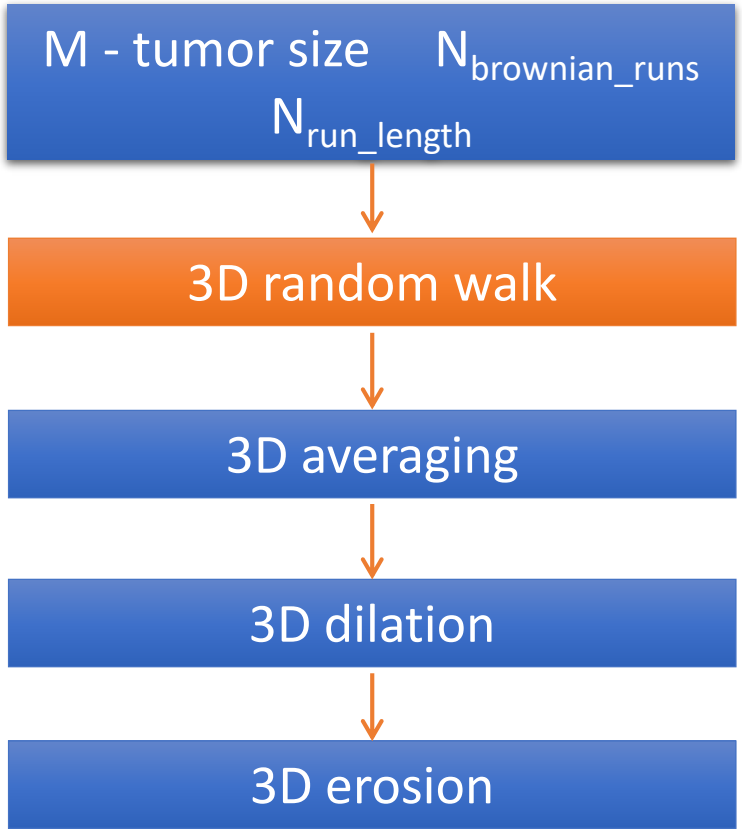
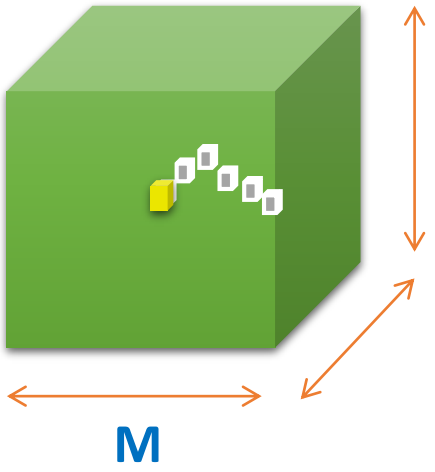
Mathematically modelled lesions - irregular masses





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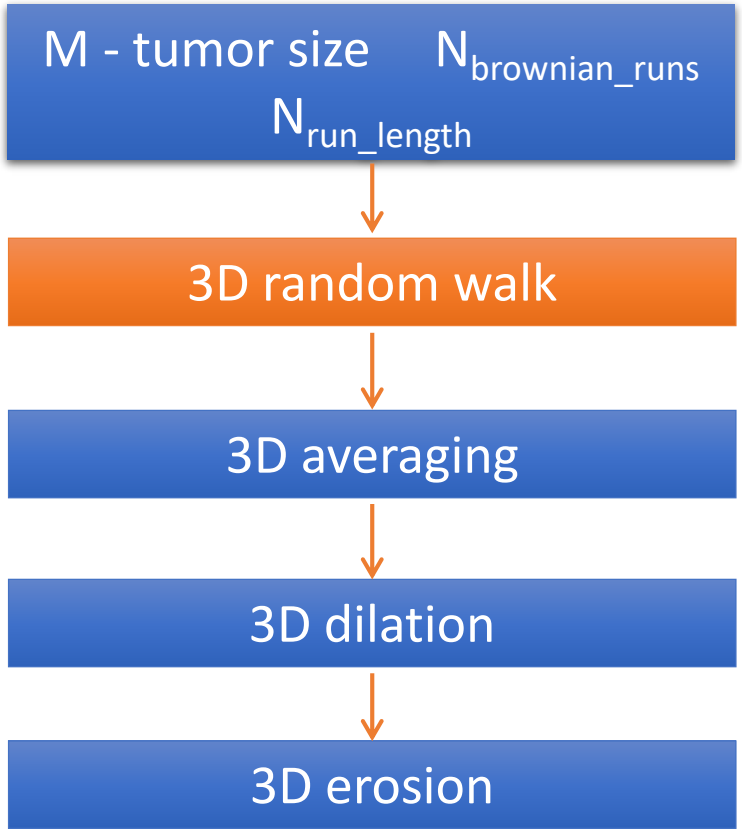
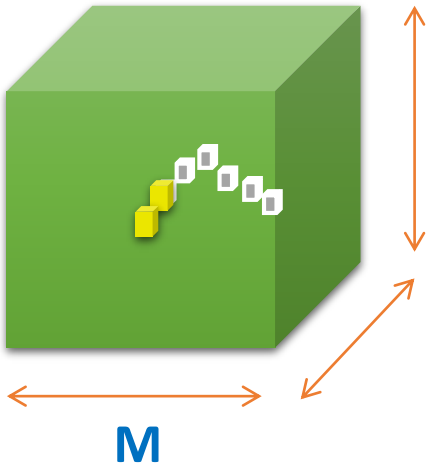
Mathematically modelled lesions - irregular masses





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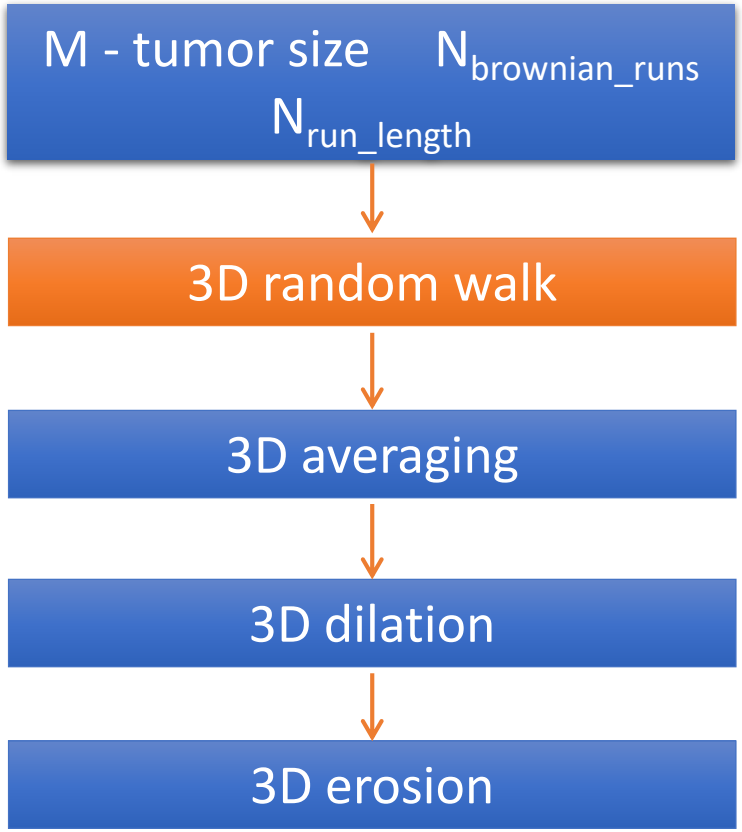
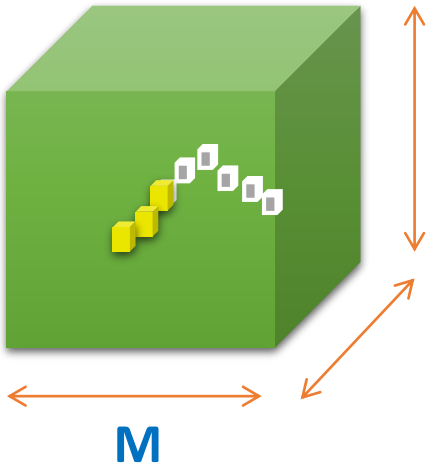
Mathematically modelled lesions - irregular masses





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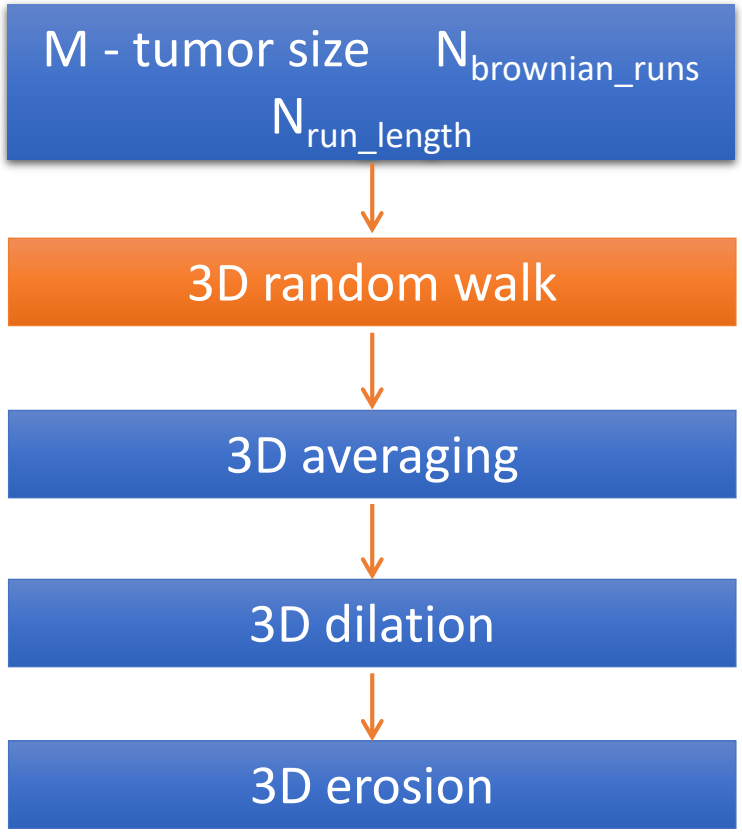
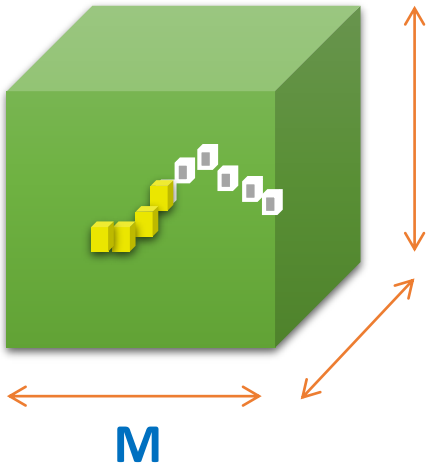
Mathematically modelled lesions - irregular masses





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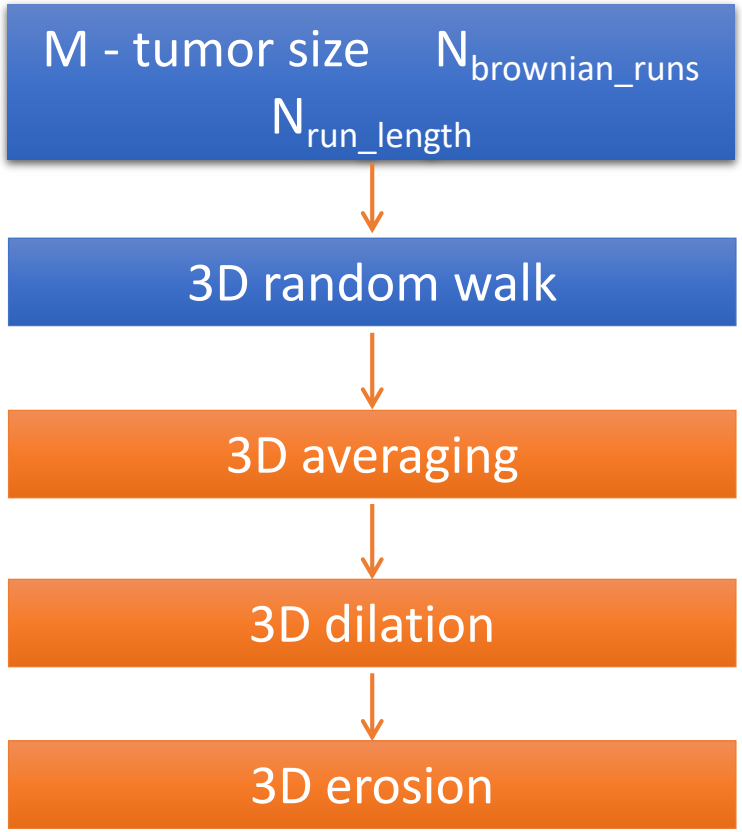
Mathematically modelled lesions - irregular masses

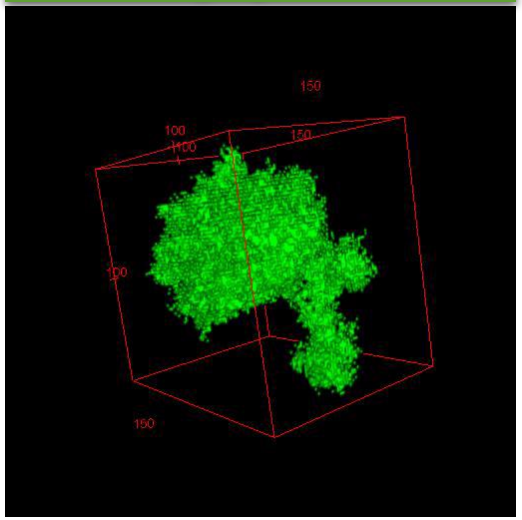


Models

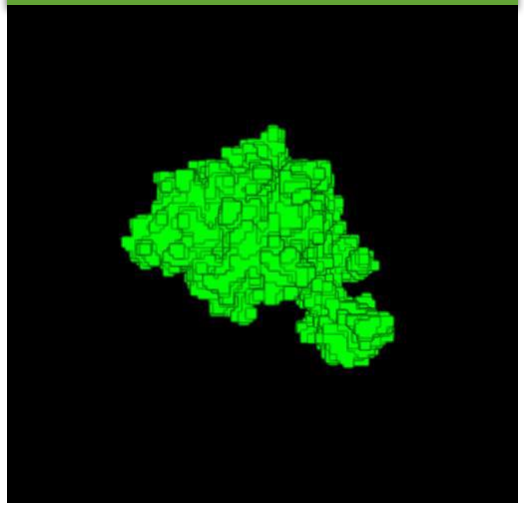
M = 200

$N_{brownian\_runs}$ = 300

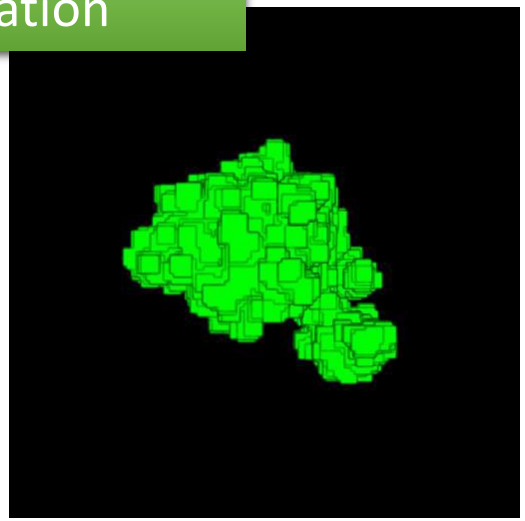
N_{run_length} =200



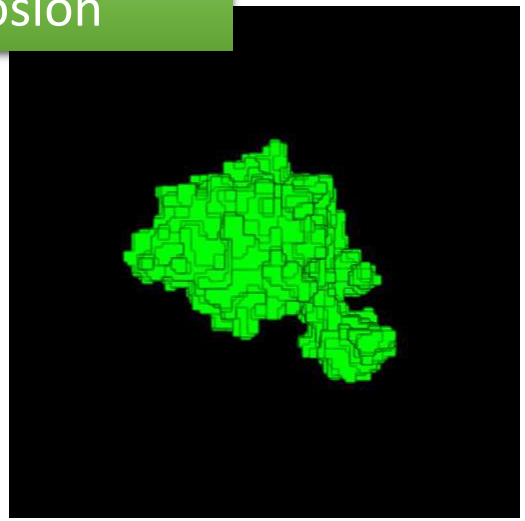
3D averaging



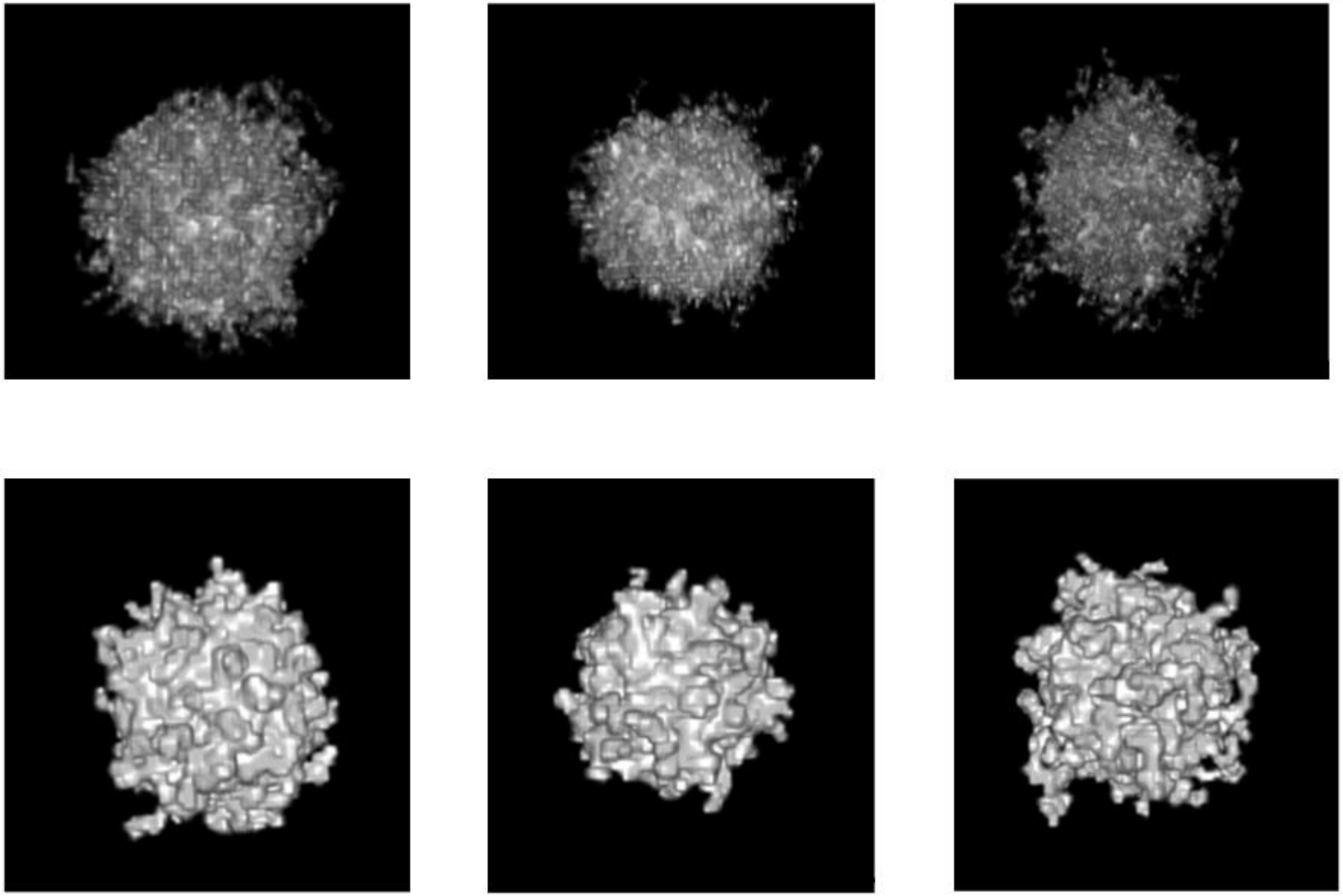
3D dilation



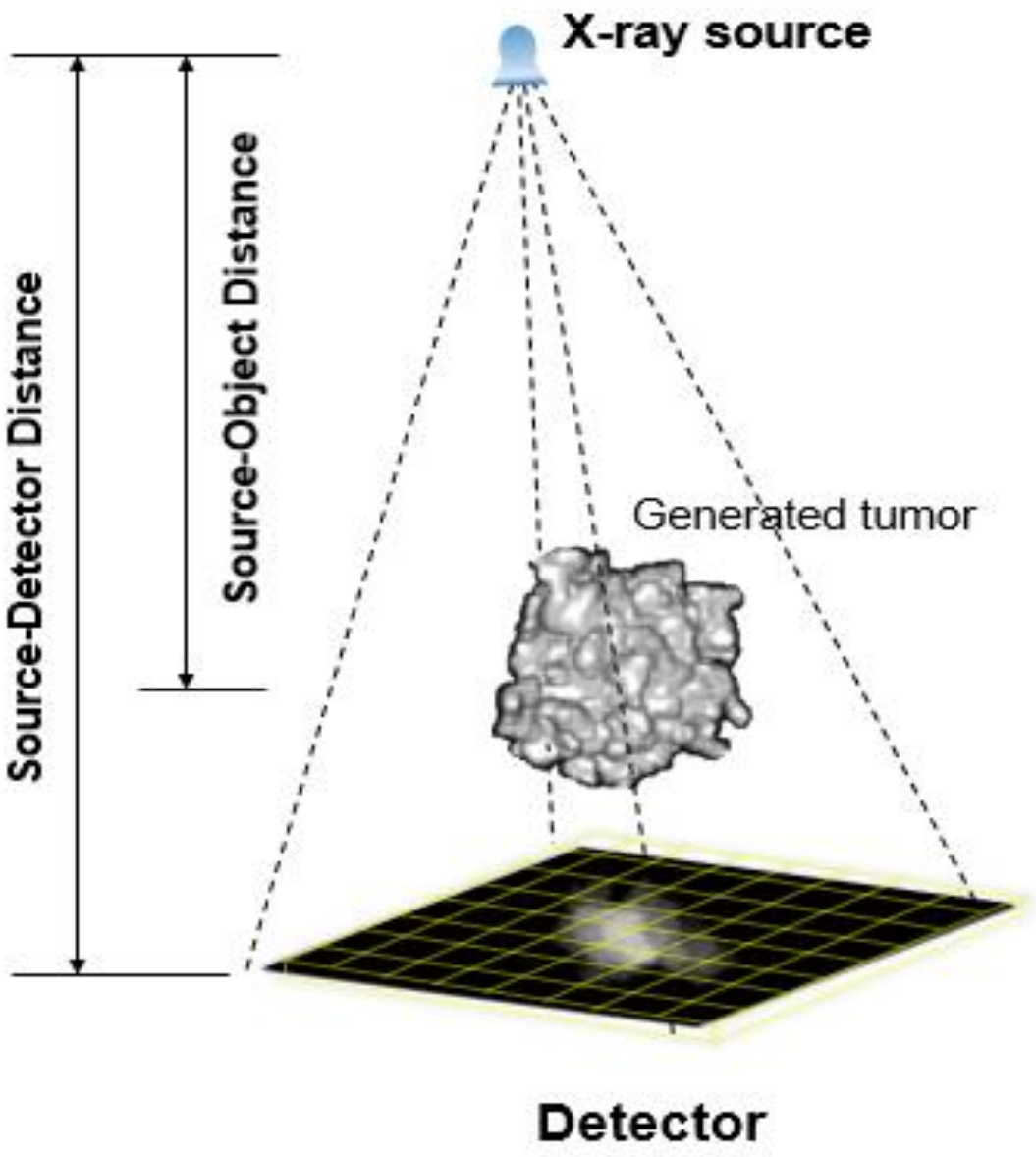
3D erosion

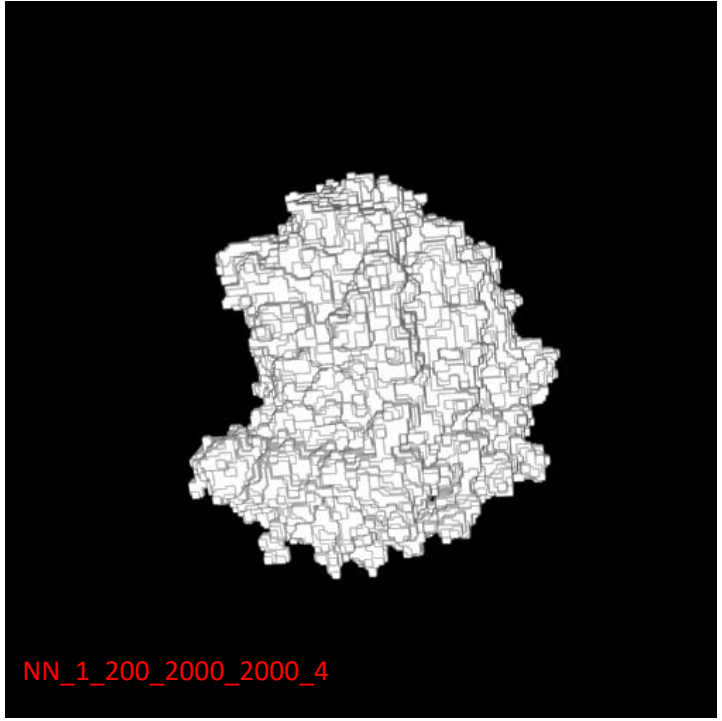


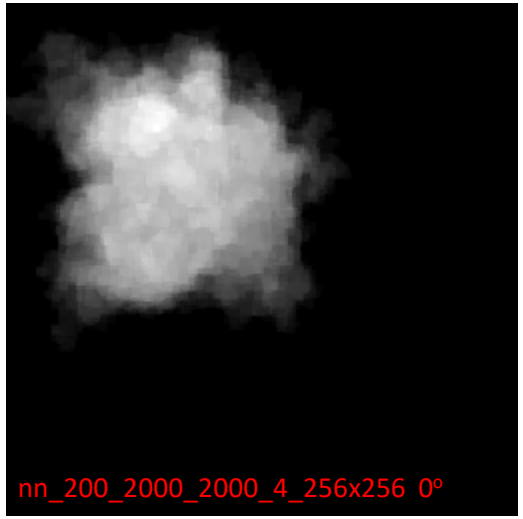
Models

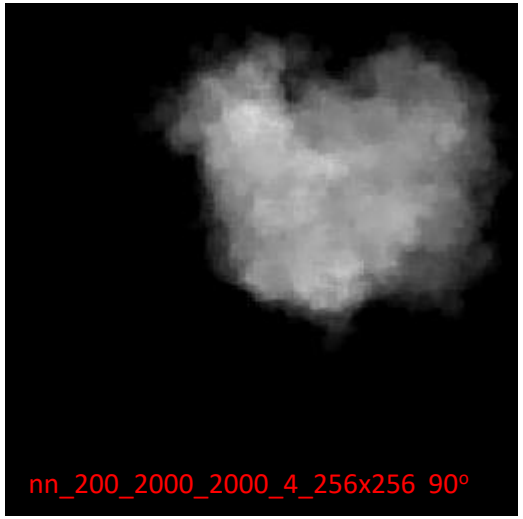


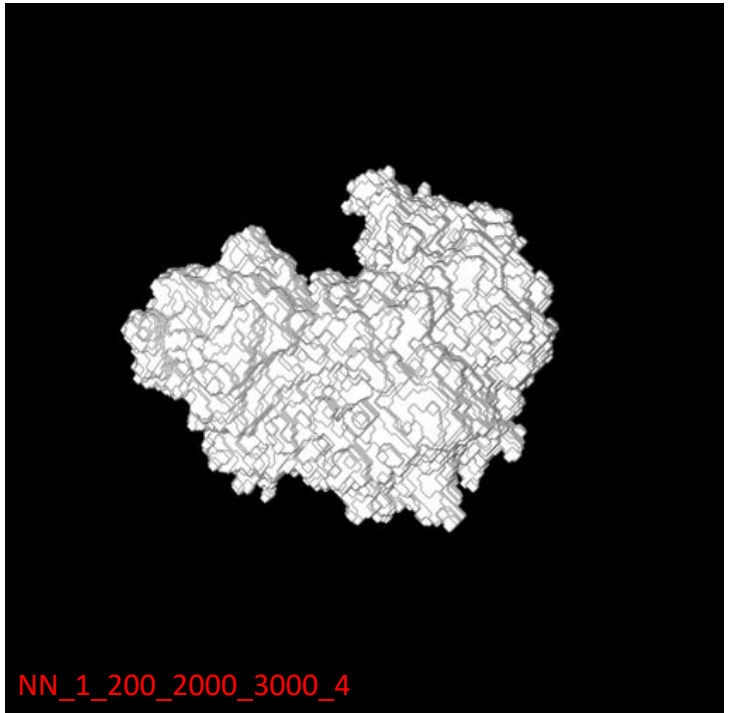
Evaluation

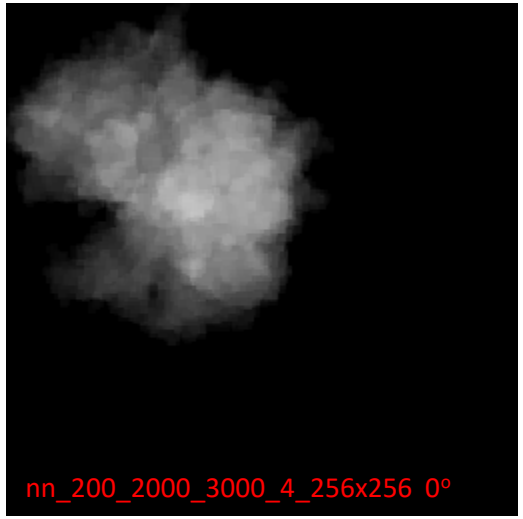

X-ray source
Source-Detector Distance
Source-Object Distance
Generated tumor
Detector

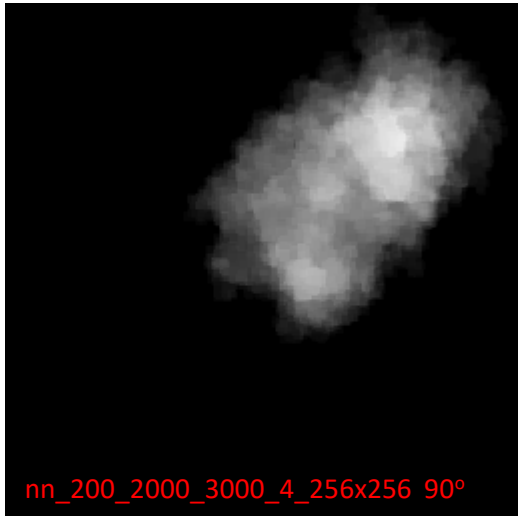

NN_1_200_2000_2000_4

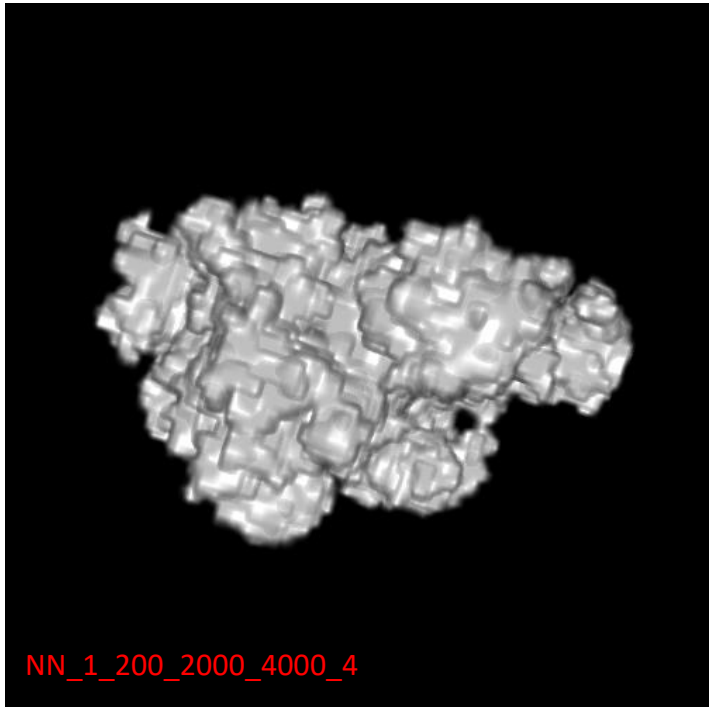

nn_200_2000_2000_4_256x256_0°


nn_200_2000_2000_4_256x256_90°


NN_1_200_2000_3000_4


nn_200_2000_3000_4_256x256_0°


nn_200_2000_3000_4_256x256_90°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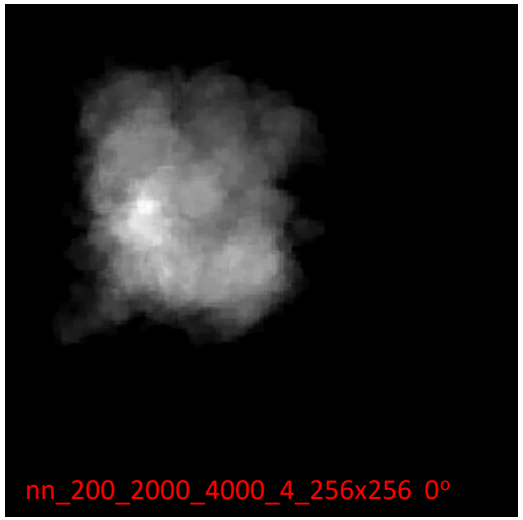
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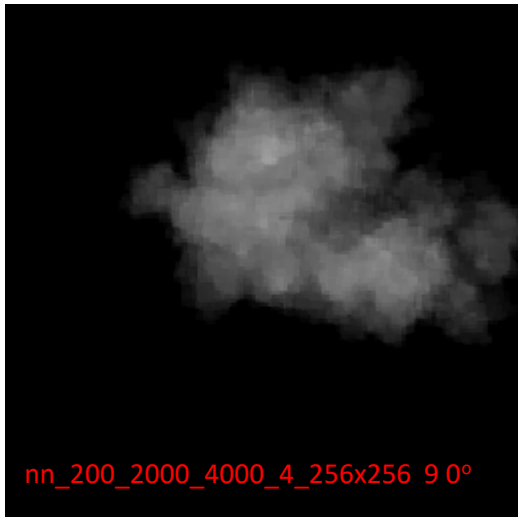
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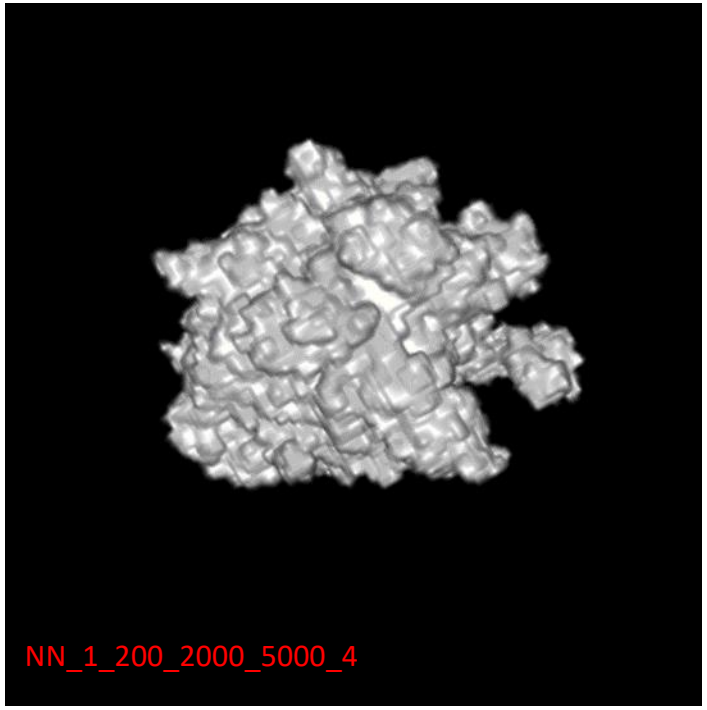
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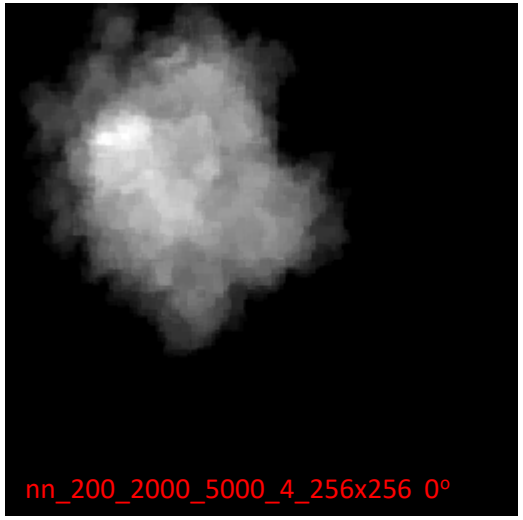
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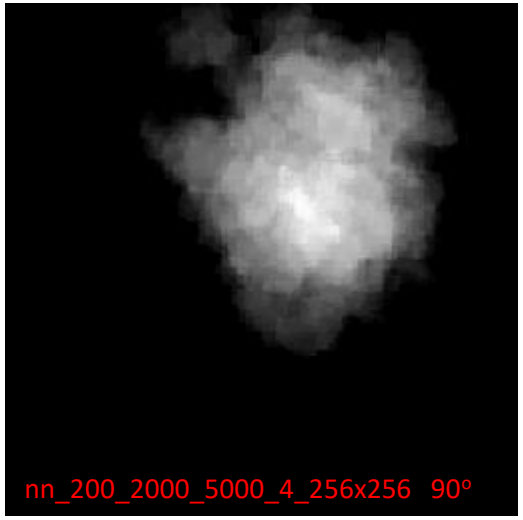
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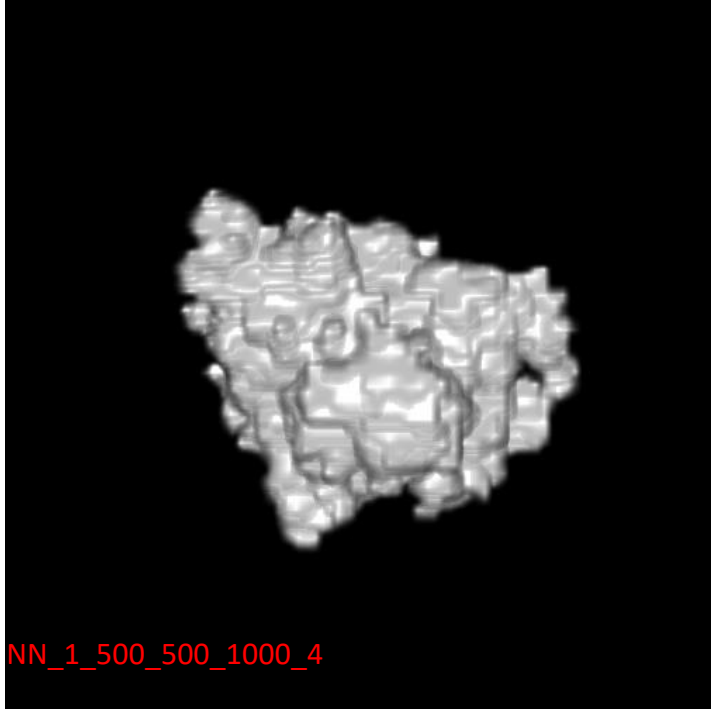
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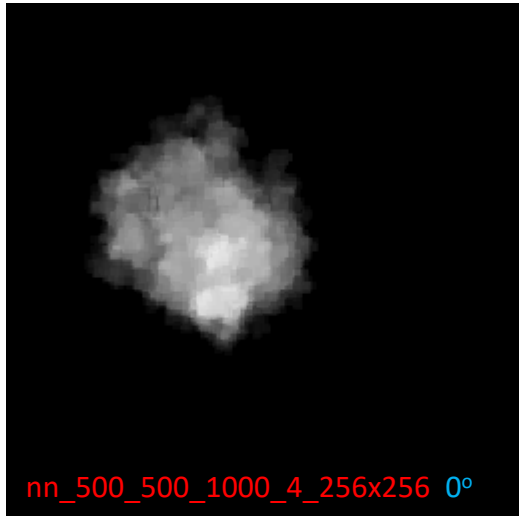
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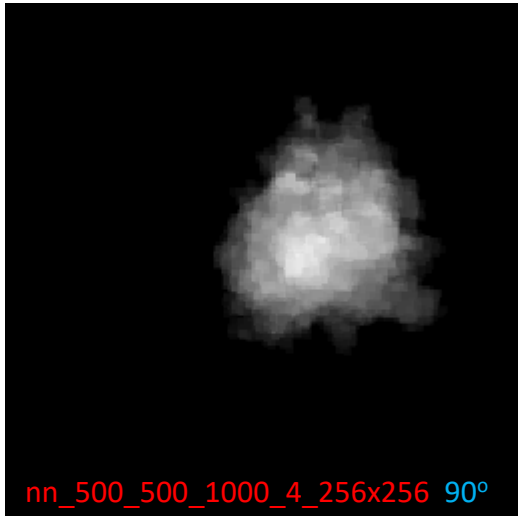
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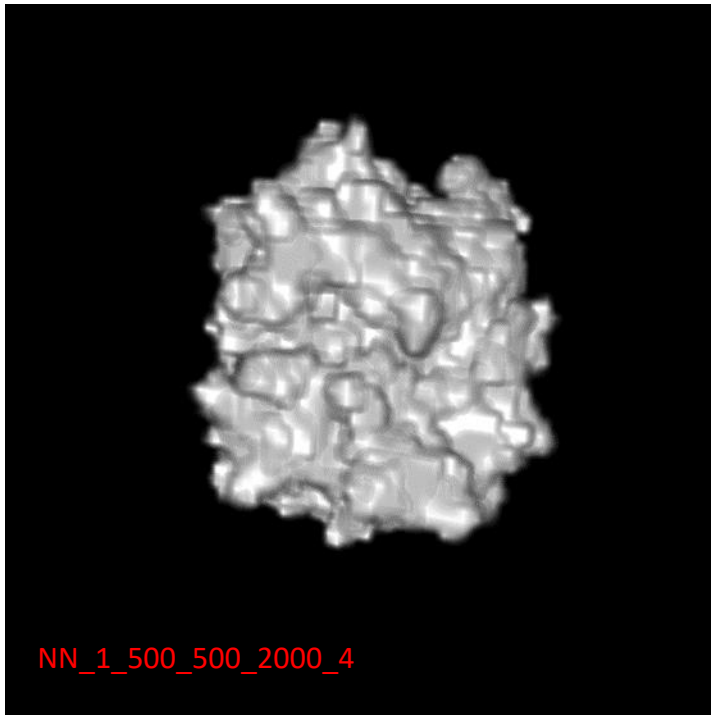
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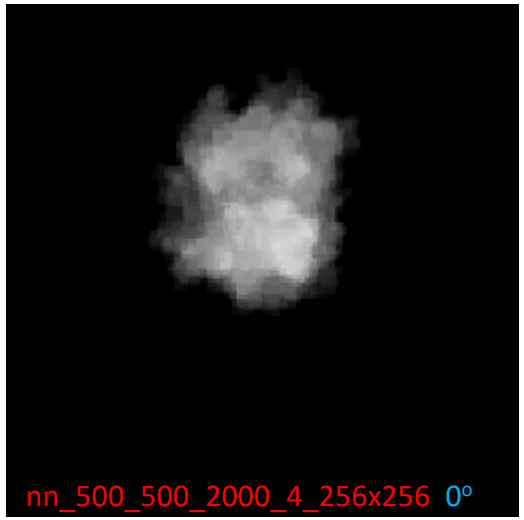
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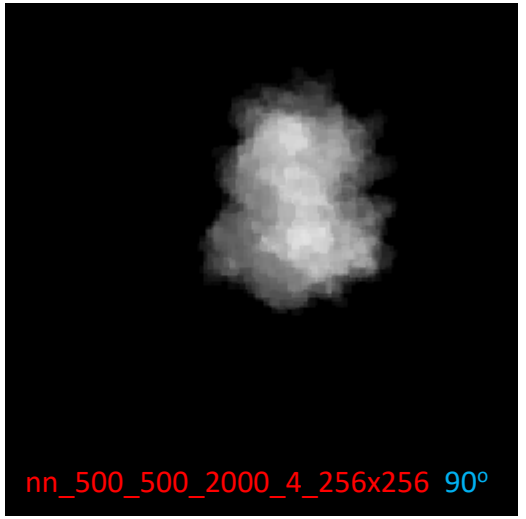
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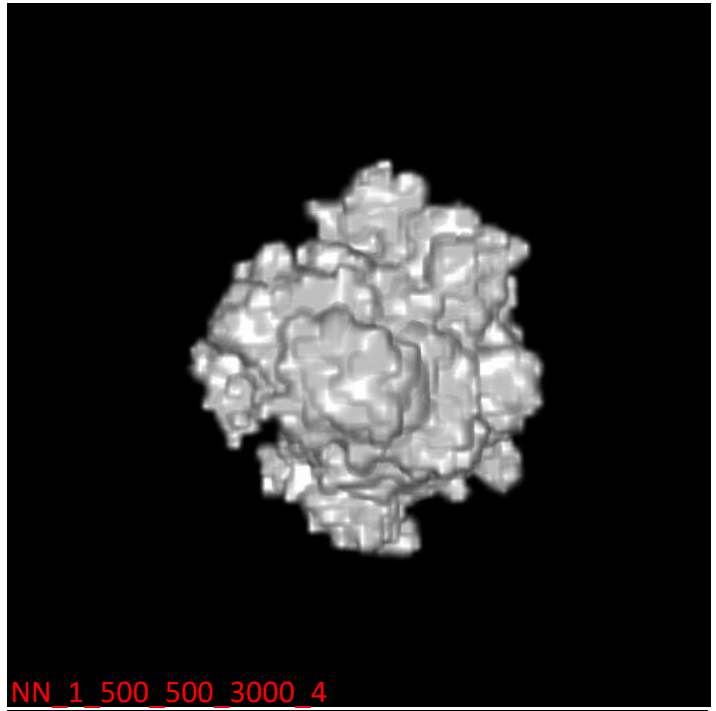
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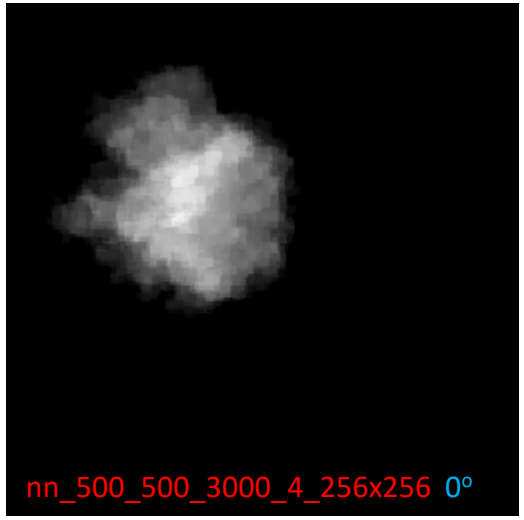
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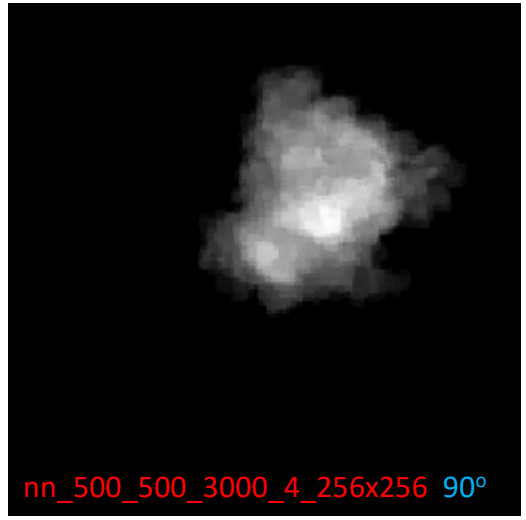
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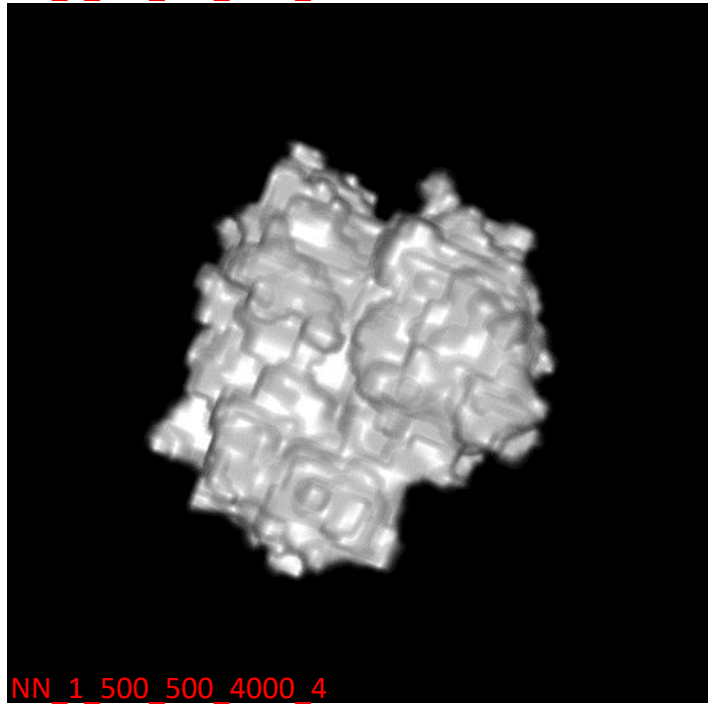
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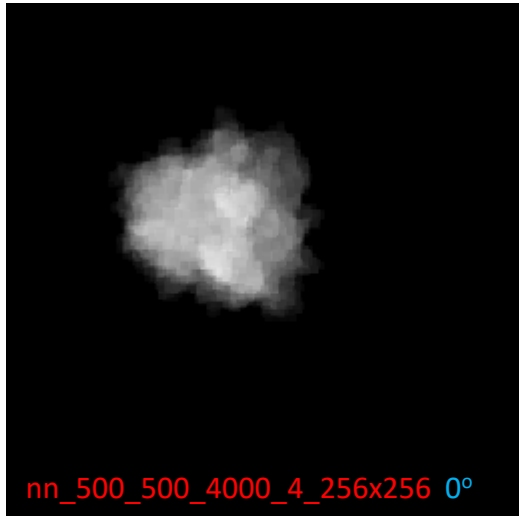
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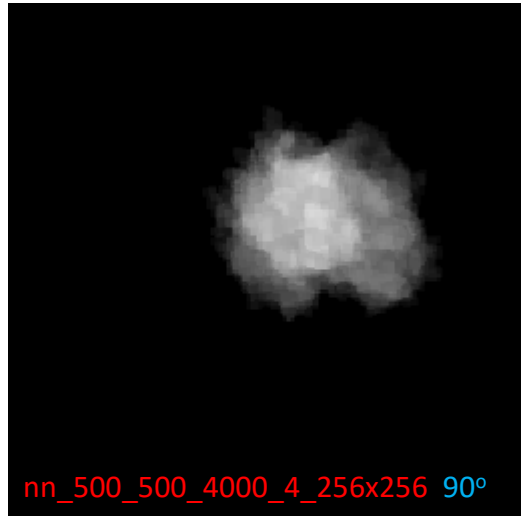
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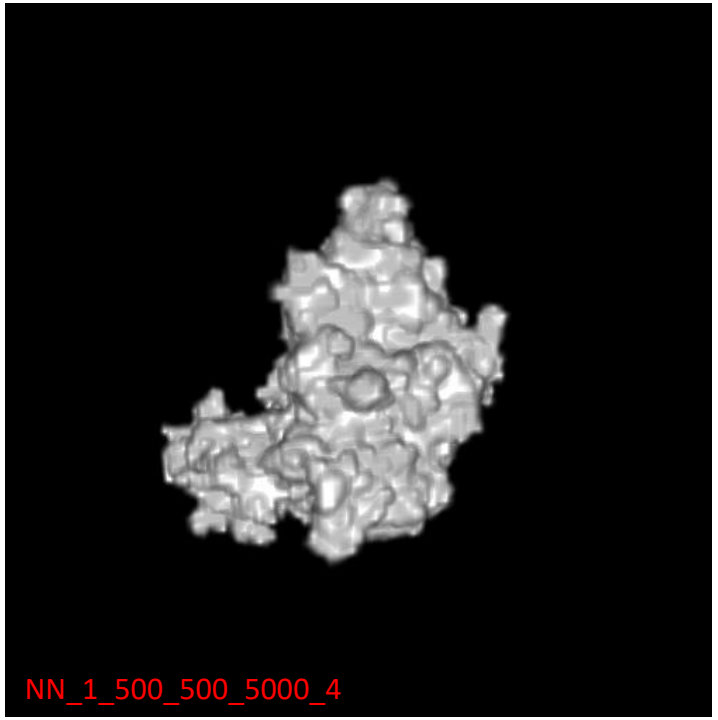
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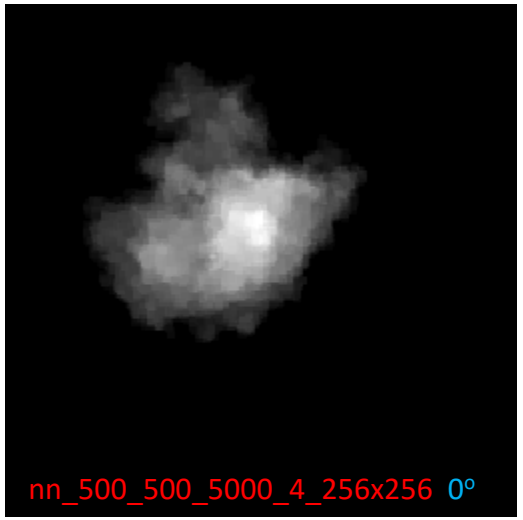
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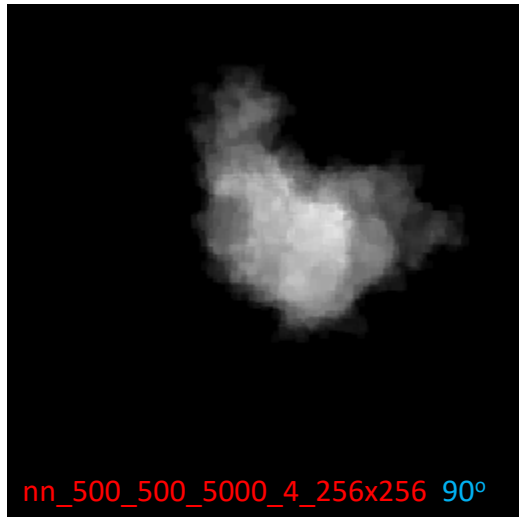
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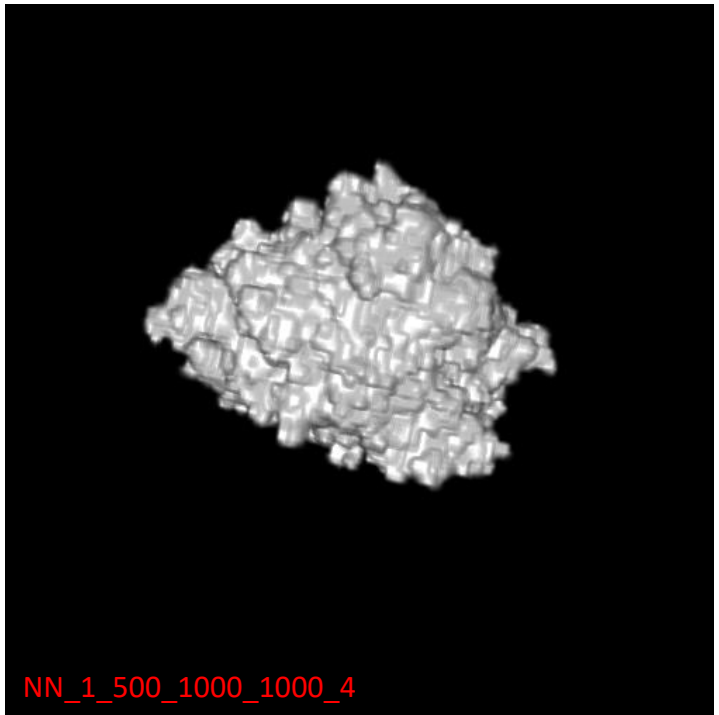
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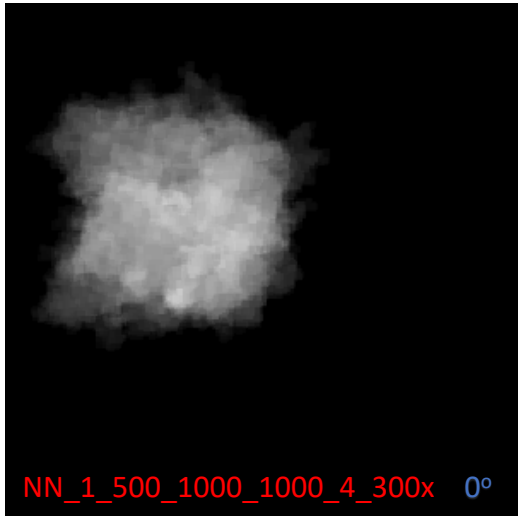
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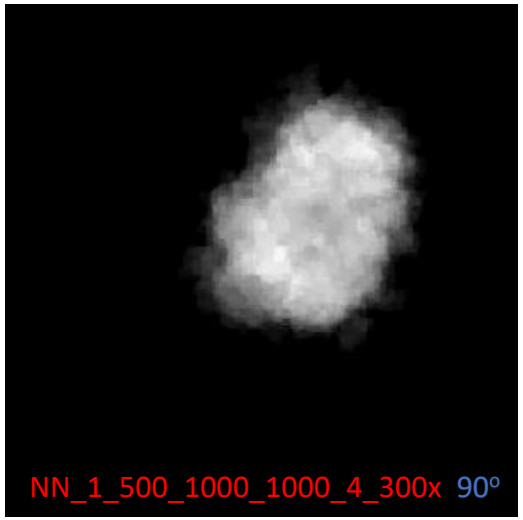
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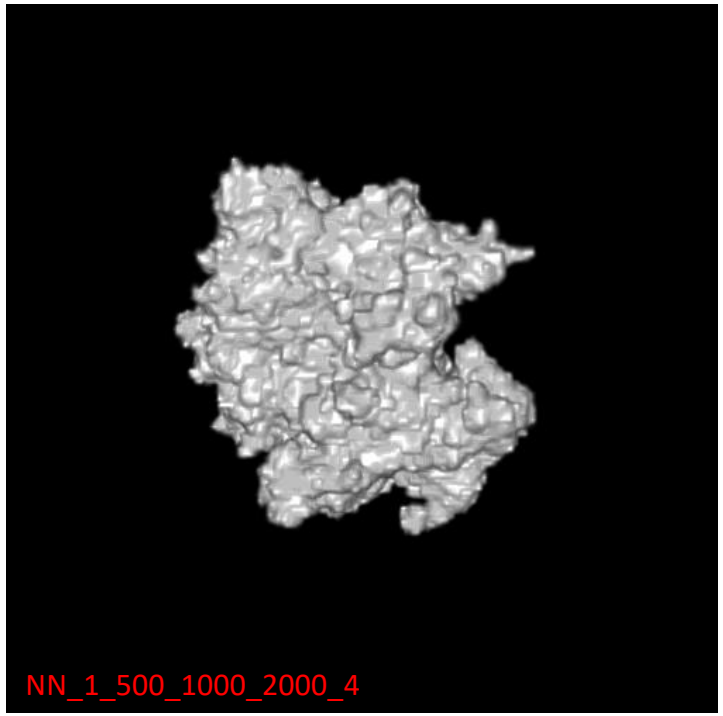
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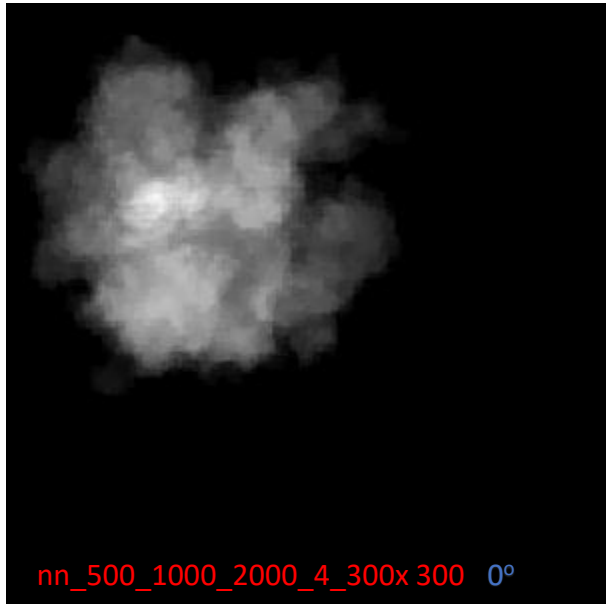
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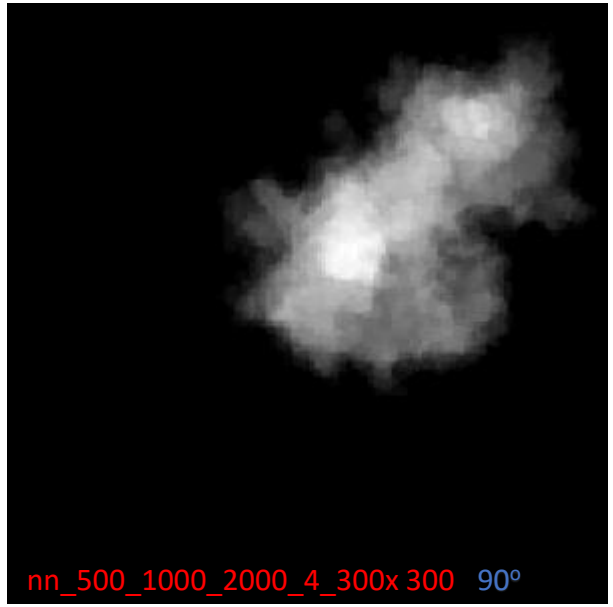
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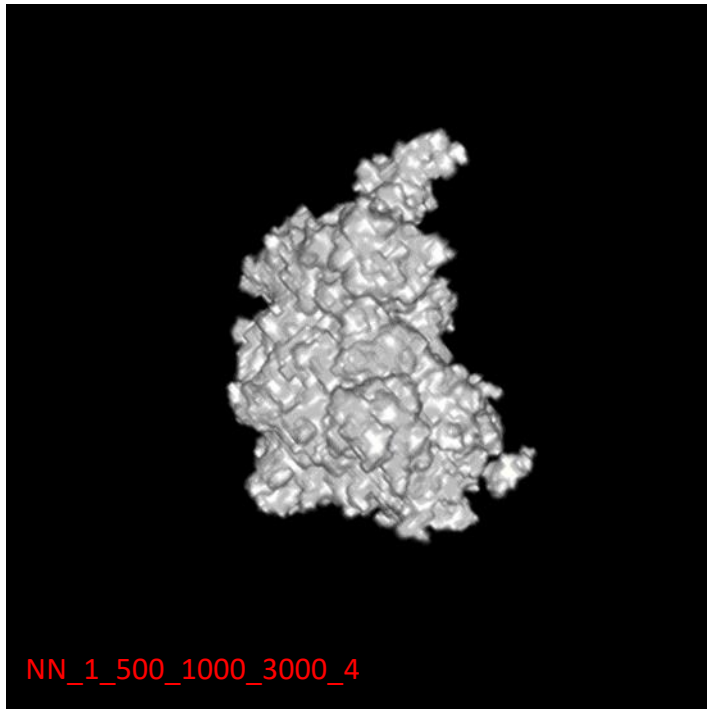
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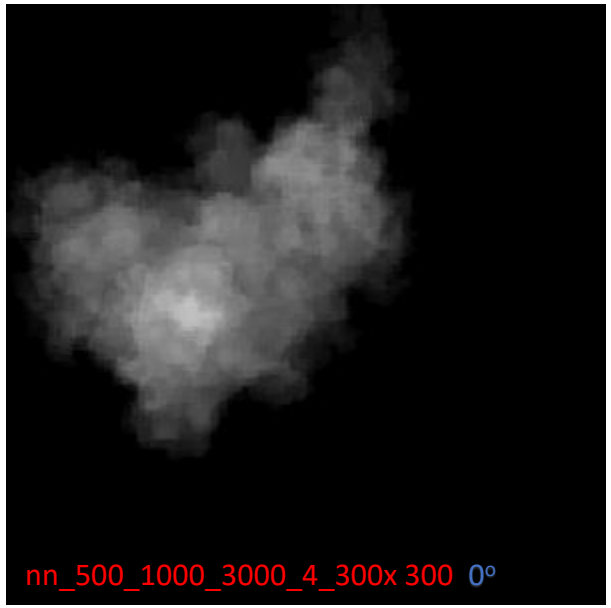
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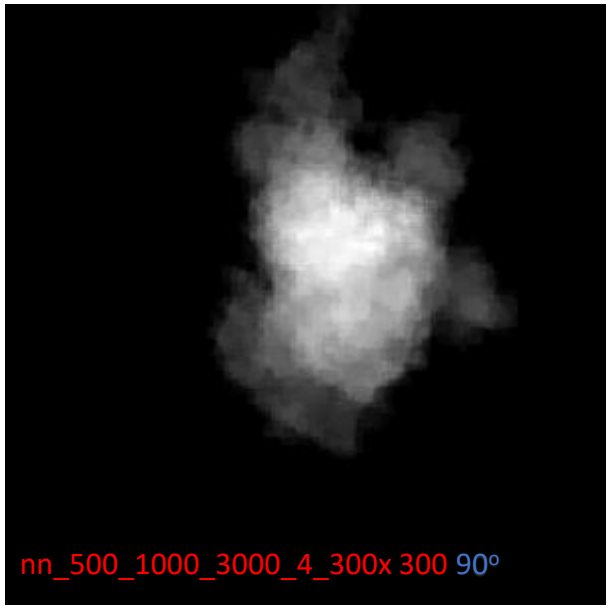
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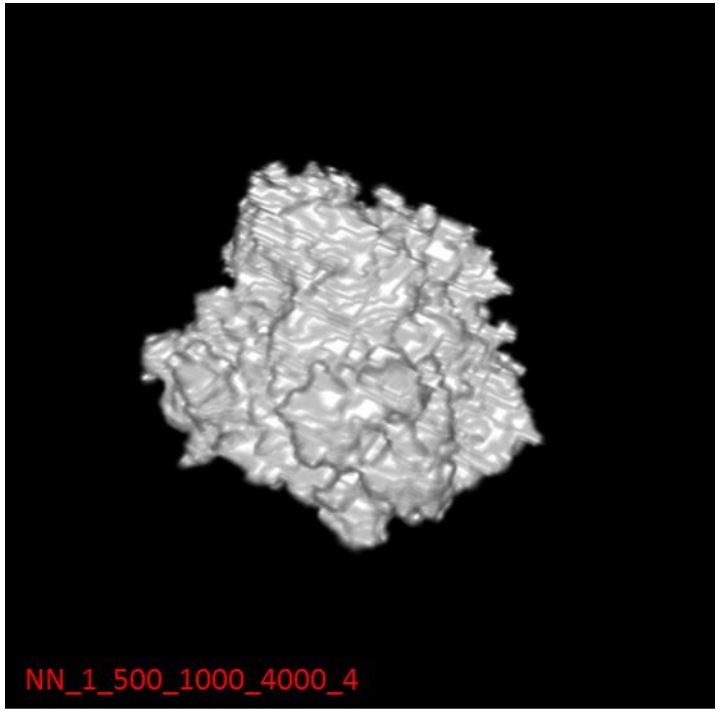
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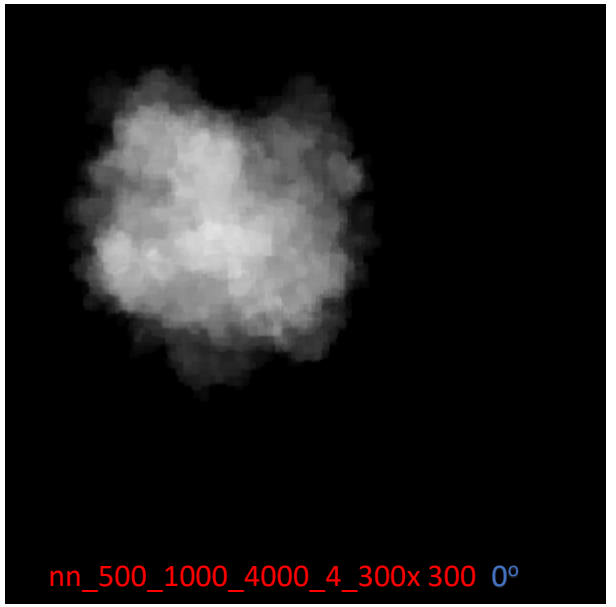
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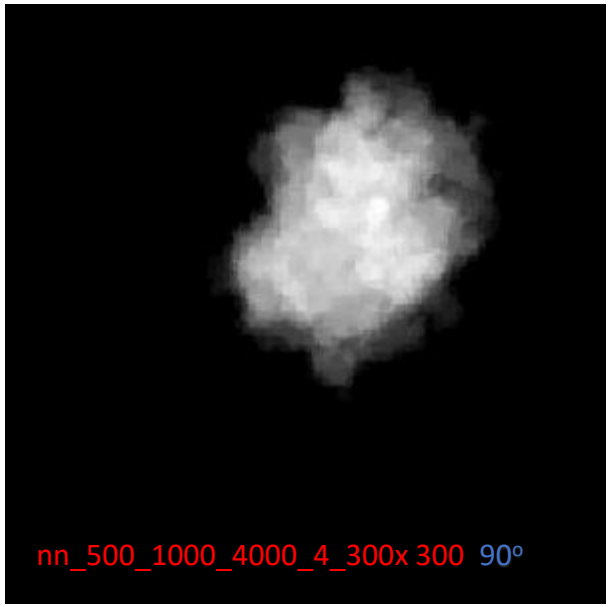
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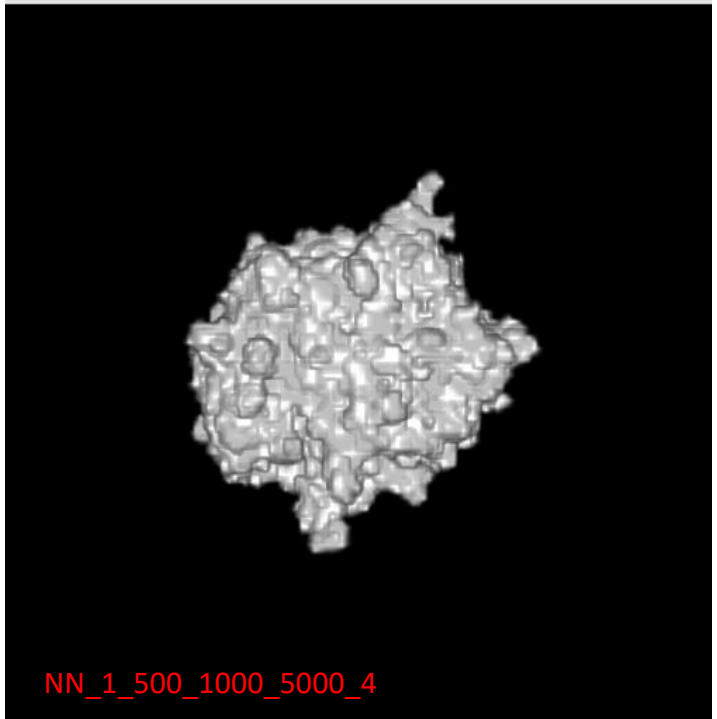
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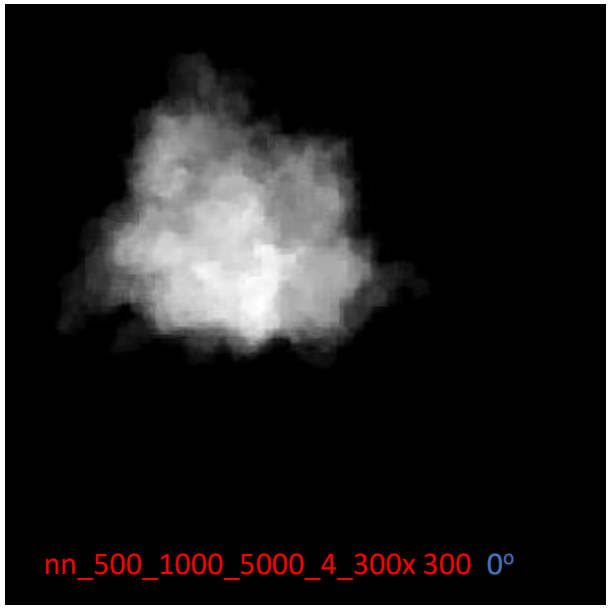
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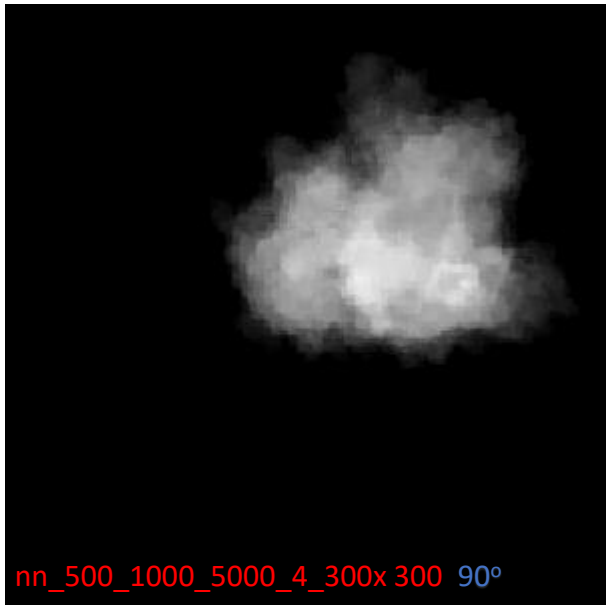
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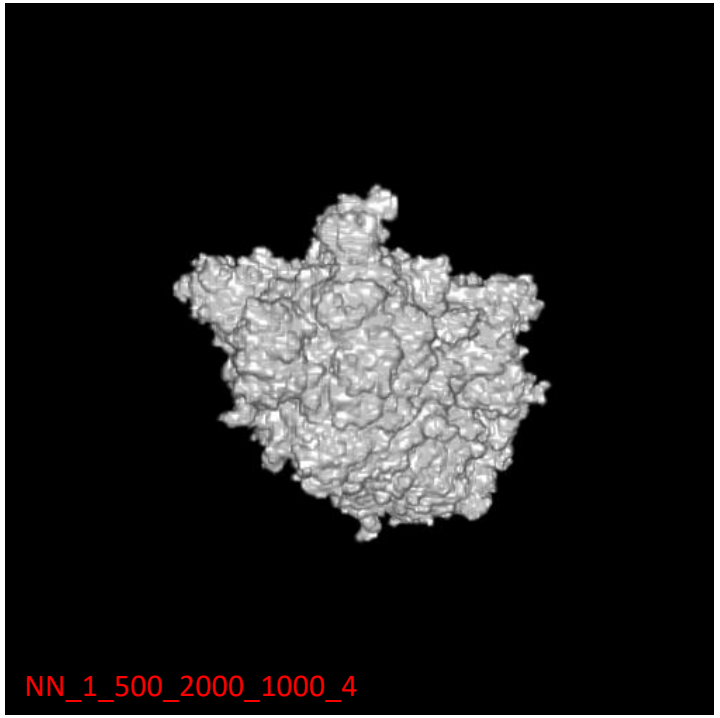
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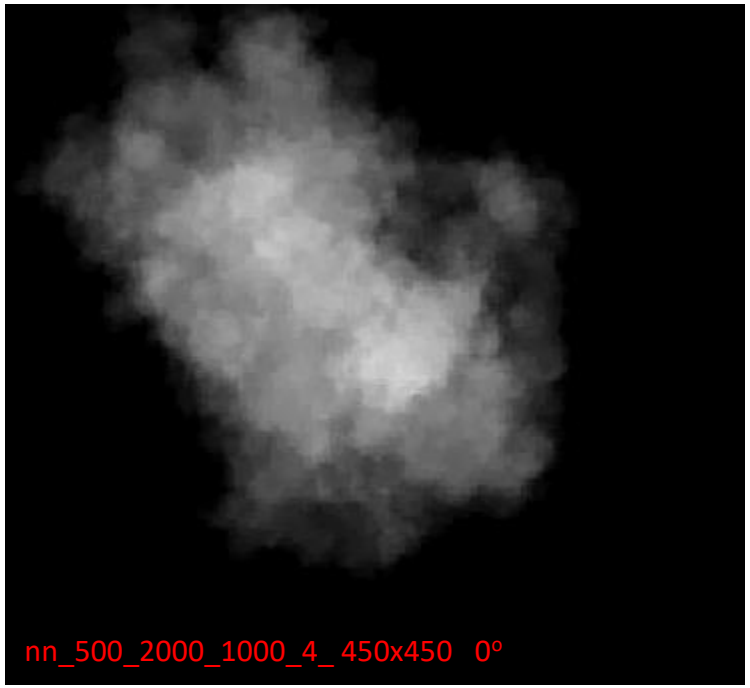
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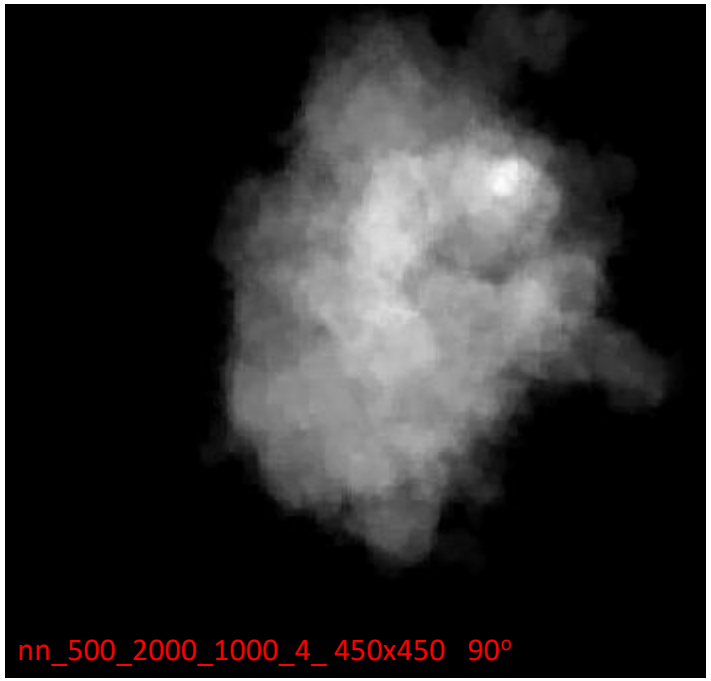
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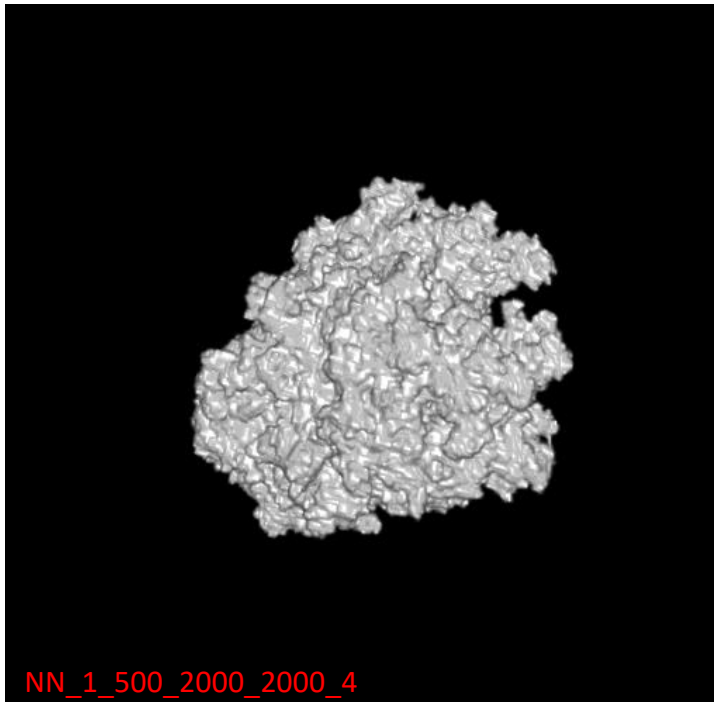
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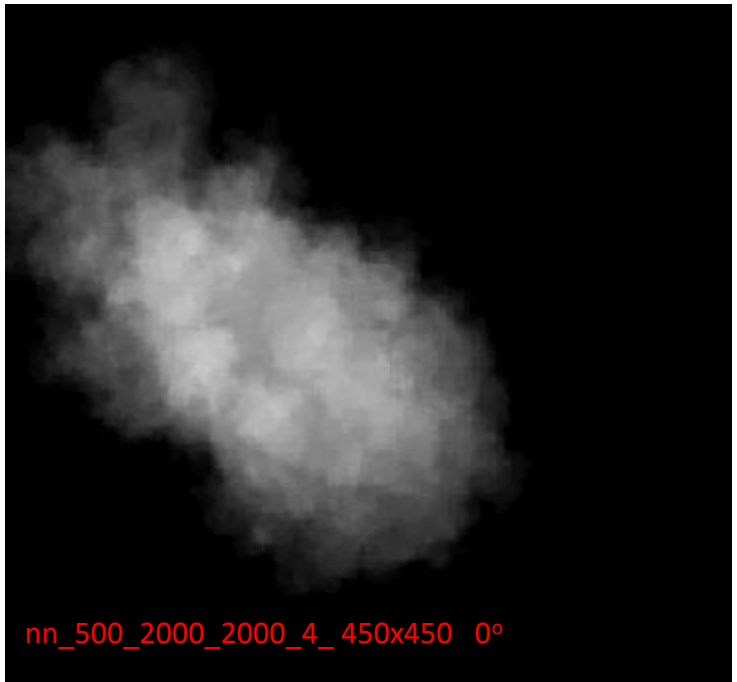
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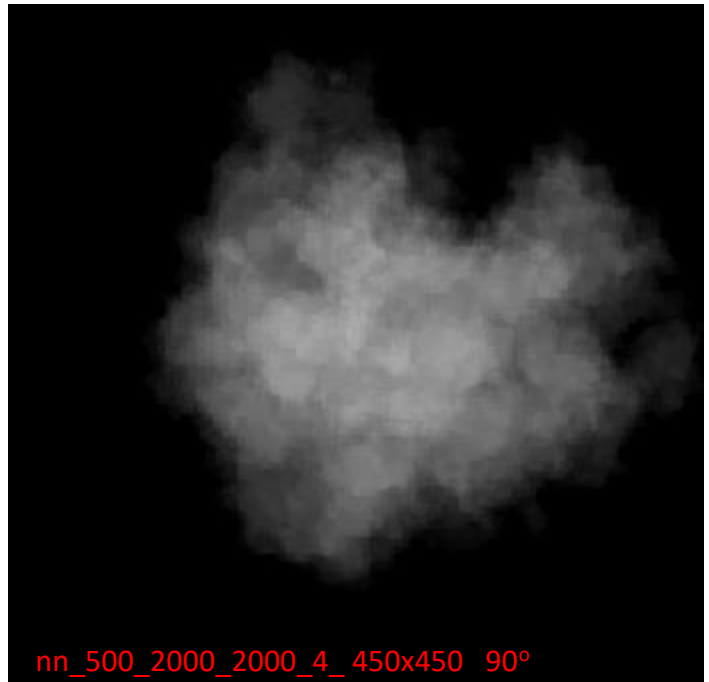
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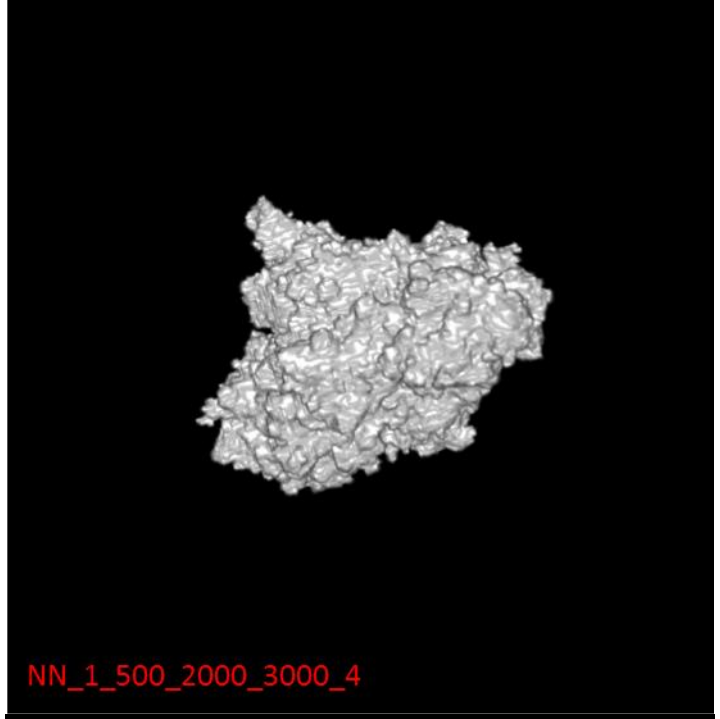
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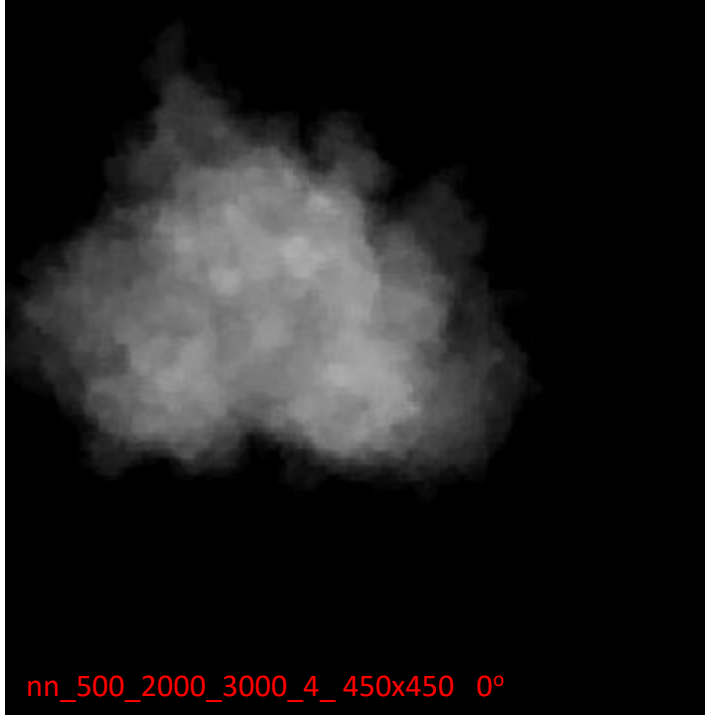
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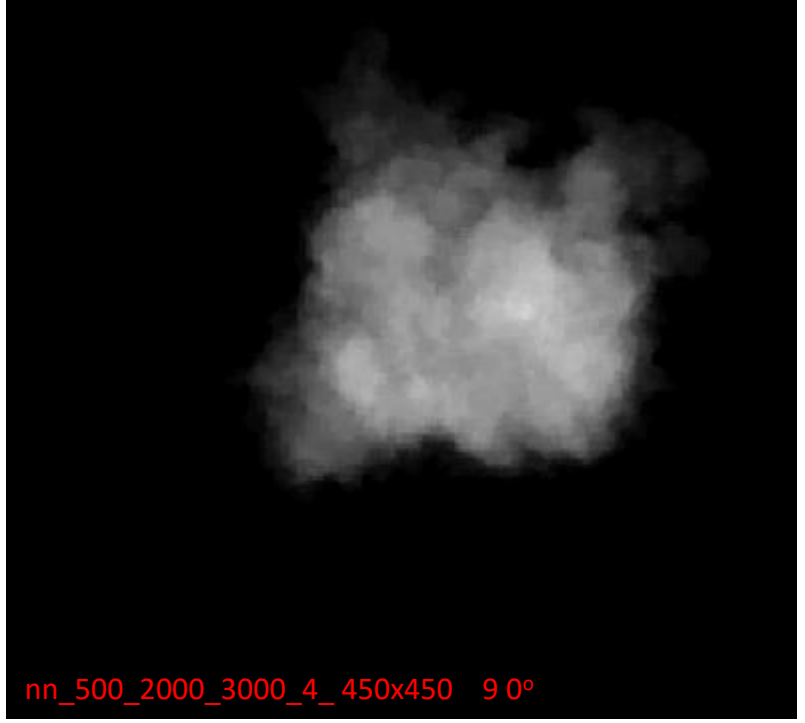
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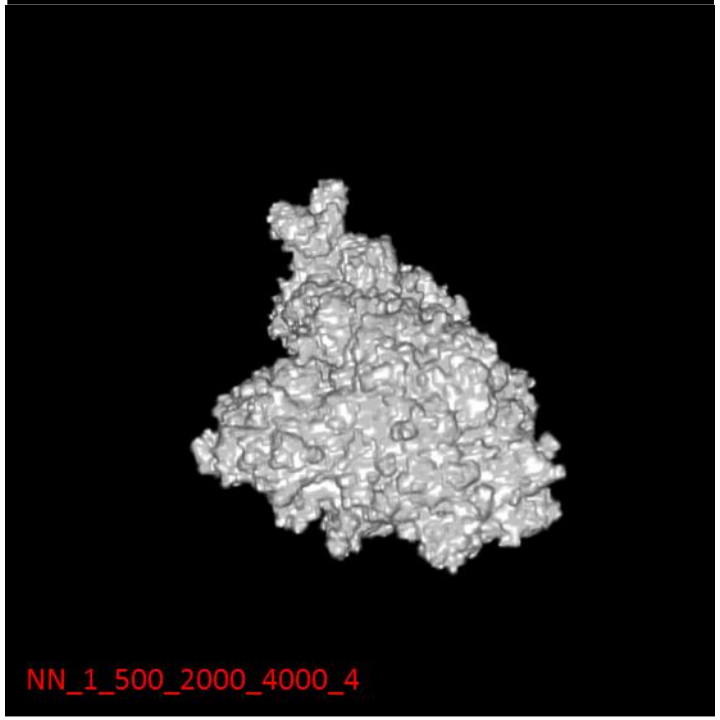
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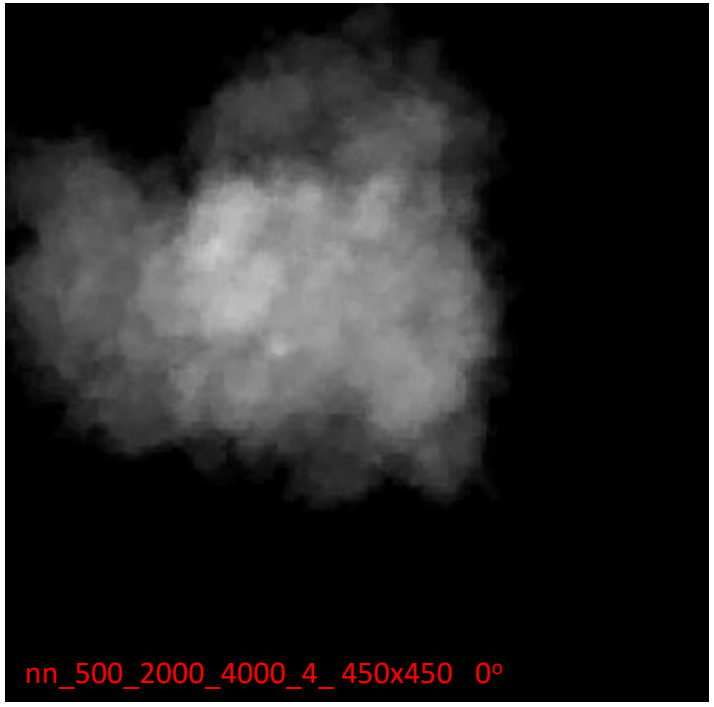
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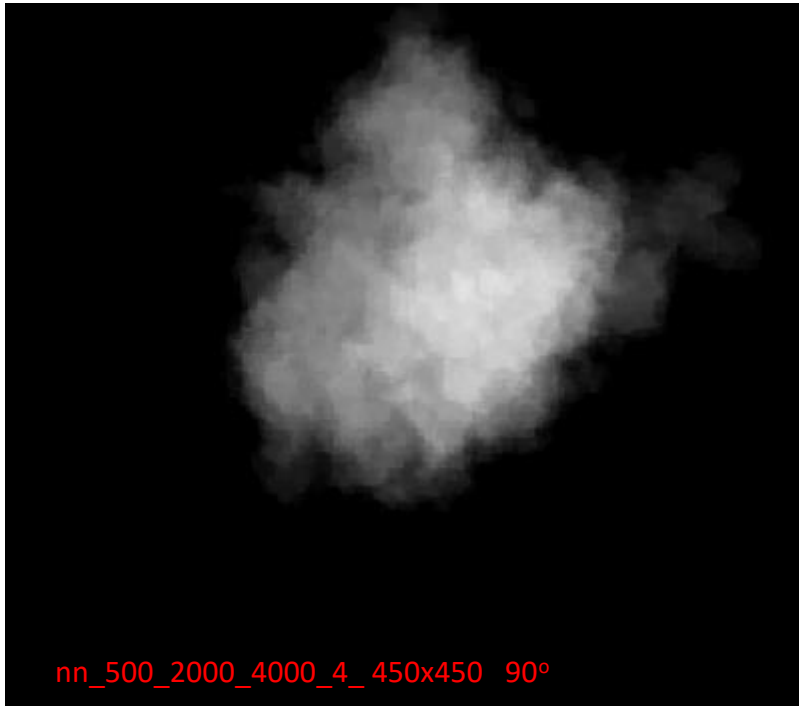
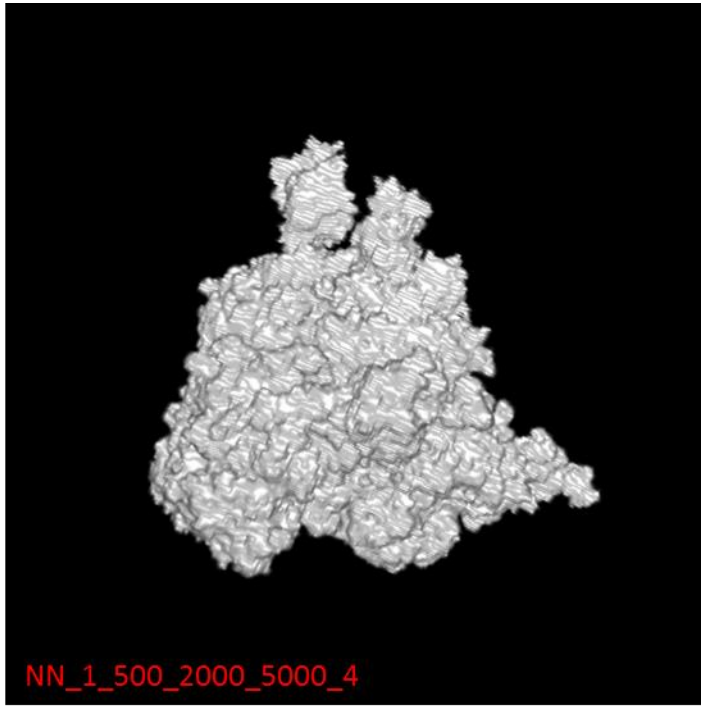

nn_500_2000_4000_4_ 450x450 90°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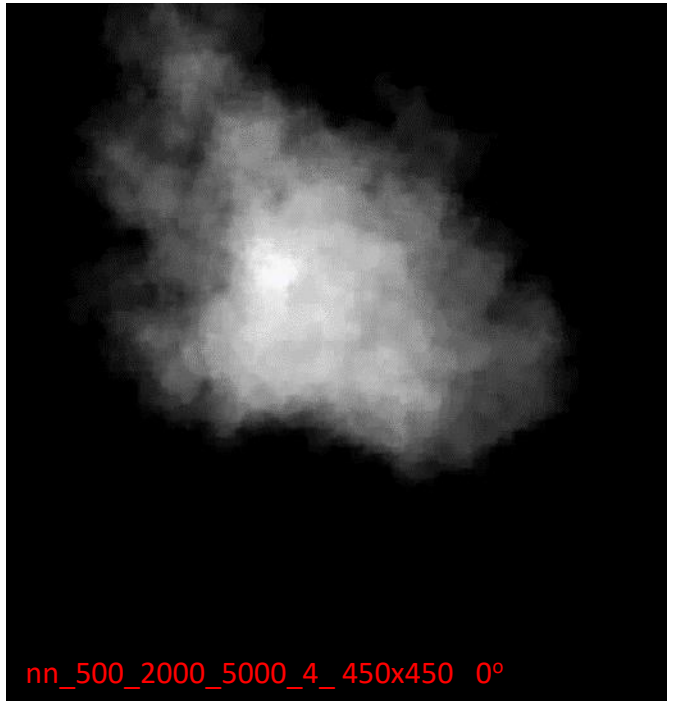
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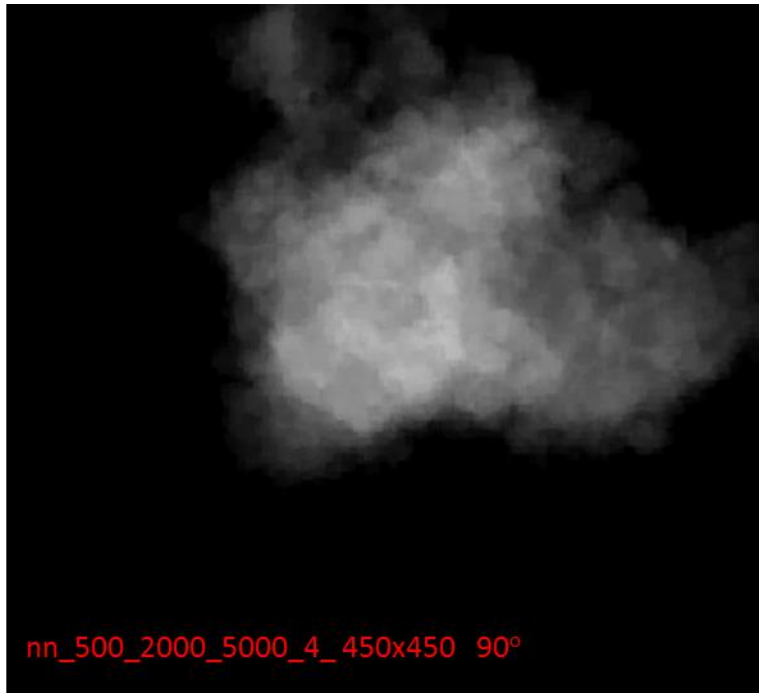
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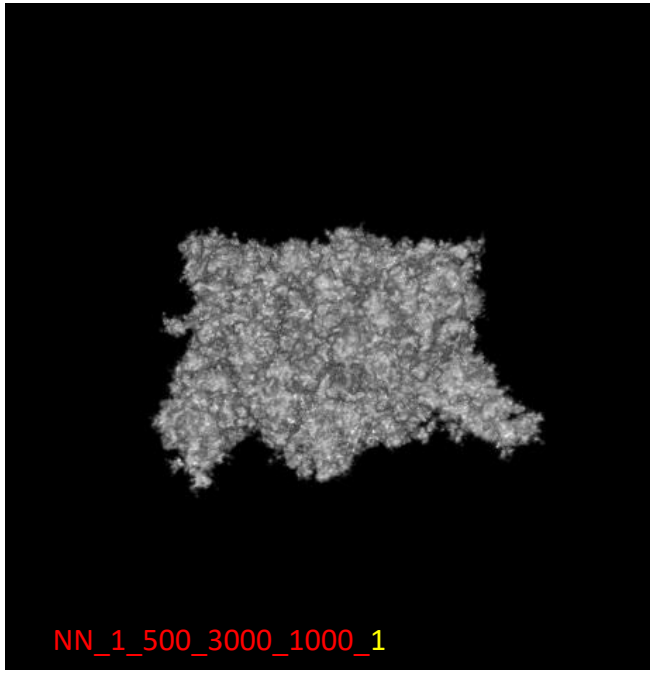
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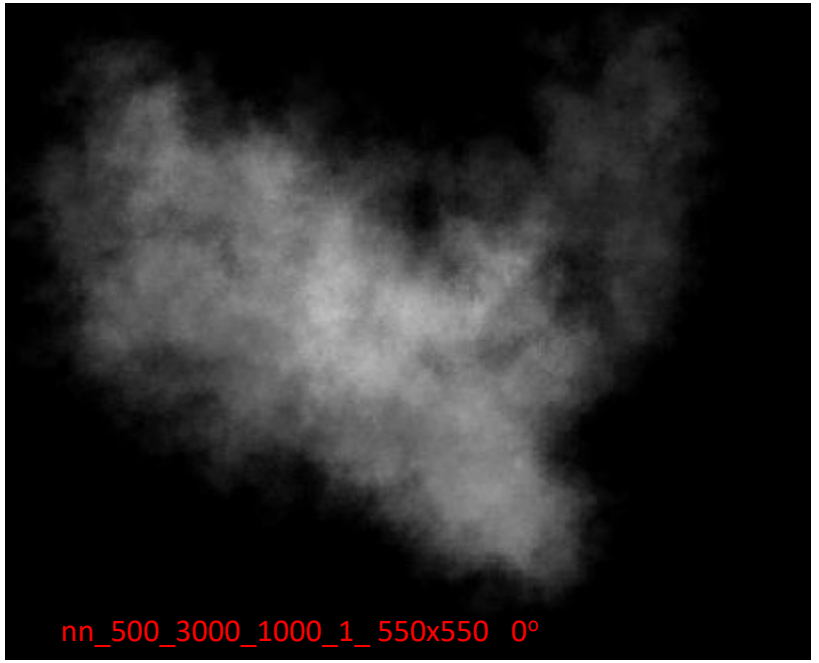
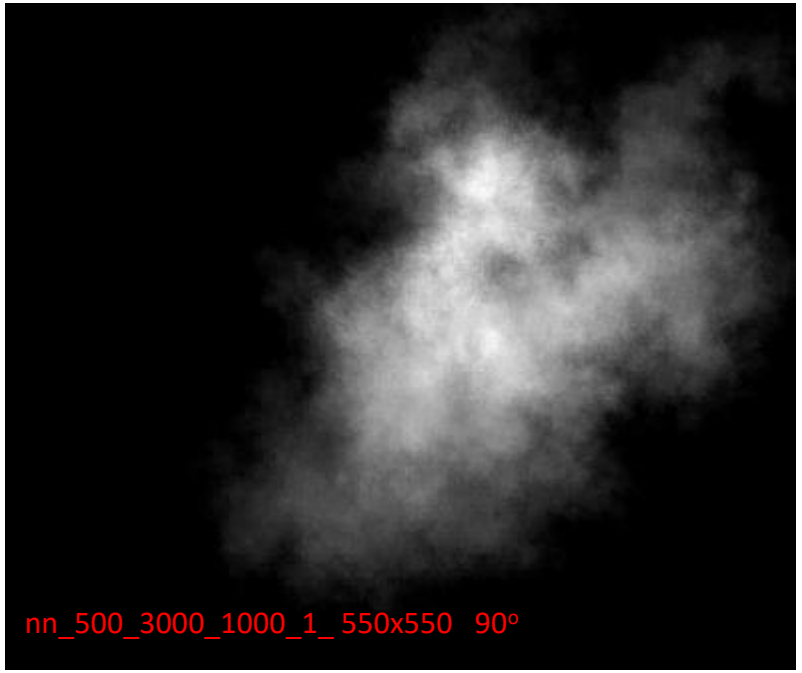

nn_500_3000_1000_1_ 550x550 0º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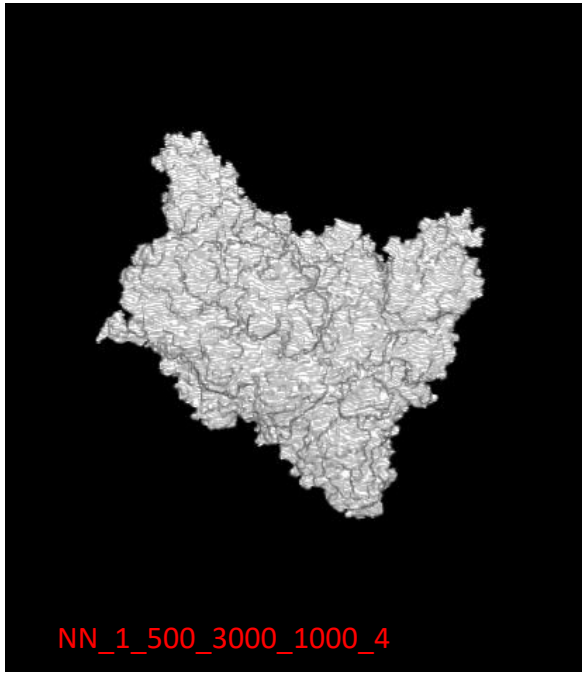
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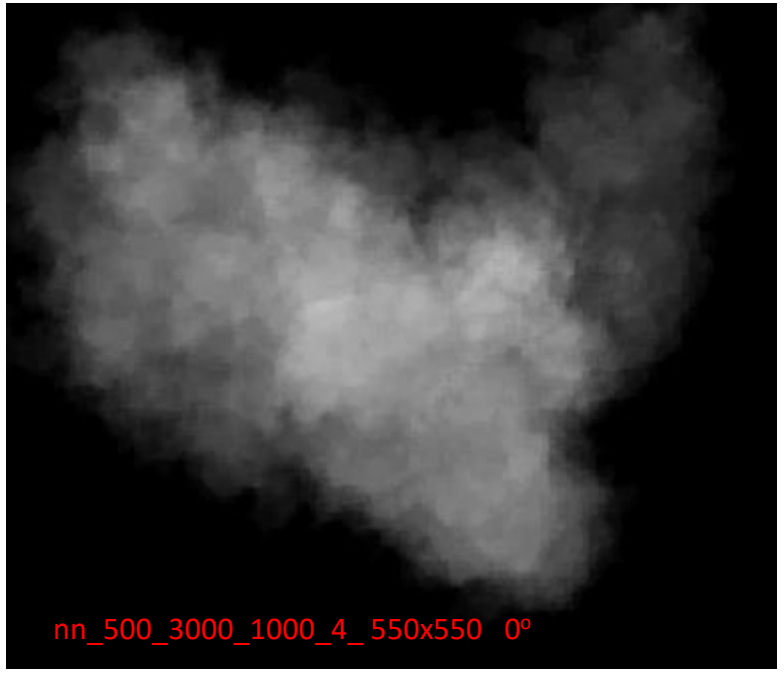
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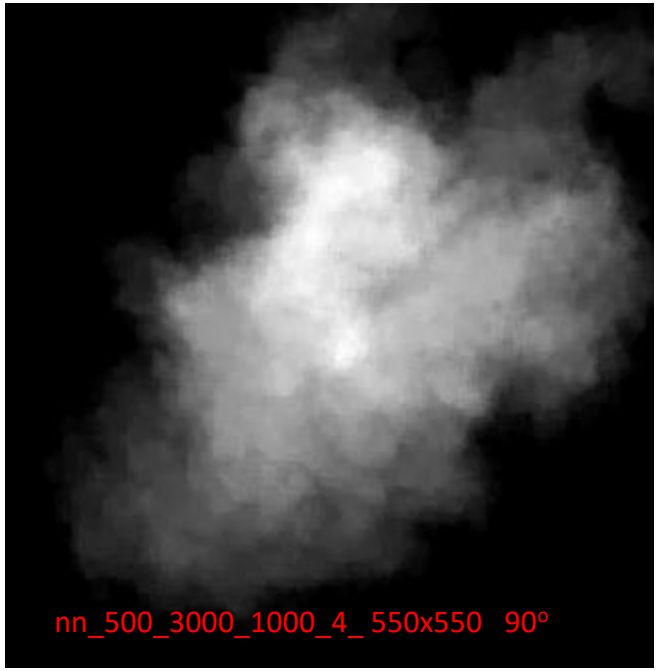
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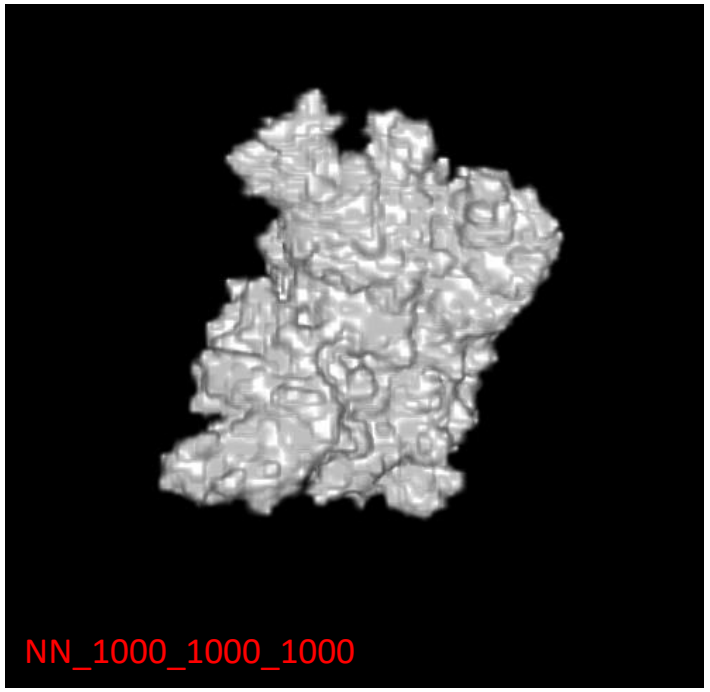
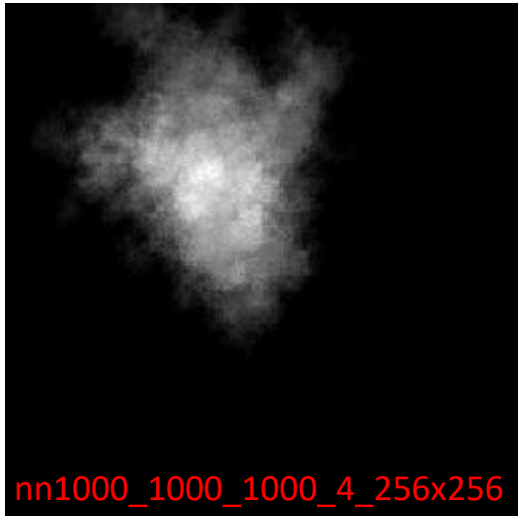
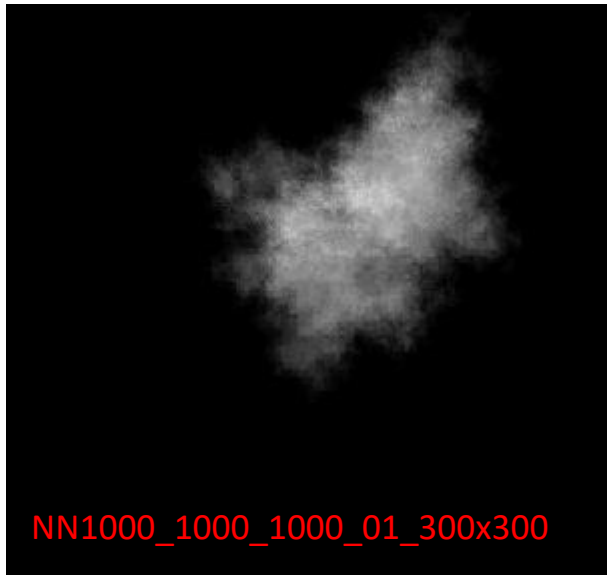
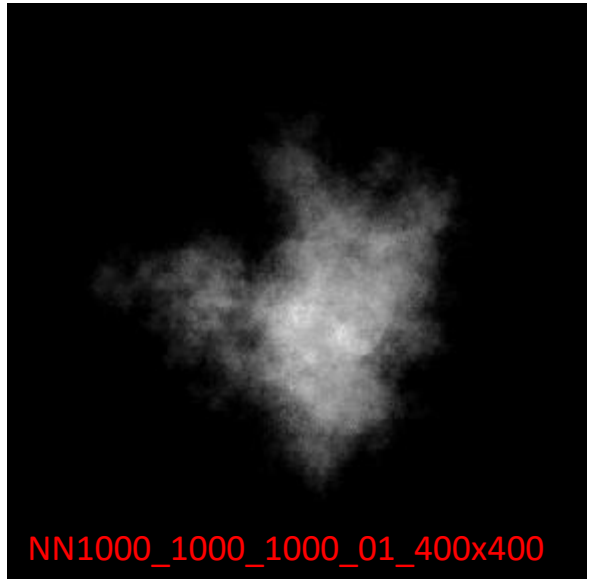
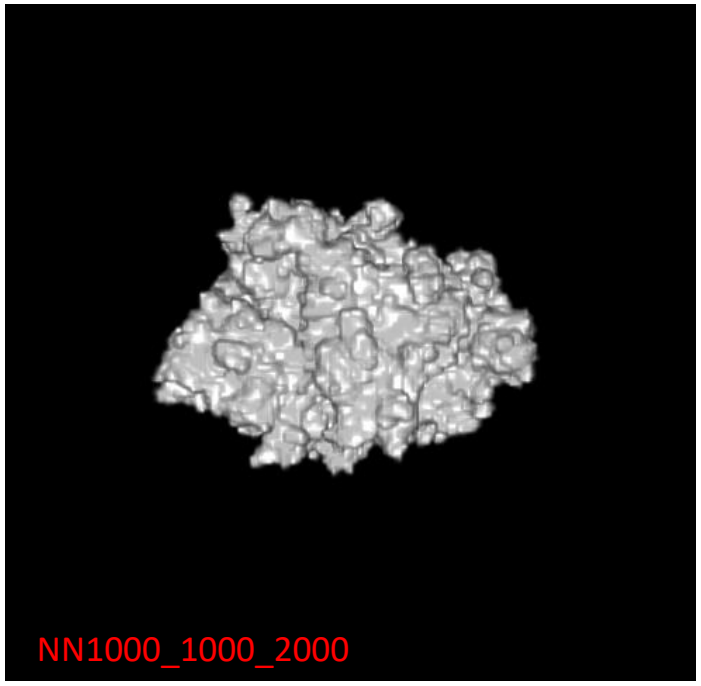
Ray step 0.05 mm

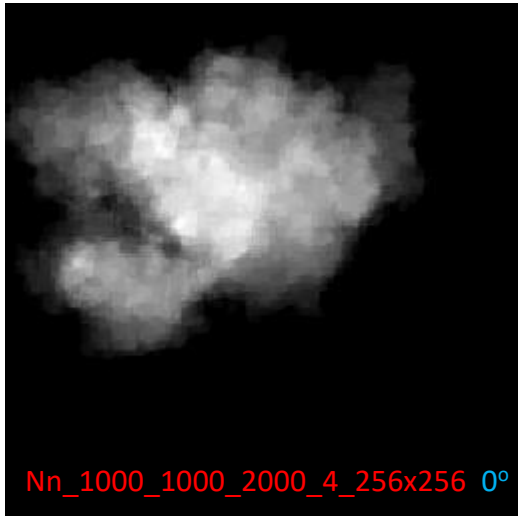


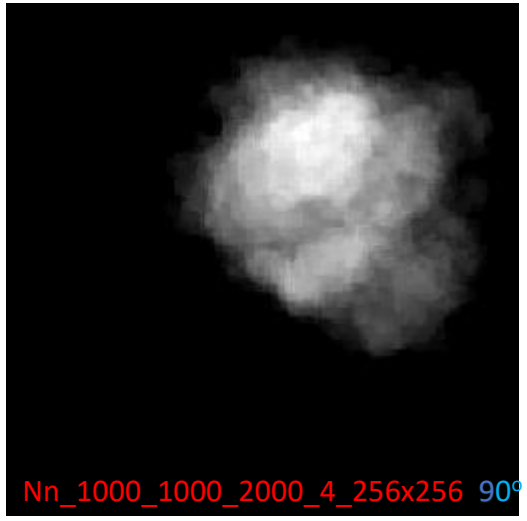


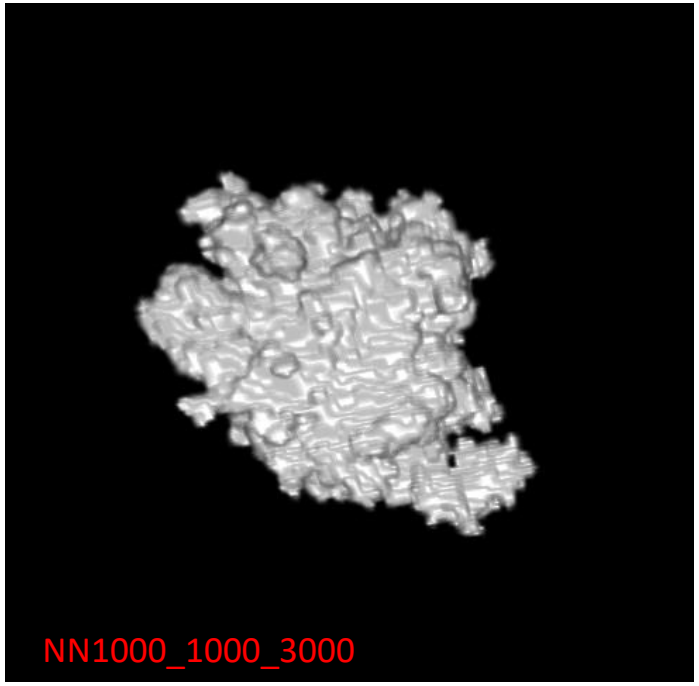








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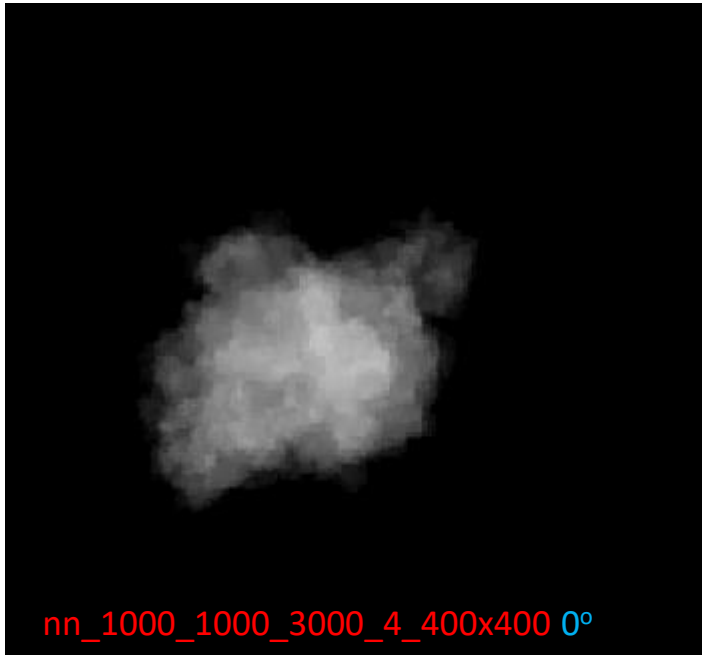
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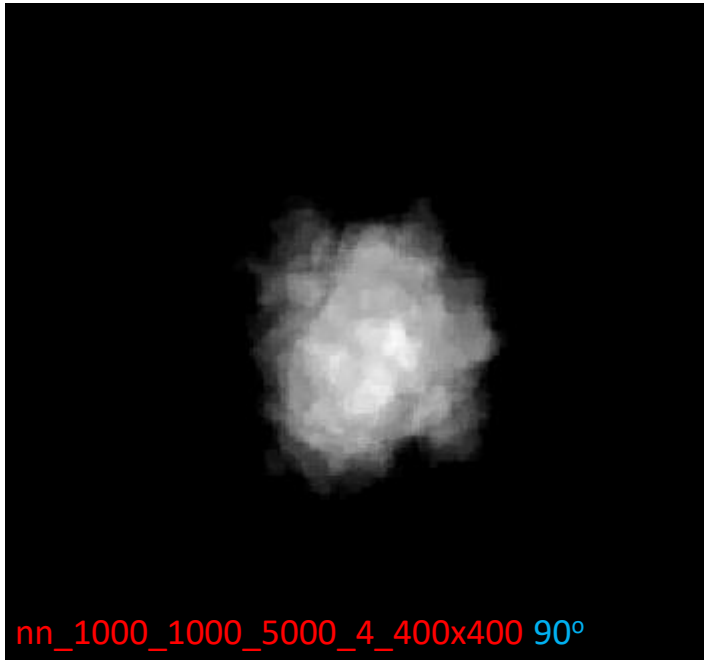
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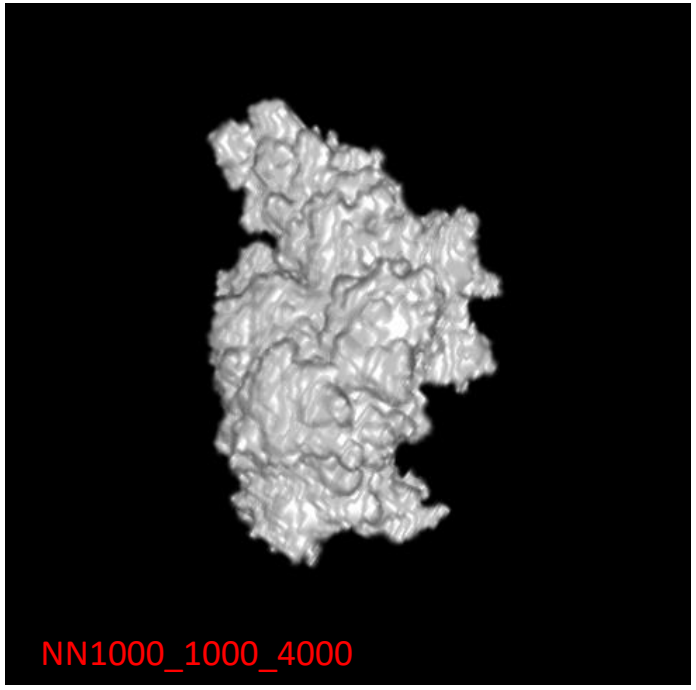
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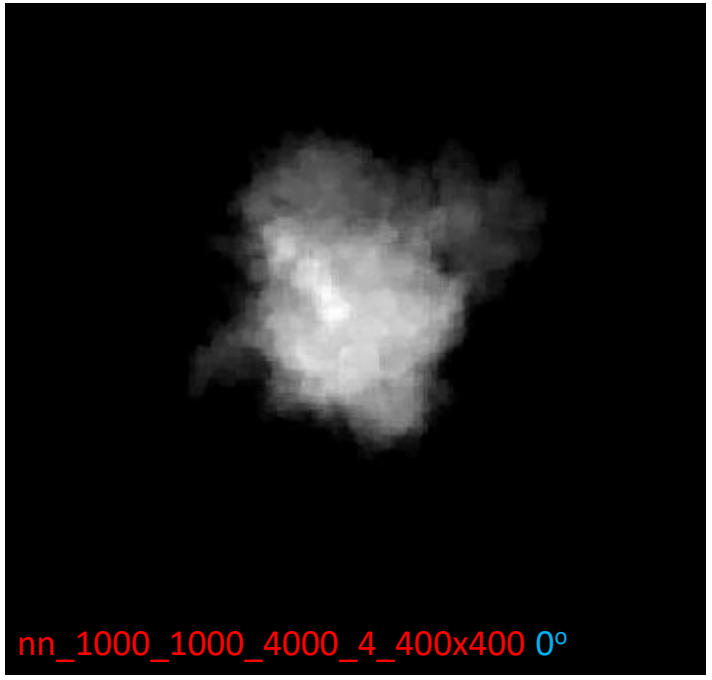
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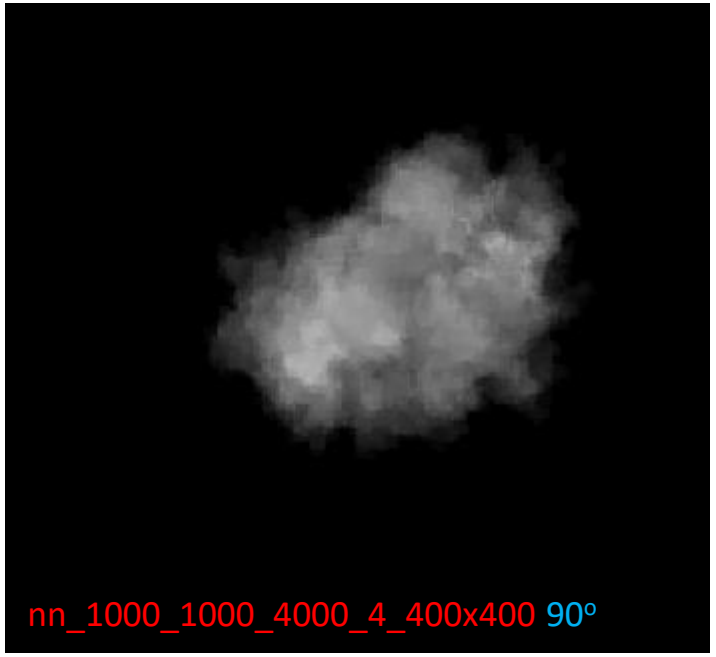
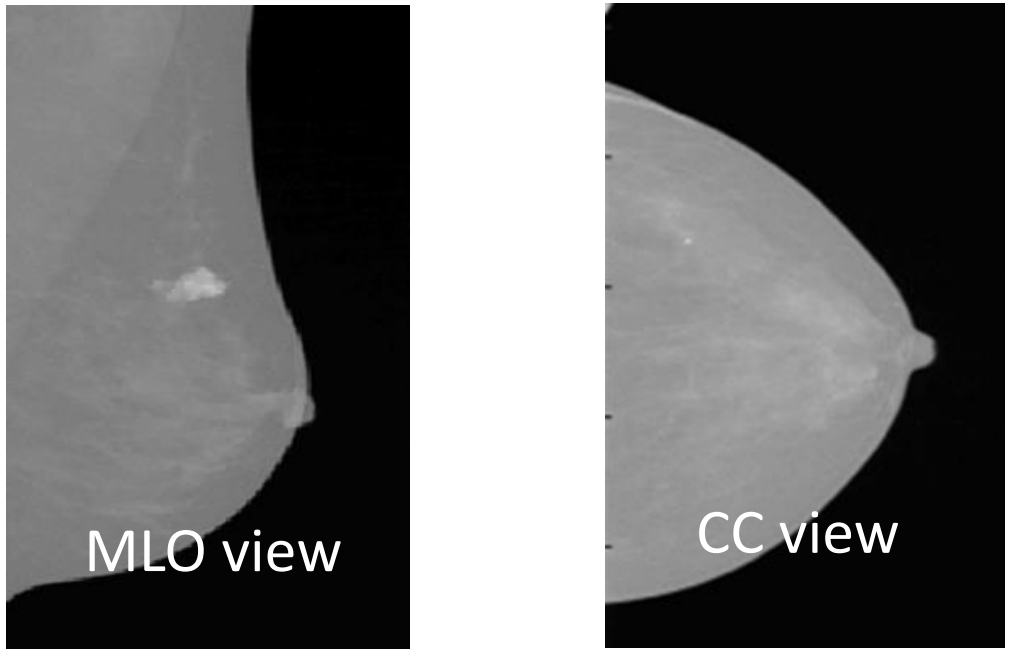

nn_1000_1000_4000_4_400x400 90º

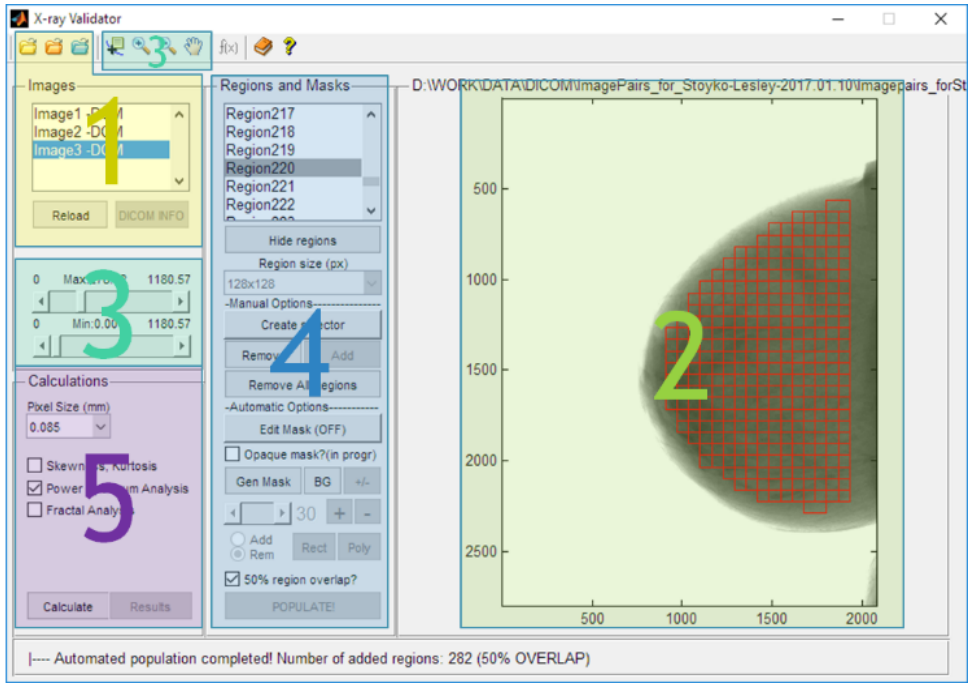
Under development



Gospodinova, 2018, ACT2018, Ohrid

The created Images are stored in a database and will be used in the further assessment, research and educational activities.

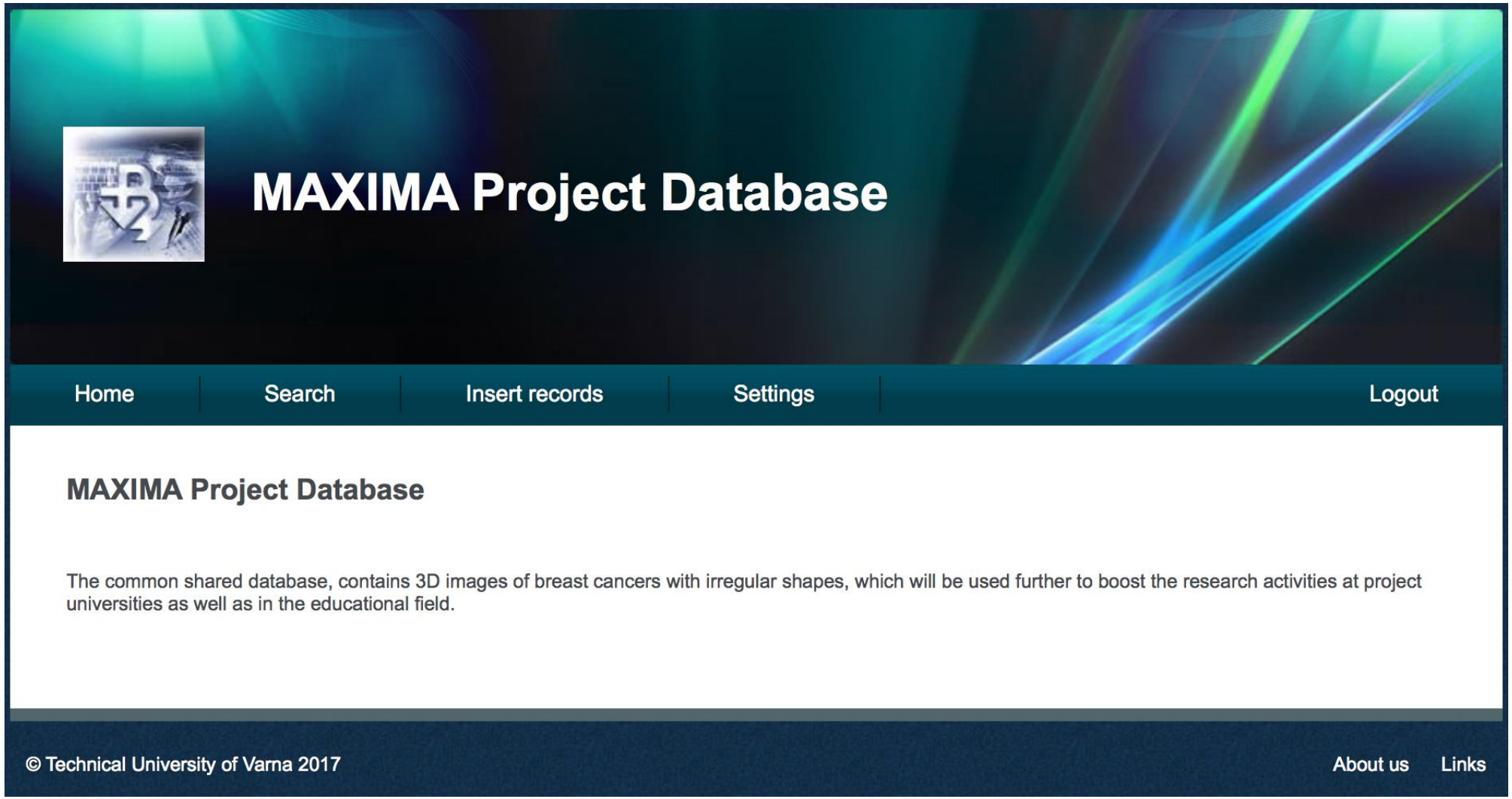
Objective evaluation



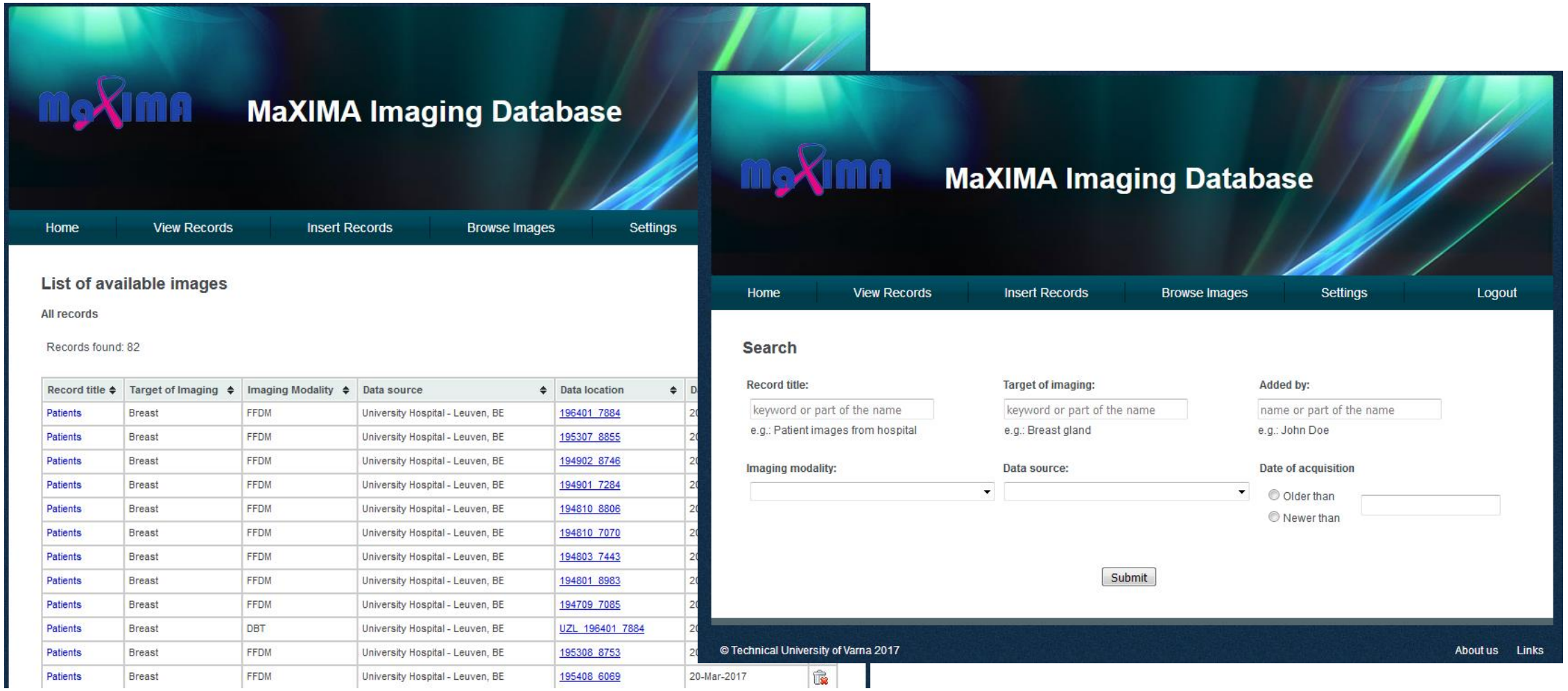
Subjective evaluation

4 AFC

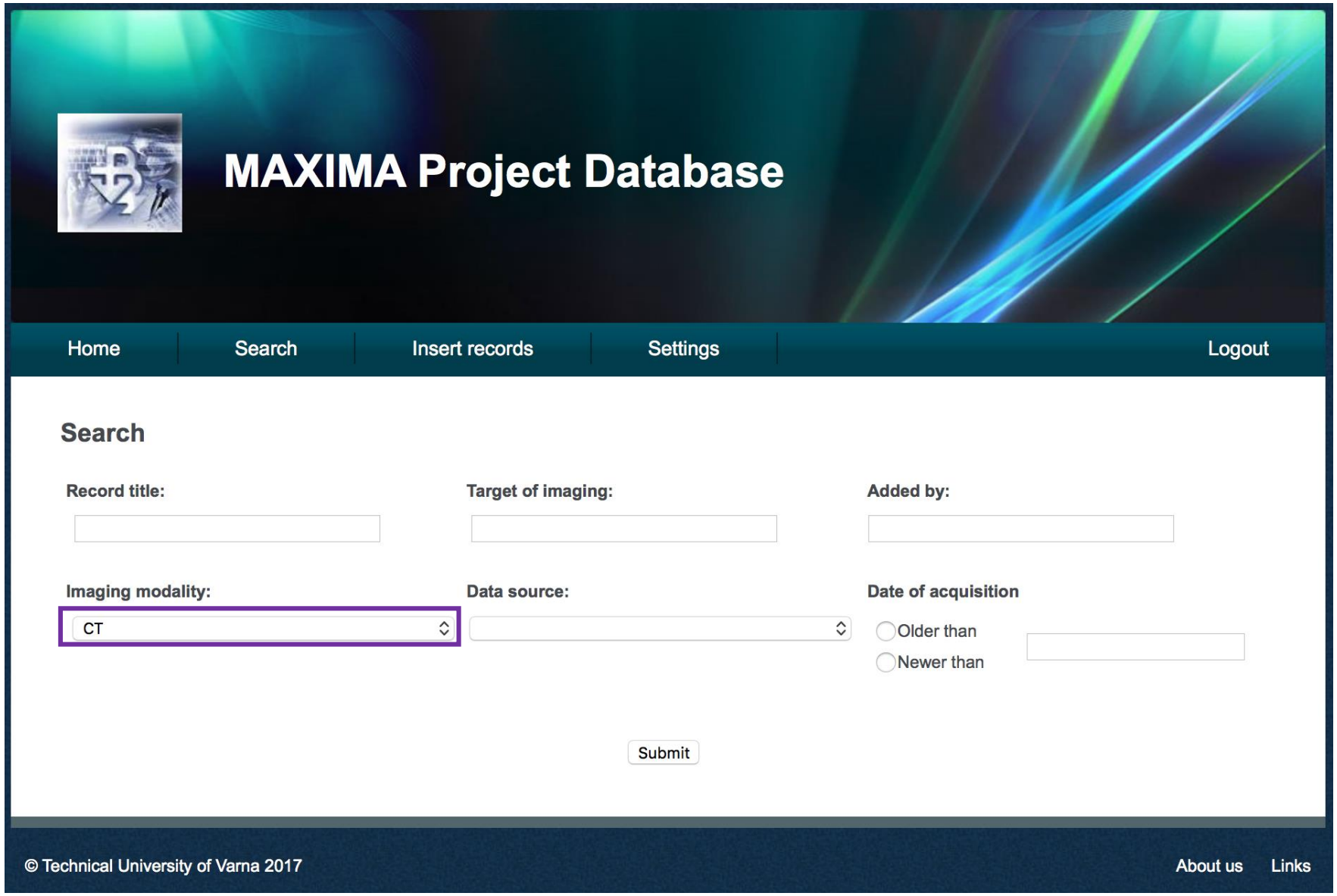
Database organisation



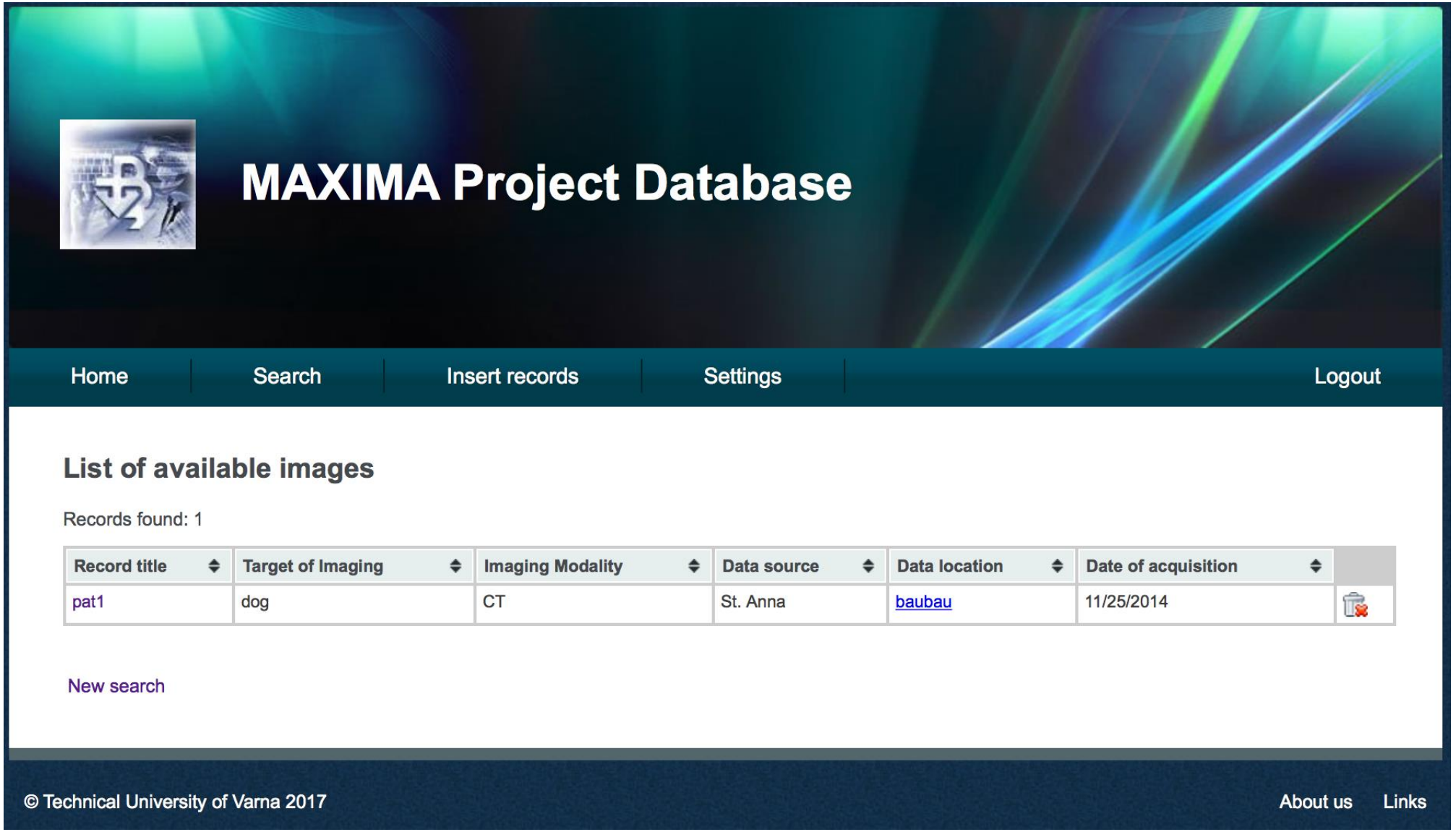
Database web-based interface



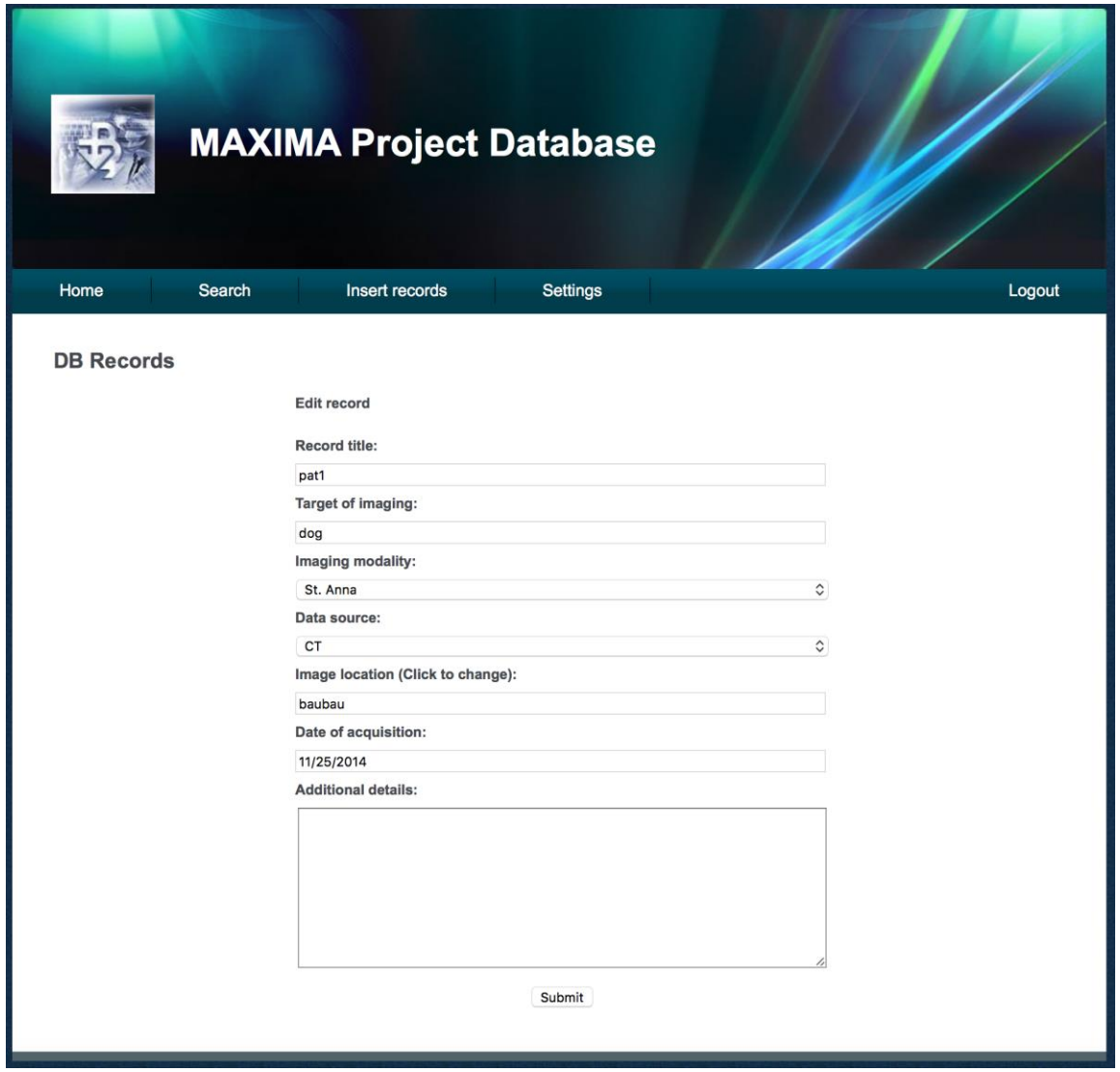
Database organisation

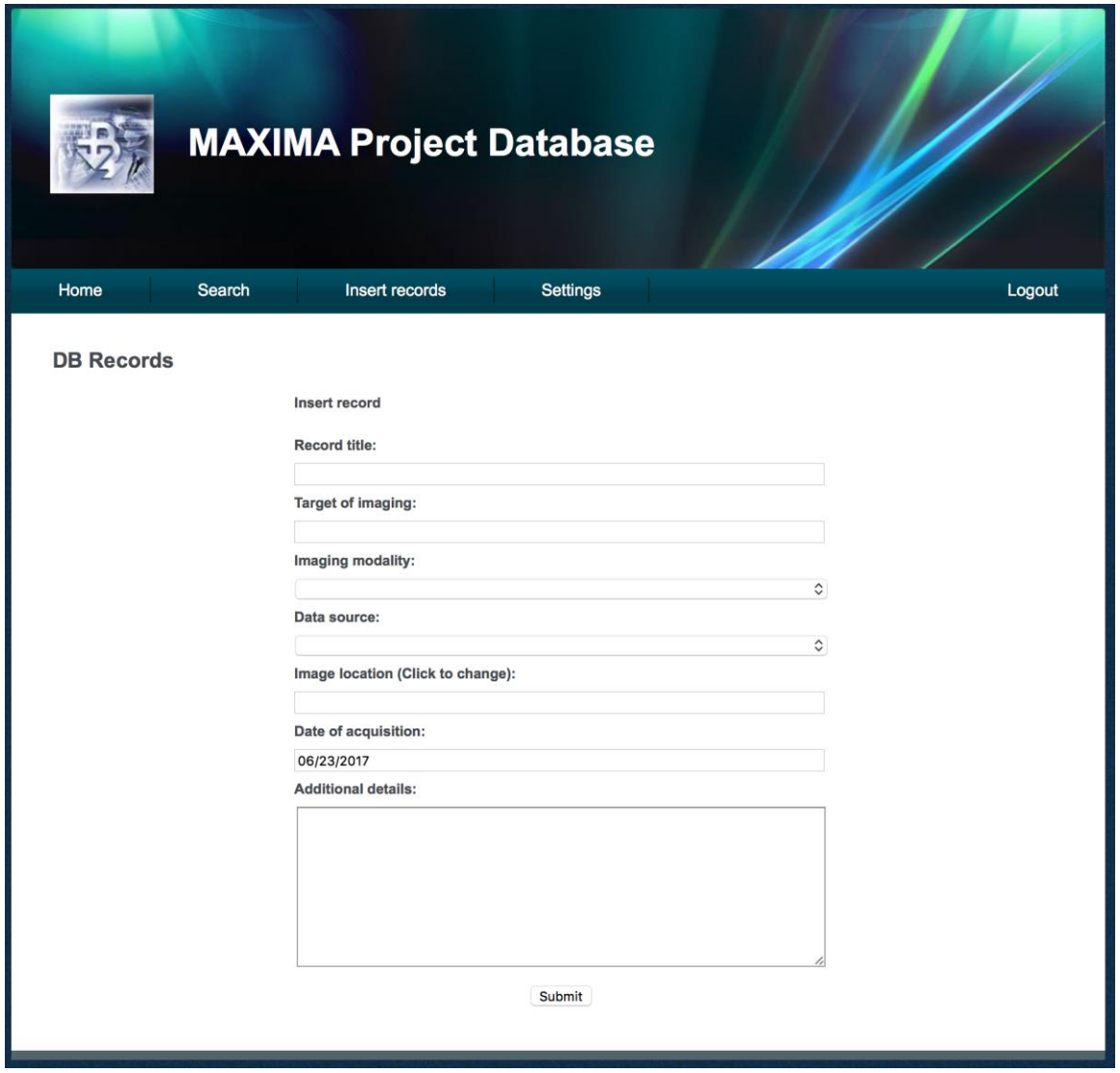


Database organisations

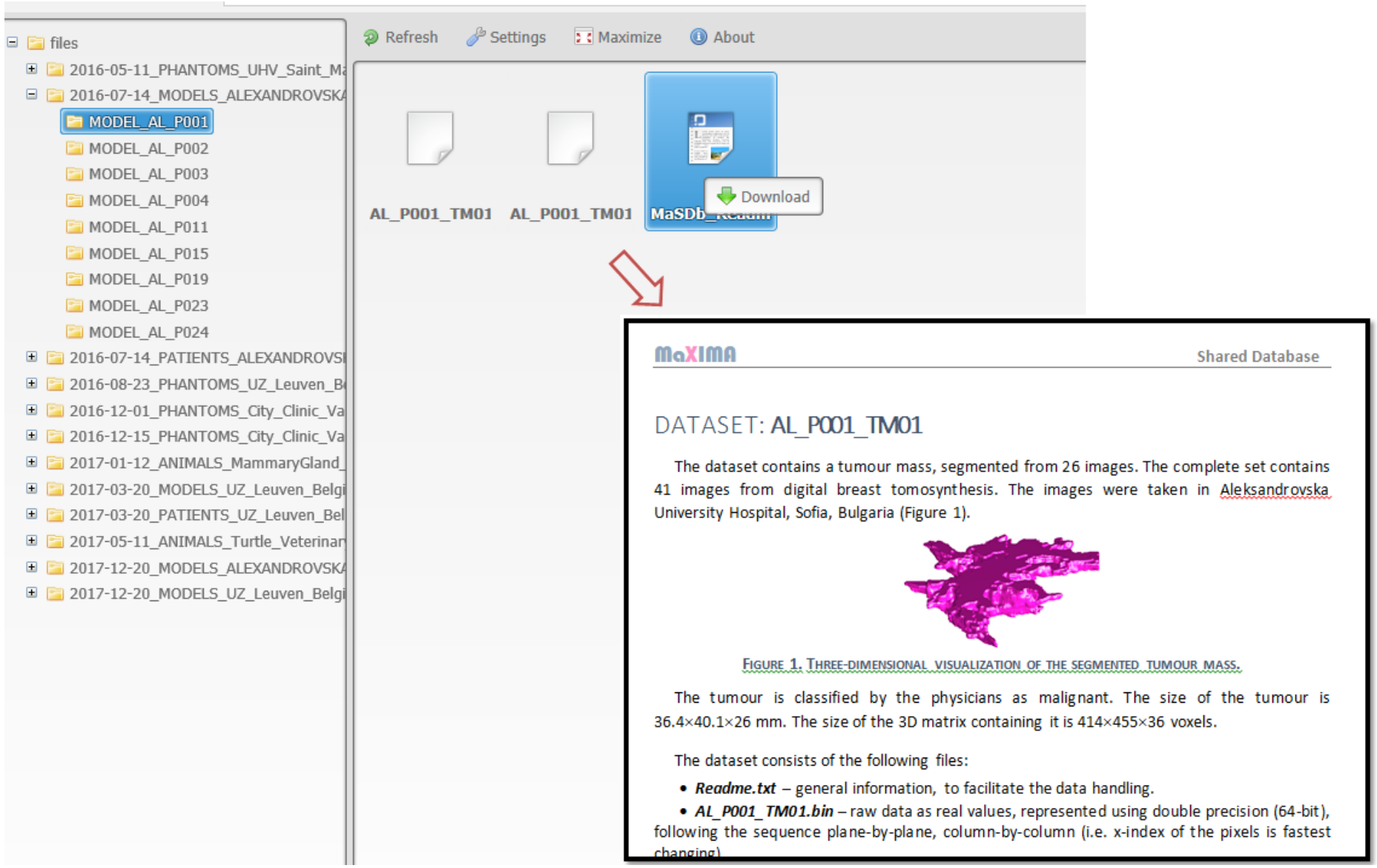


Database organisation





Irregular masses - description



Outline

- Why realistic models of abnormalities?
- Our approach and advances
- Exploitation of results in practice

Exploitation of results

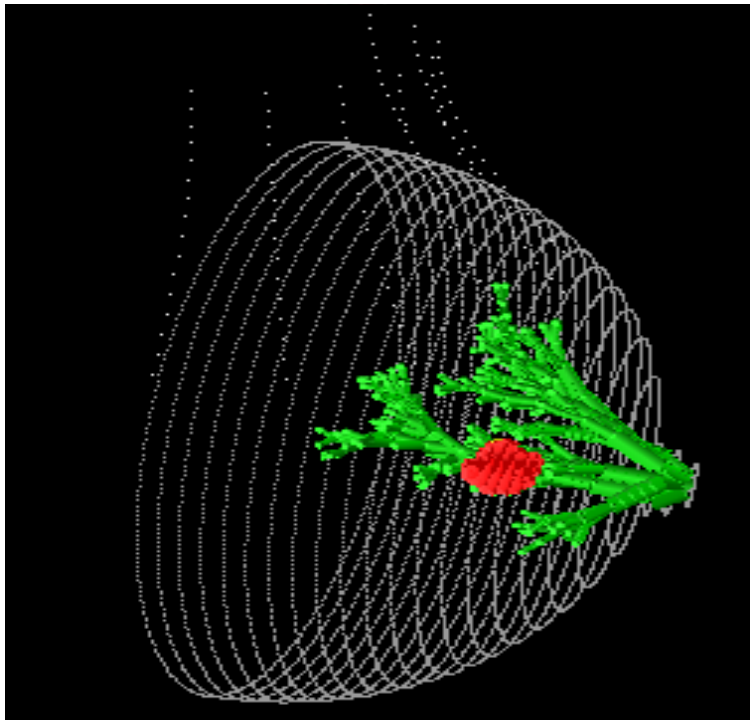
- Research
- Education
- Fun

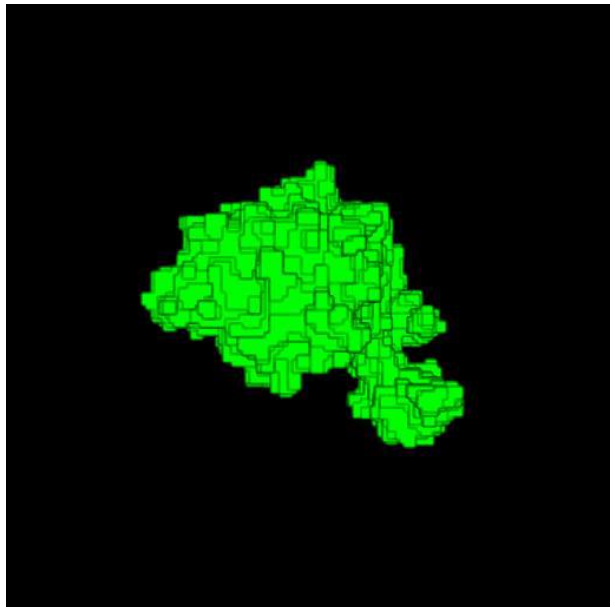
Exploitation of results

- Research
- Education
- Fun

Research

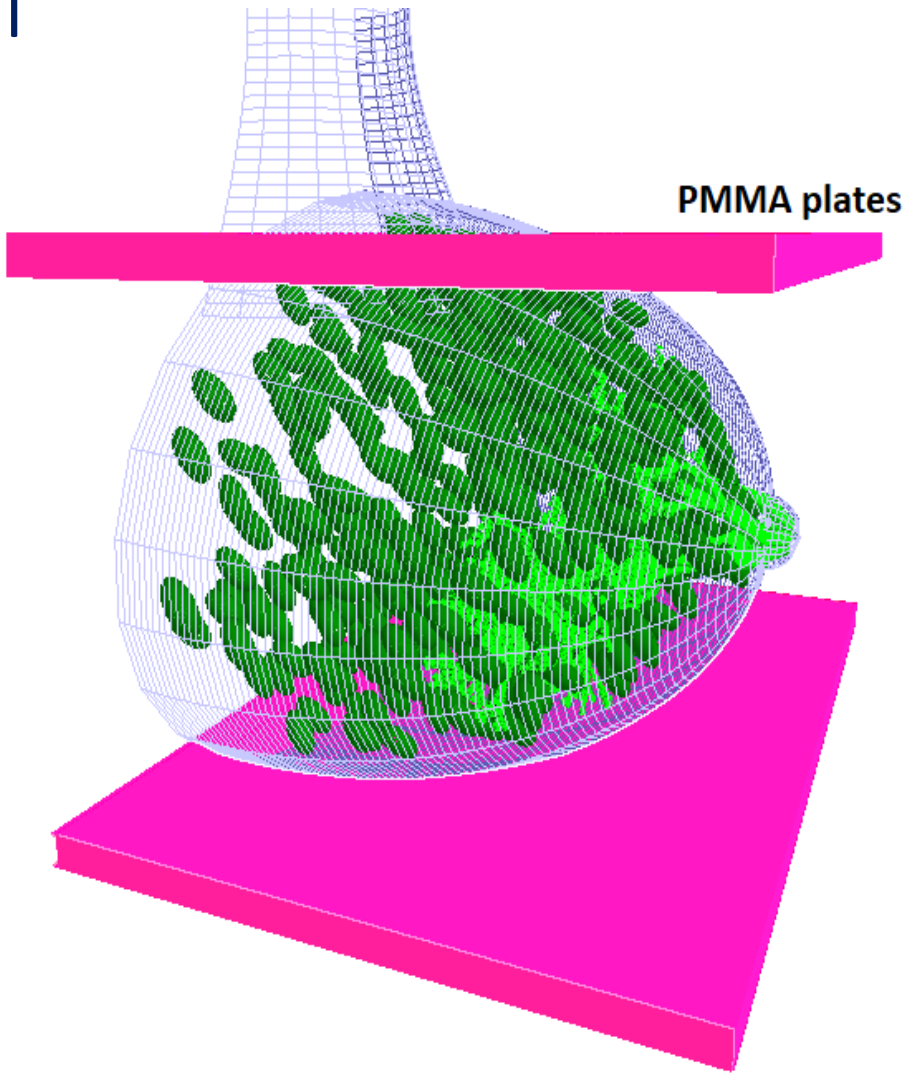
To study novel breast imaging techniques





Creation of breast model

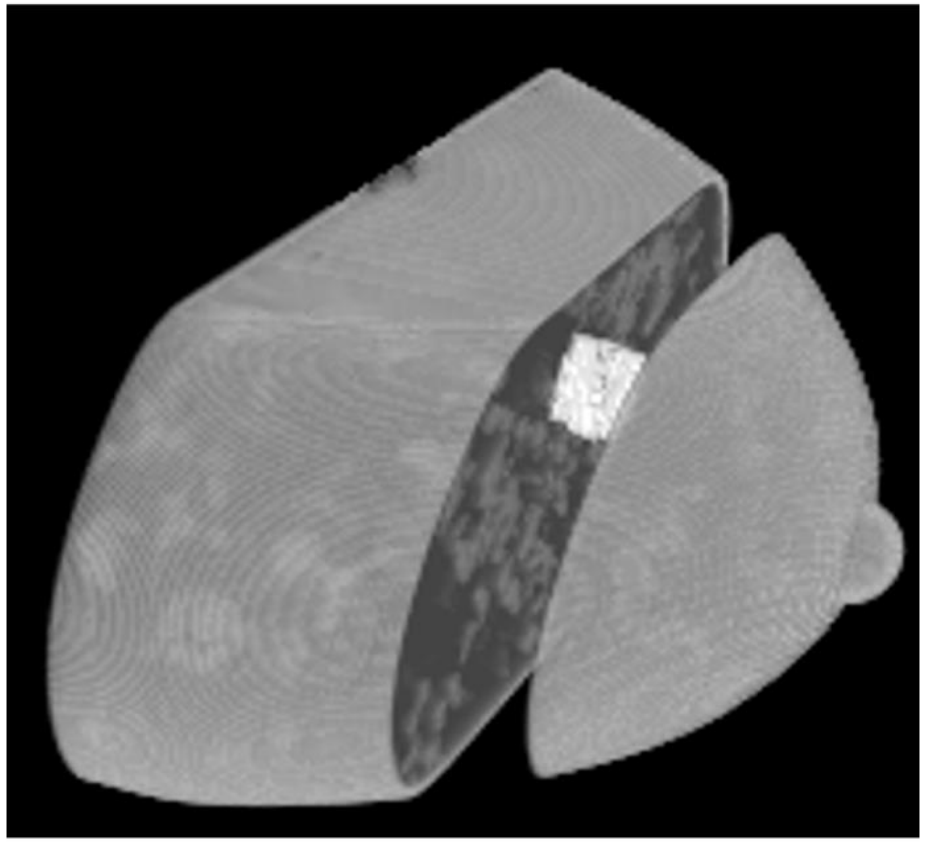
- Simulation of the compression procedure



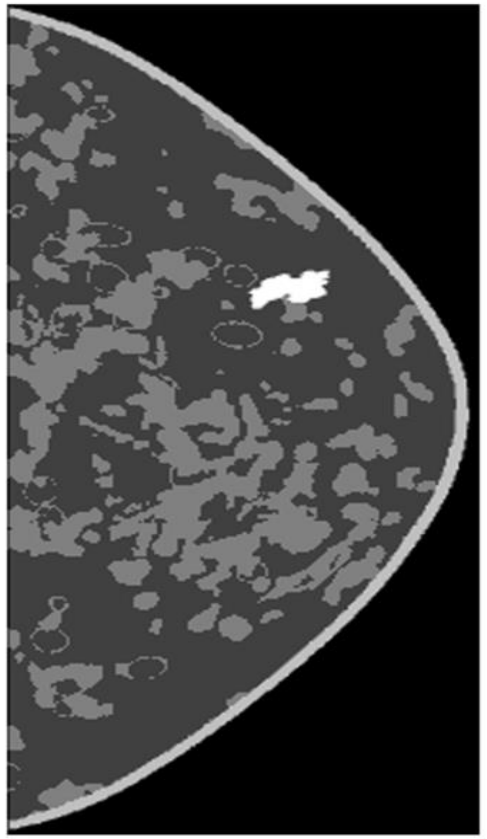
Dukov et al, IUPESM, 2018

Compressed breast model

3D view

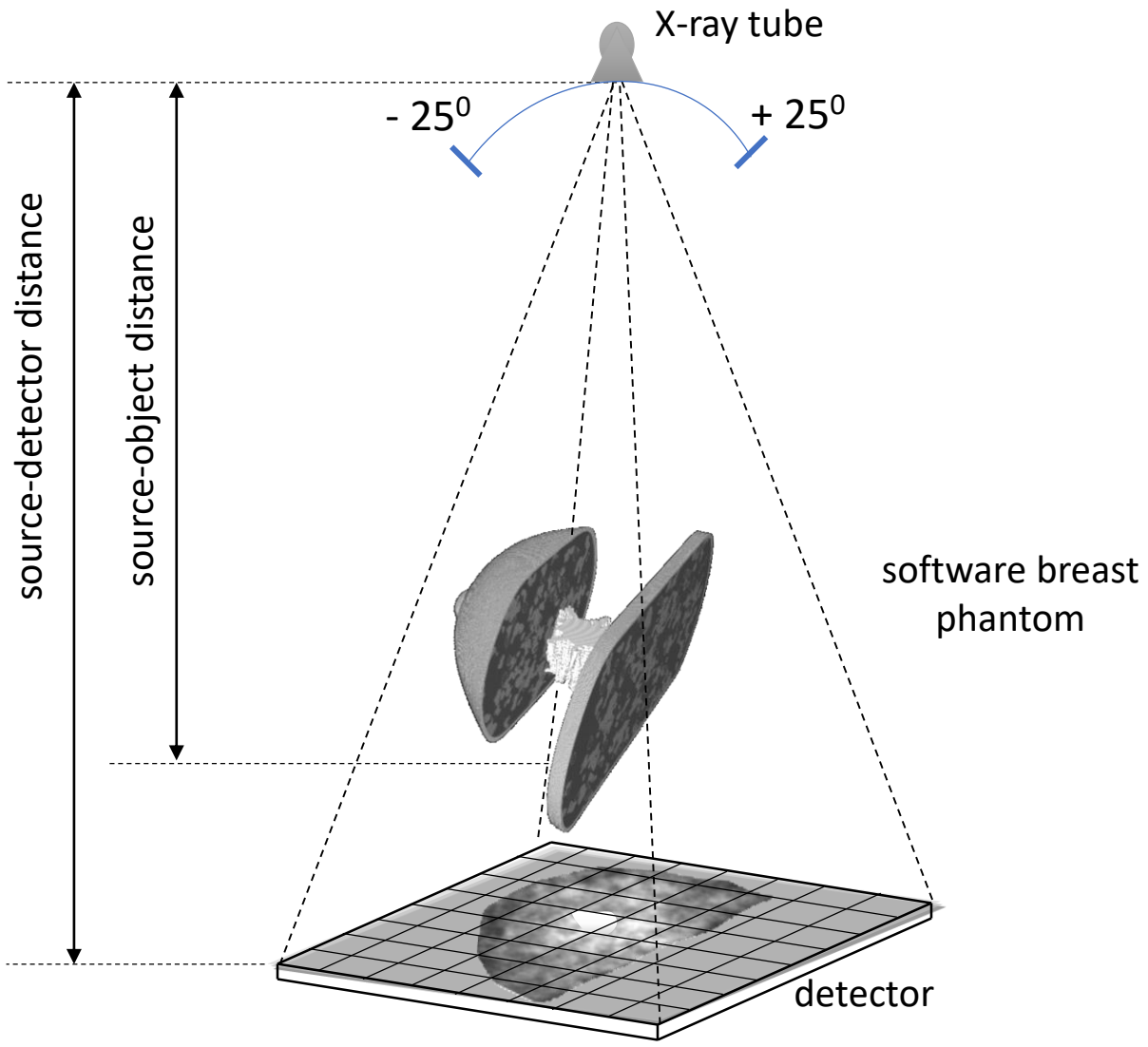


slice



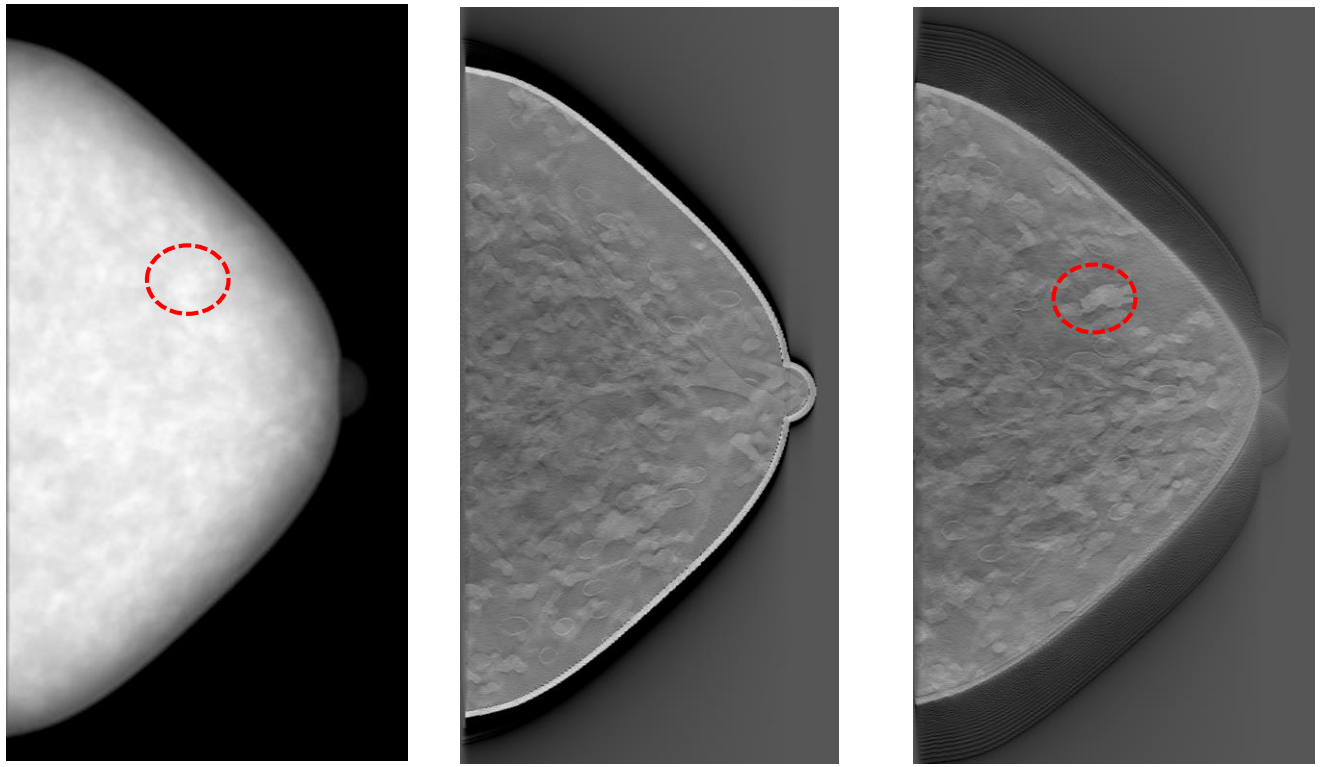
Dukov et al, IUPESM, 2018

Example



Software
X-ray Imaging
Simulators

Images obtained with the software phantom

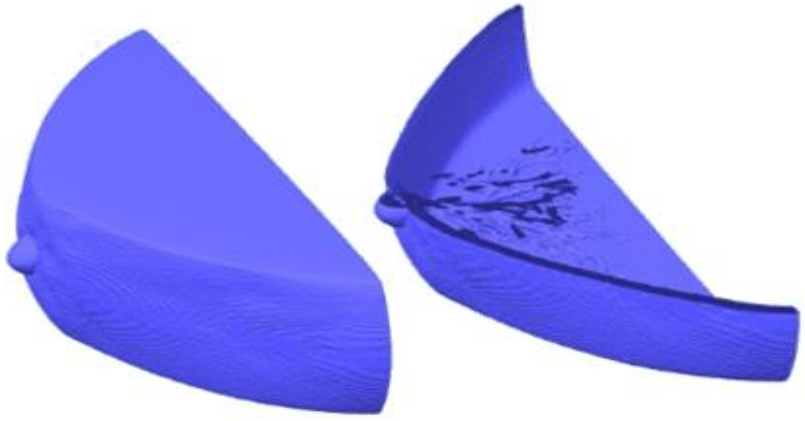


(a) (b) (c)

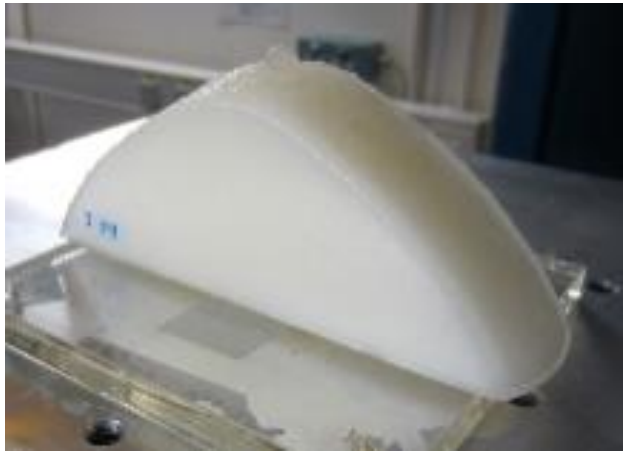
Dukov et al, IUPESM, 2018

Phantoms for the study

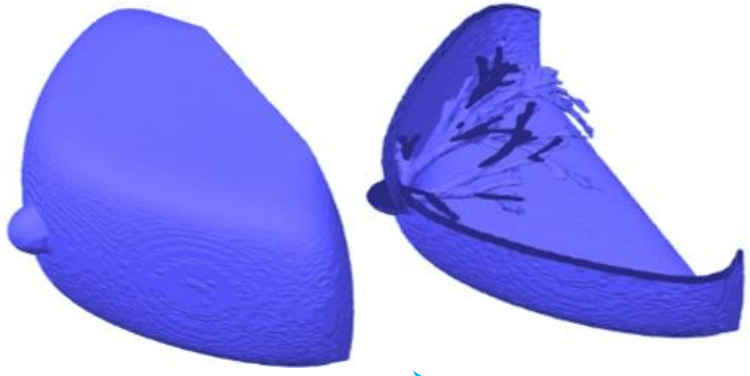
- Breast shape – Clear resin;
- Glandular tree – Clear resin;



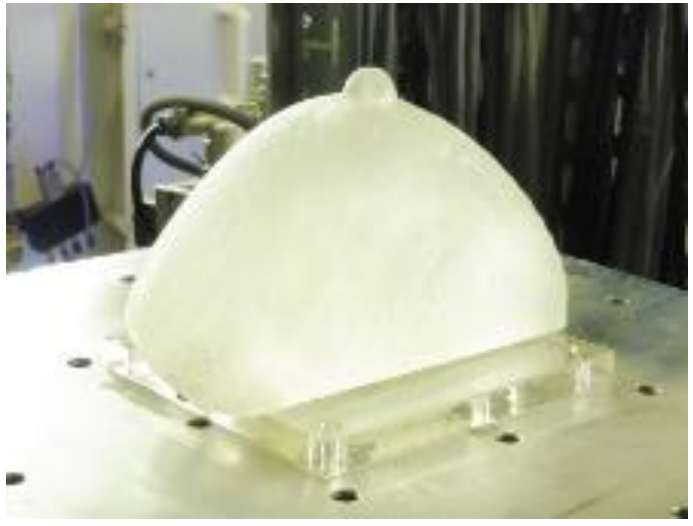
- Animal fat;
- Thickness – 31 mm;
- Wall thickness – 1.7 mm.



- Container – Clear resin;
- Glandular tree – Clear resin;

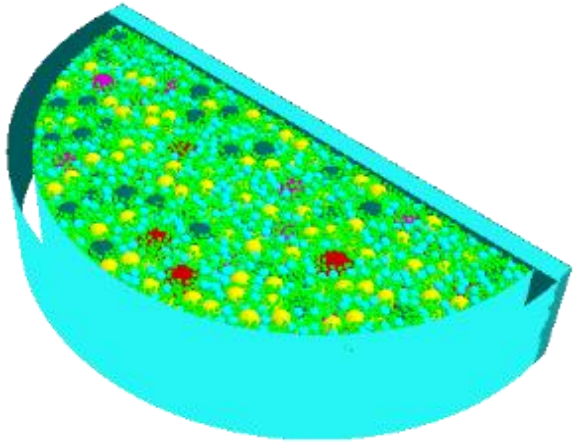


- Water;
- Thickness – 49 mm;
- Wall thickness – 2.4 mm.



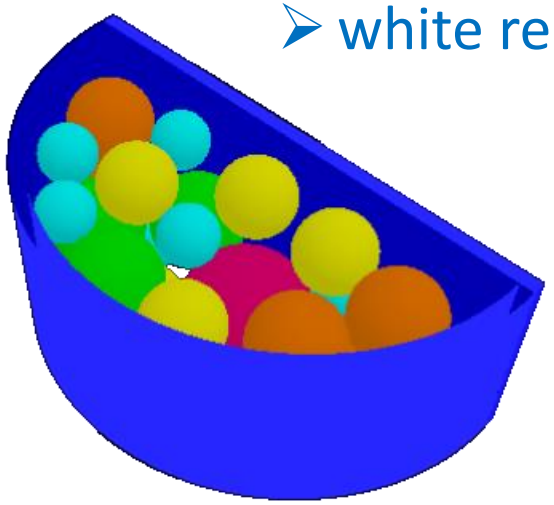
Phantoms for the study

- ~ 33000 PMMA spheres;
- radiuses [0.79 - 7.94] mm;

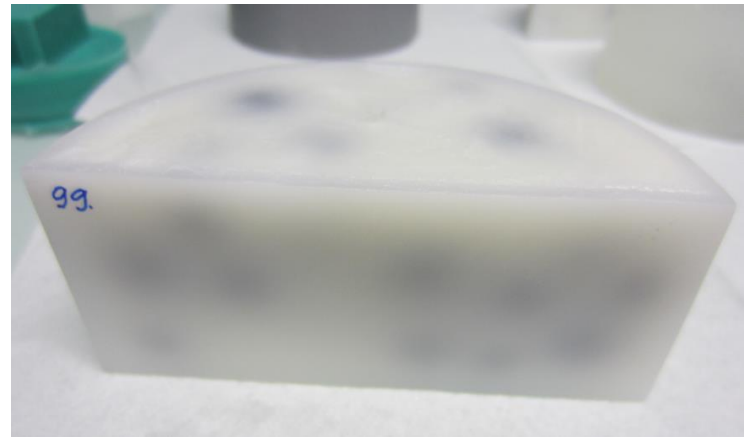


- PMMA container;
- water.

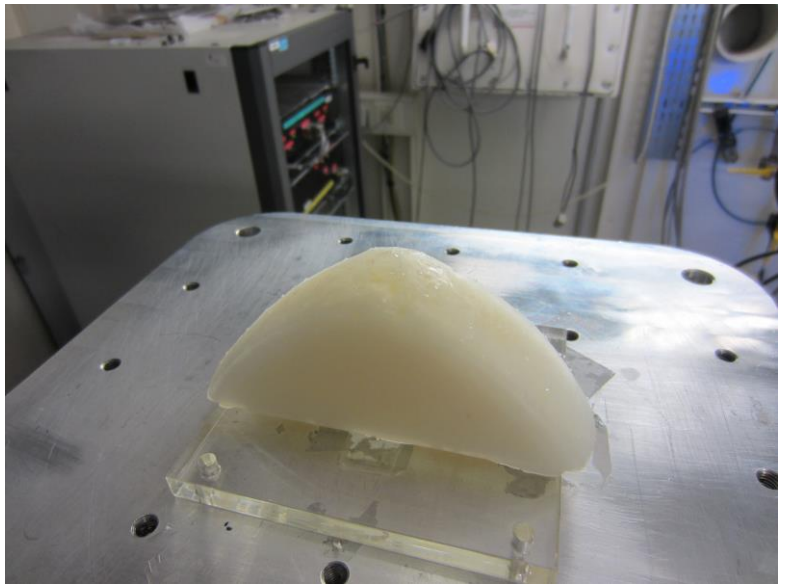
- 27 spheres from Gray resin;
- radiuses [6 - 13] mm;
- white resin container;



- animal fat;
- wall thickness 3 mm.



Setup



- ✓ **60keV**
- ✓ **Planar images**
- ✓ **Tomosynthesis - 25 projection images**

Exploitation of results

- Research
- Education
- Fun

Eutempe-net training course, Varna 22-26/05/2017

- How to model x-ray imaging chain;
- How to model breast;
- How to model breast cancer;
- How to work in a team;
- How to write abstracts;
- How to present a scientific work.

Virtual study to investigate the detectability of breast abnormalities on 2D mammography and digital breast tomosynthesis

Kristina Tri Wigati[1,2], Hannah Manssens[3], Liesbeth Vancoillie[2], Lesley Cockmartin[4], Djarwani S. Soejoko[1], Hilde Bosmans[2,4], and Kristina Bliznakova[5]

[1] *Department of Physics, Faculty of Mathematics and Natural Sciences, University of Indonesia*
[2] *Department of Imaging and Pathology, Faculty of Medicine, KU Leuven*
[3] *Barco nv, Belgium*
[4] *Department of Radiology, University Hospitals Leuven*
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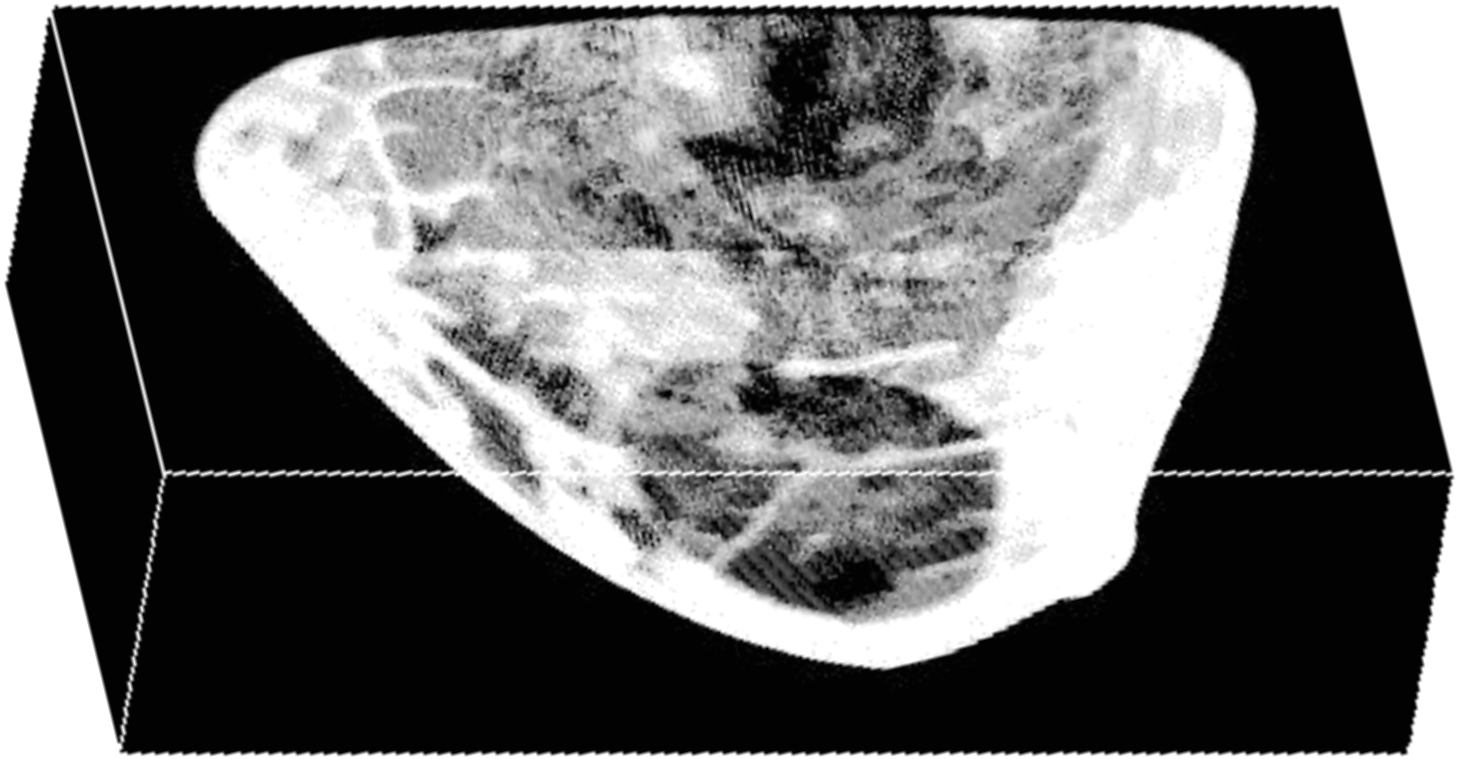
Abstract: This paper describes the use of virtual clinical trial software, as developed and improved in the frame of the Horizon2020 MaXIMA project, to study particular aspects of 2D mammography and digital breast tomosynthesis. A voxel-based breast phantom with inserted mathematical models of an irregular mass and two microcalcifications was created. Image acquisition was simulated by using

Phantom

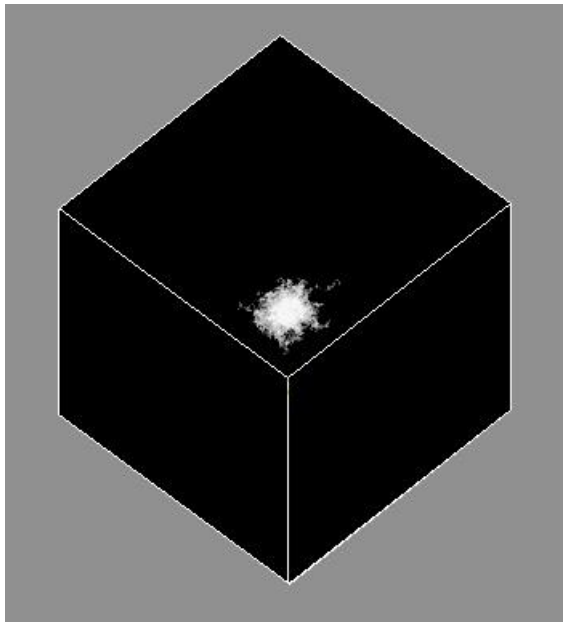
Dimension of the phantom:
Width : 641 pixels
Length : 357 pixels
Height : 175 pixels

Voxel size:
0.27 mm [each side]

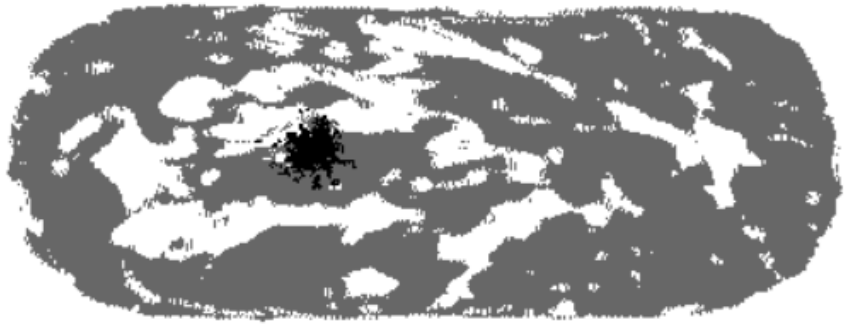


Breast abnormalities

Irregular mass



- The voxelized of irregular mass matrix was placed about the center of the normal breast phantom;
- Resolution: 0.27 mm/pixel



Virtual clinical study

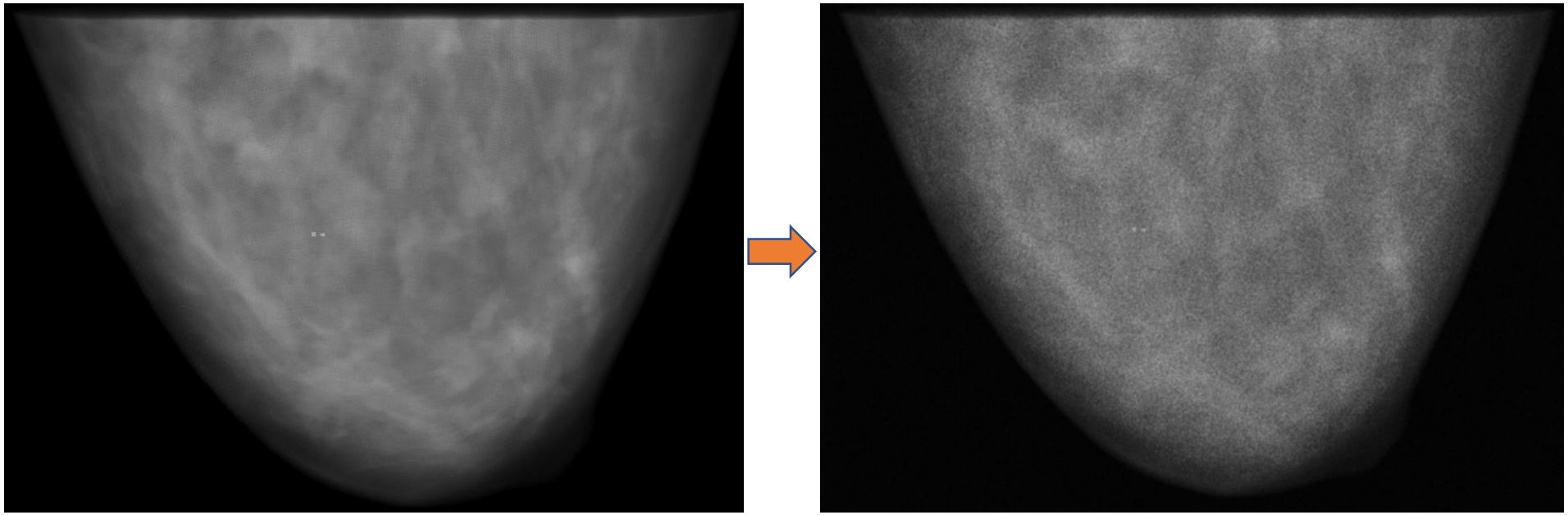
Table 4. Mean pixel value, signal difference, SDNR and contrast of the irregular mass in the 2D mammography and DBT reconstructed slice at Z = 0.

System	*Mean pixel value*	*SD*	*SDNR*	*Contrast (%)*
2D Mammography	2.25	0.05	1.66	2.47
DBT ±9°, 10 proj	84.84	10.42	0.21	14.00
DBT ±13°, 14 proj	83.49	9.65	0.21	13.07
DBT ±15°, 16 proj	84.64	10.88	0.25	14.75
DBT ±21°, 22 proj	86.24	10.95	0.25	14.54
DBT ±25°, 26 proj	87.49	12.80	0.30	17.14

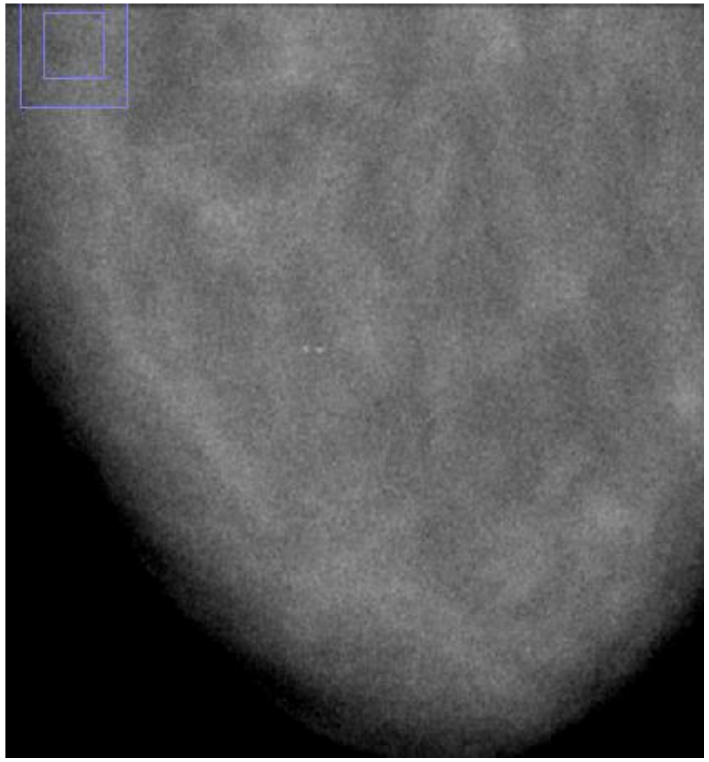
Table 5. Measurements of FWHM calculated using Gaussian interpol
and contrast profiles of the

Kristina Tri Wigati, Hannah Manssens, JMPB, 5(1), p. 124-138, 2018

Addition of noise



Qualitative comparison



Mammography

Tomosynthesis with 26 projection images

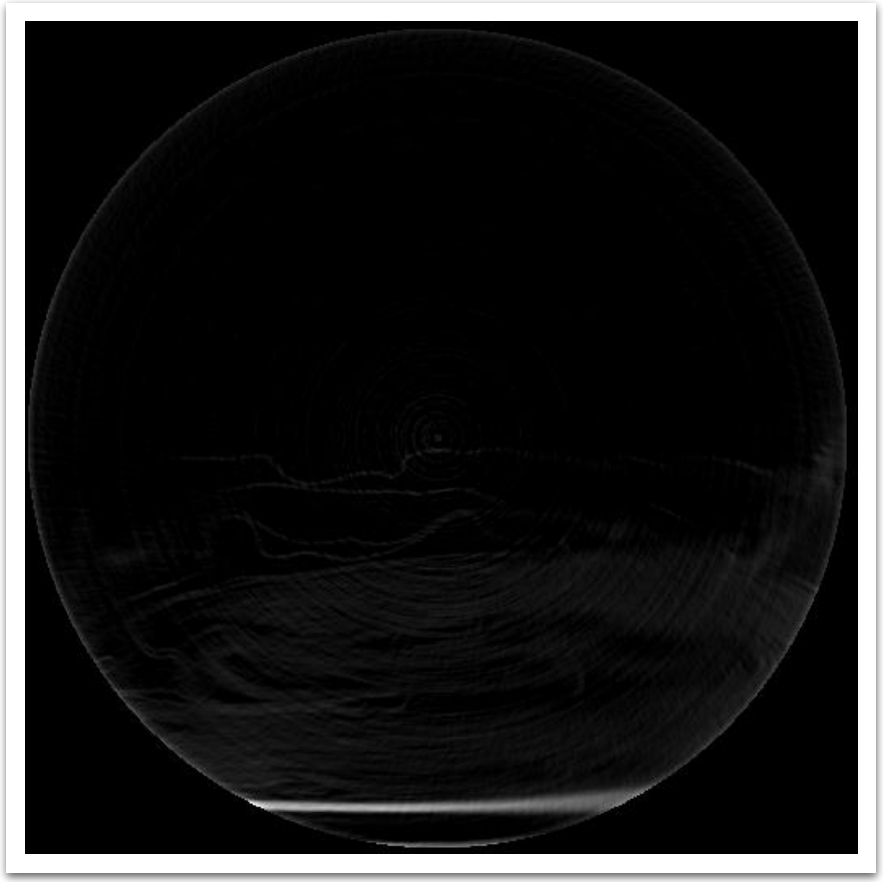
Exploitation of results

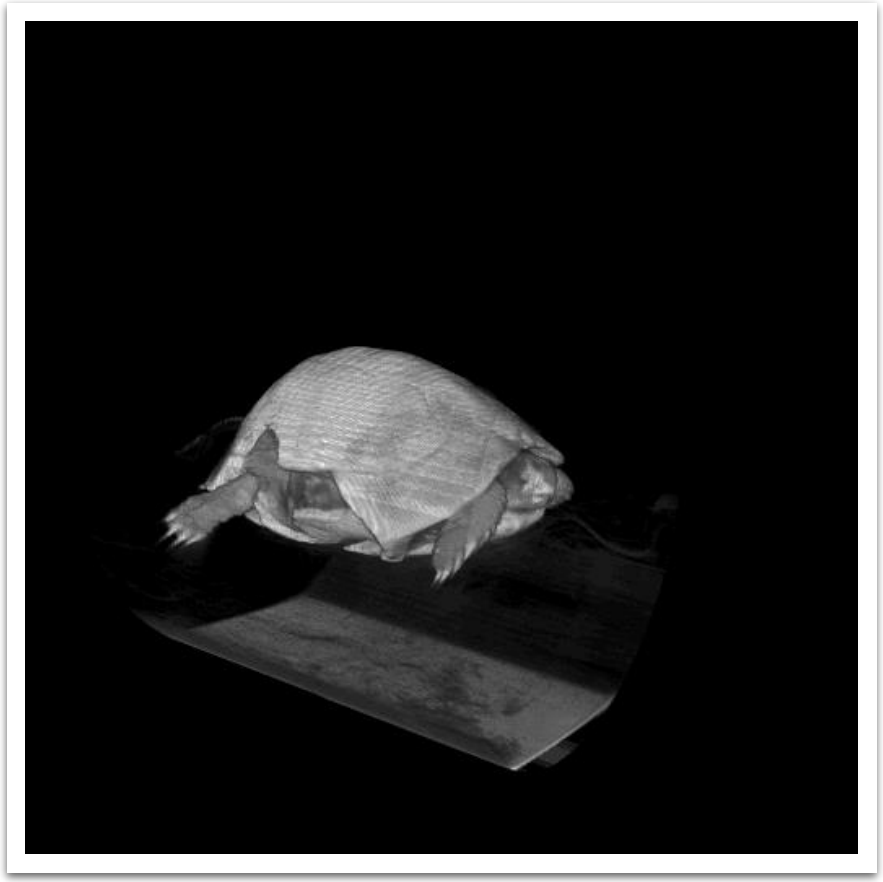
- Research
- Education
- Fun

Exploitation

Dukov et al, FOCHOS 2017

CT Scanning

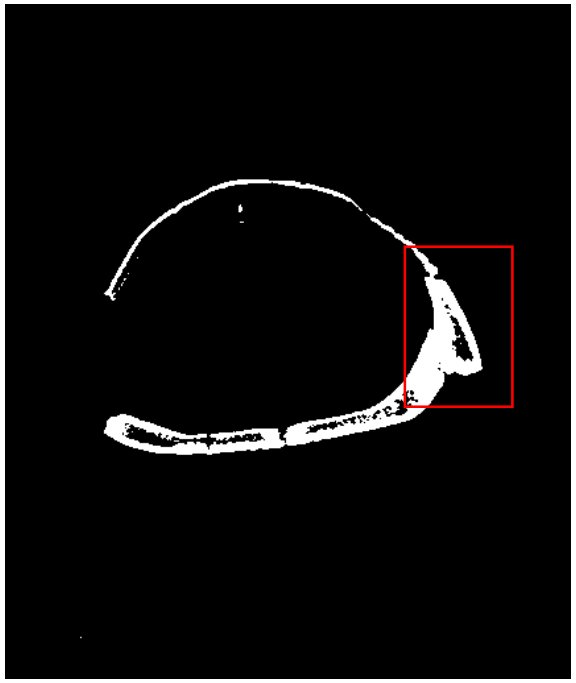




Dukov et al, FOCHOS 2017

Segmenting a health part

binarization



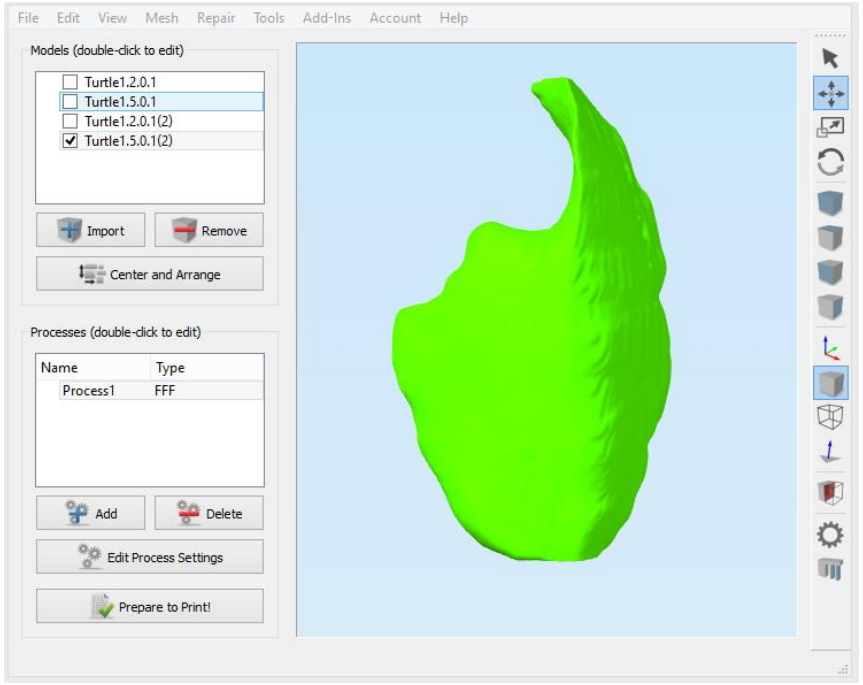
segmenting the health part

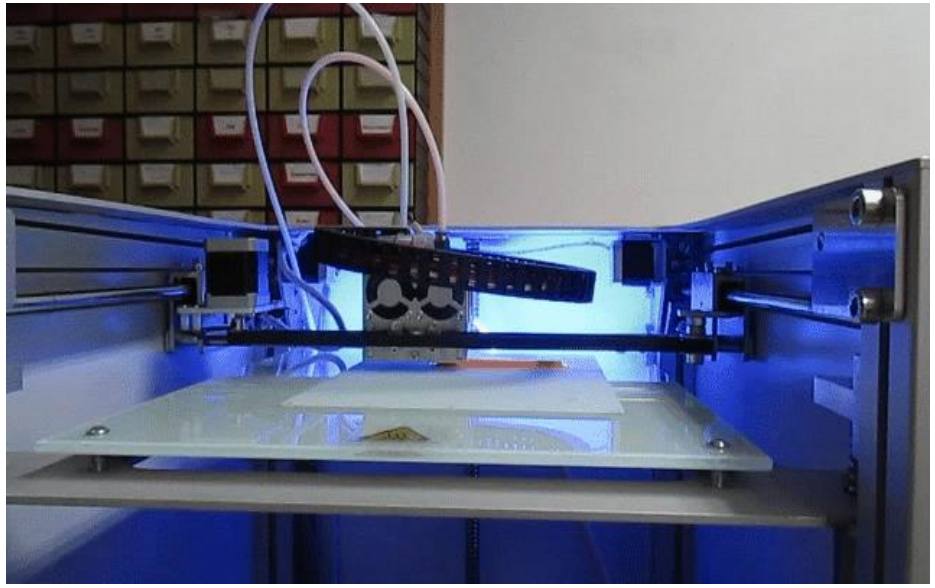
mirror image

morphological corrections

Dukov et al, FOCHOS 2017

3D printing





Dukov et al, FOCHOS 2017

Exploitation

Dukov et al, FOCHOS 2017

Conclusions

- The developed database will serve as an imaging data source for researchers, working on breast imaging and early breast cancer detection with the help of existing or newly developed imaging modalities.

Acknowledgments

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 692097.