AP 4 - Image Segmentation

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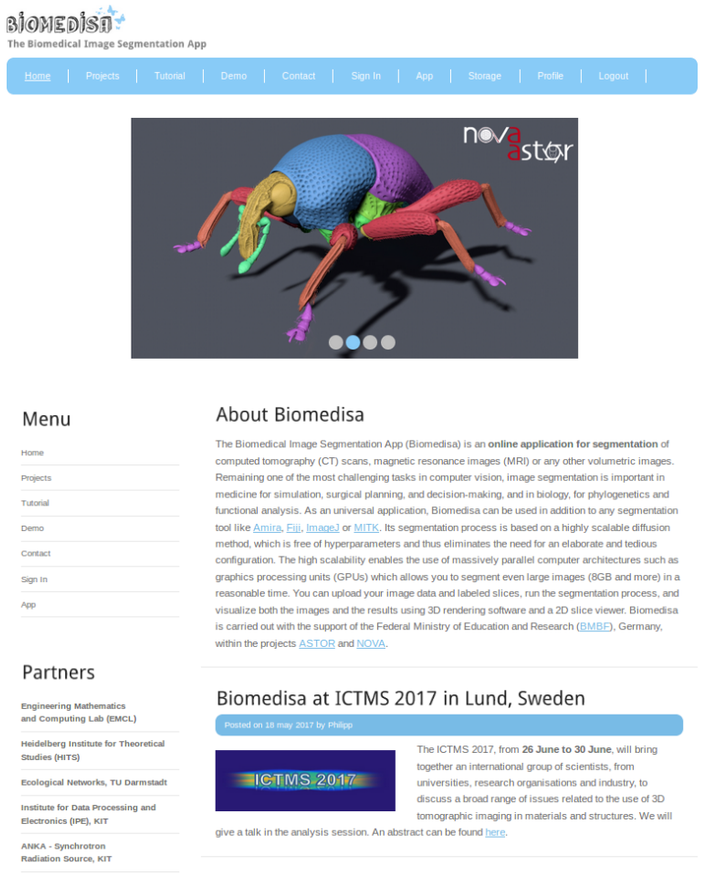
Overview

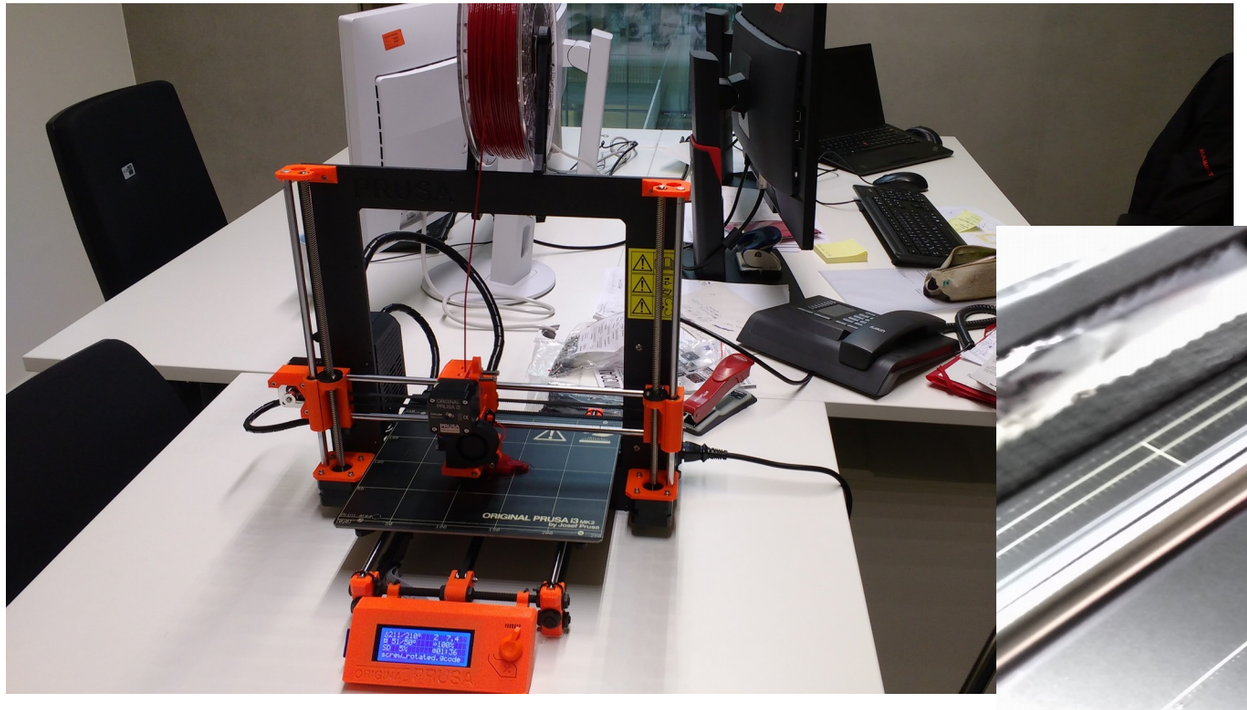
- **New features**
  - Labeling in any axis
  - Removing outliers
  - Supporting Amira label files
  - 3D printer
  - Uncertainty localization

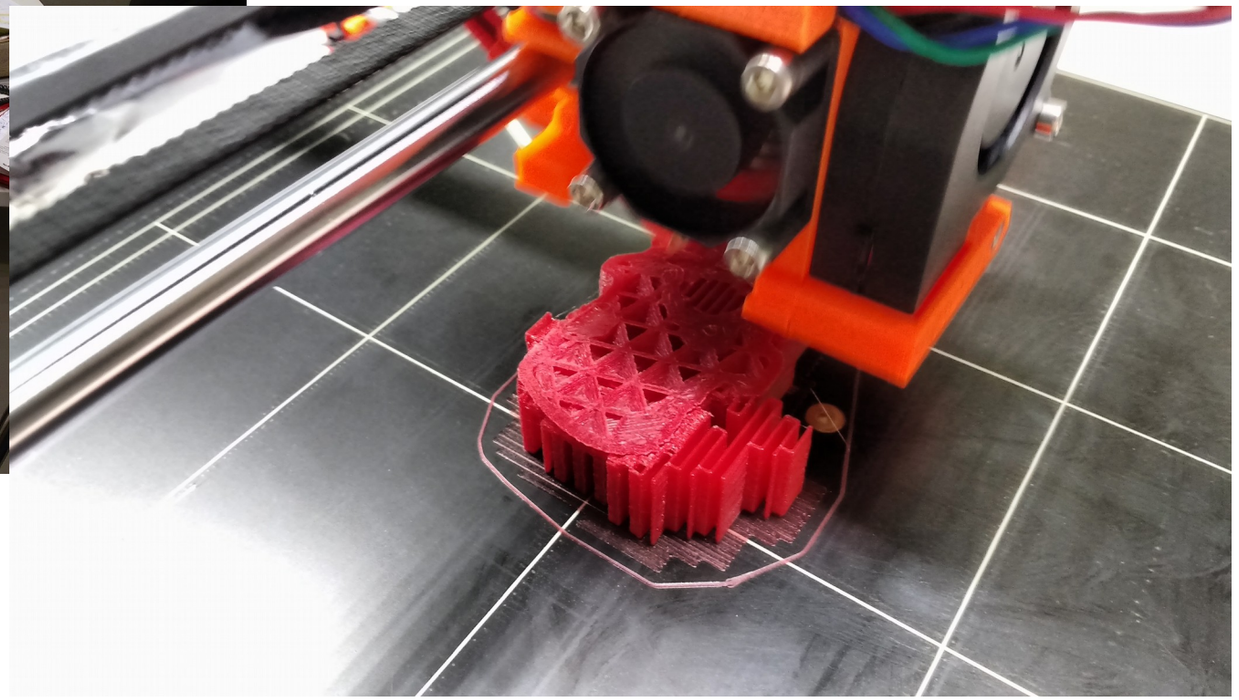
- **Fourier Transform for image registration**
  - Removing sample holder
  - Merging Objects

- **Deep learning for image segmentation**

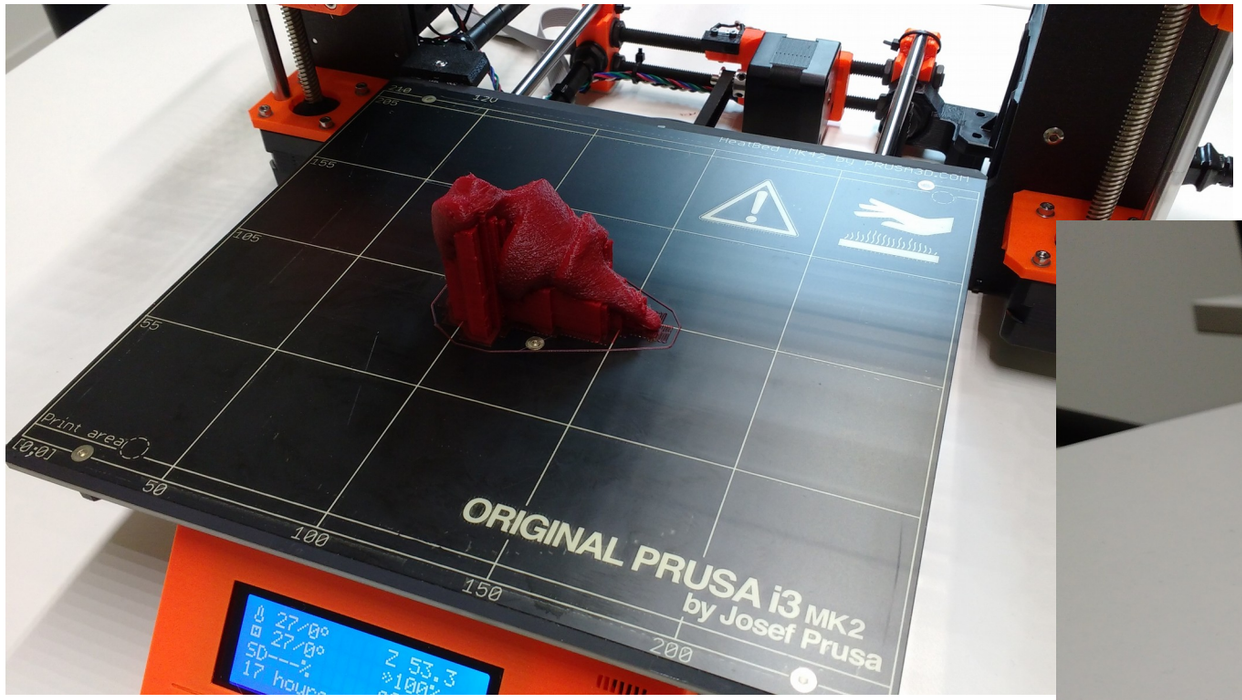


3D Printer



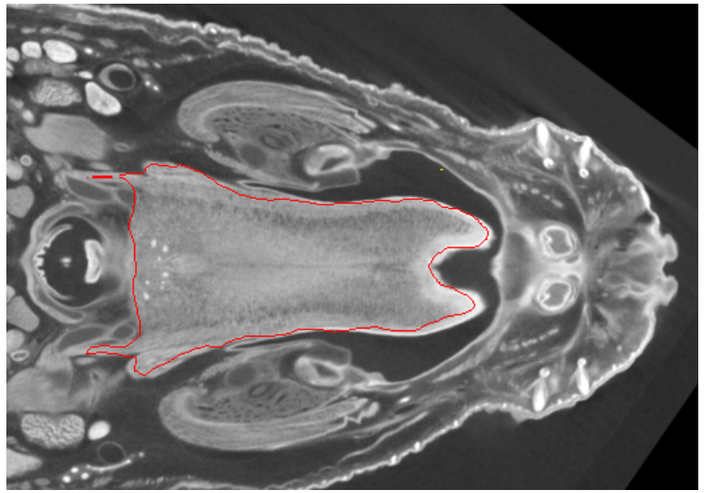


3D Printer

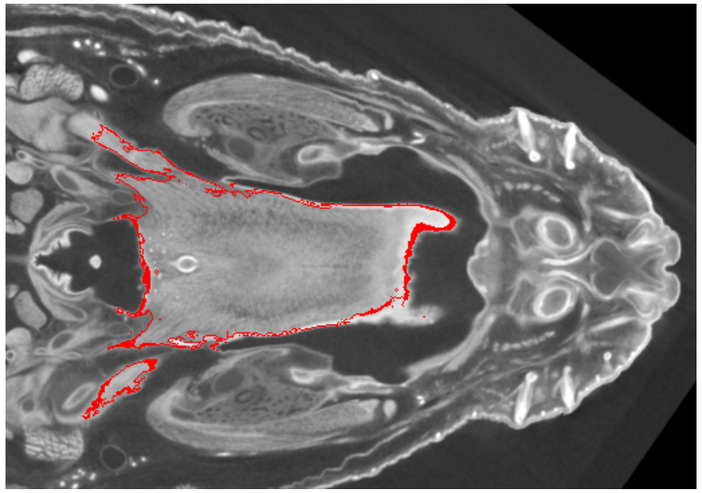


Evaluation of image segmentation by means of a 3D print?

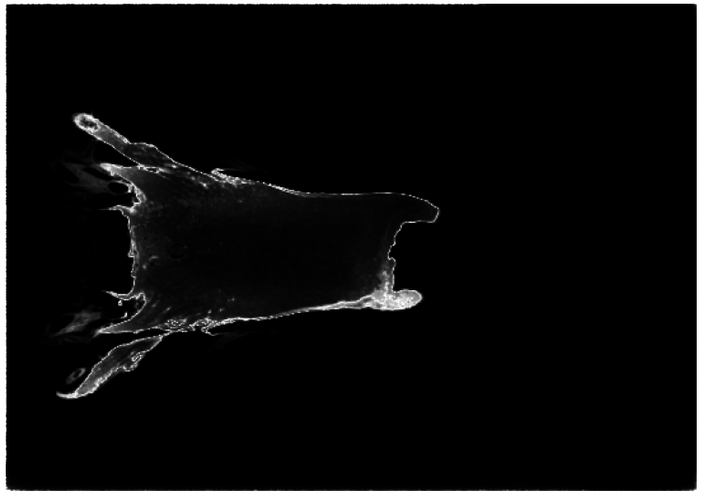
Uncertainty localization



Inaccurate labeld slice 125.



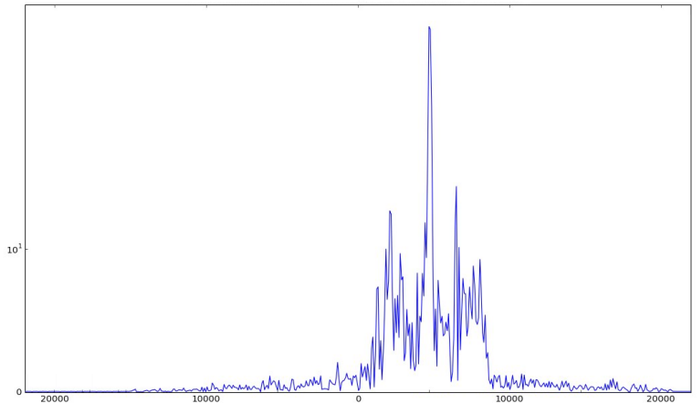
Biomedisa result (slice 133).



Uncerctainty of segmentation result (slice 133).

Fourier Transform for image registration

Q: Why is „Shazam” so fast in recognizing a song?
A: It uses the Fourier Shift Theorem.

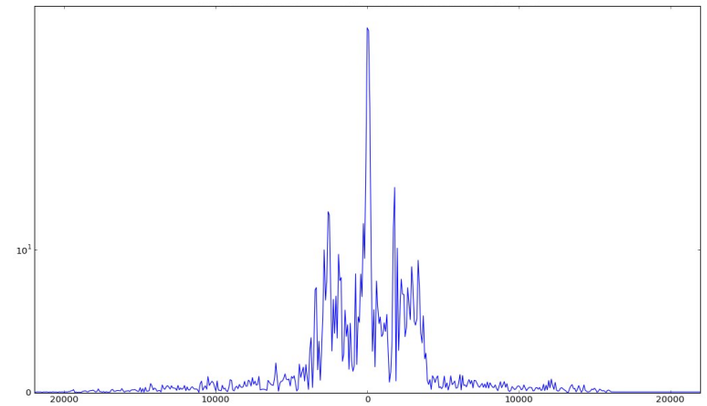


The discrete Fourier Transform is defined as:

$$F(u)=\sum_{x=0}^{N-1} f(x)\,\mathrm{e}^{-\frac{2\pi iux}{N}} \qquad \text{for } u=0,\ldots,N-1.$$

A shift in x direction $f_2(x)=f_1(x+\Delta x)$ can be expressed as

$$\begin{aligned} F_2(u) &= \sum_{x=0}^{N-1} f_1(x)\,\mathrm{e}^{-\frac{2\pi iu(x+\Delta x)}{N}} \\ &= \sum_{x=0}^{N-1} f_1(x)\,\mathrm{e}^{-\frac{2\pi iux}{N}}\,\mathrm{e}^{-\frac{2\pi iu\Delta x}{N}} \\ &= F_1(u)\,\mathrm{e}^{-\frac{2\pi iu\Delta x}{N}}. \end{aligned}$$

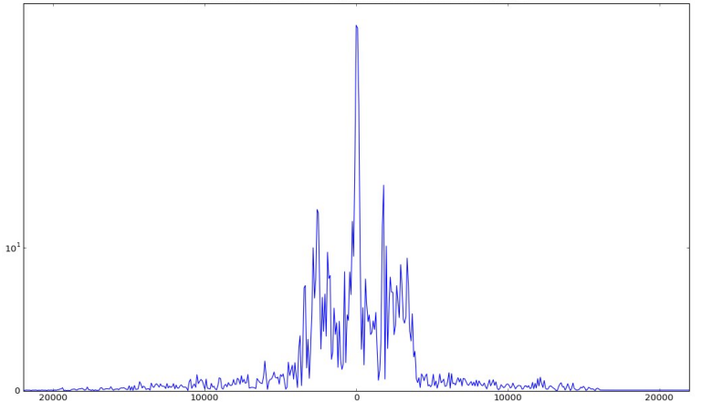


Fourier Transform for image registration

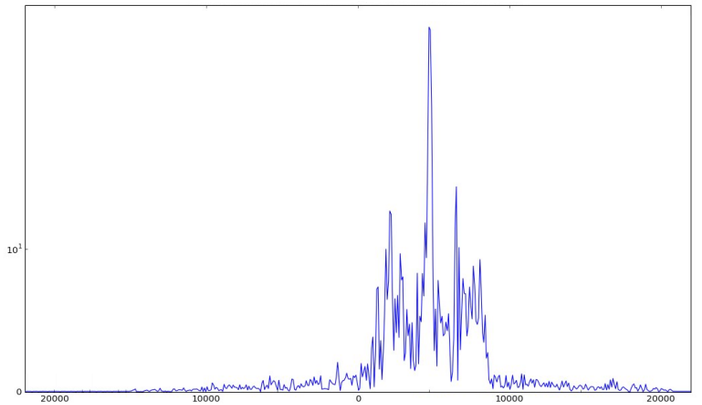
The translation Δx can be isolated by computing

$$e^{\frac{2\pi i u \Delta x}{N}} = \frac{F_1 F_2^*}{\left|F_1 F_2^*\right|}$$

where F_2^* is the complex conjugate of F_2. The inverse FT of this function has its maximum value at (Δx).

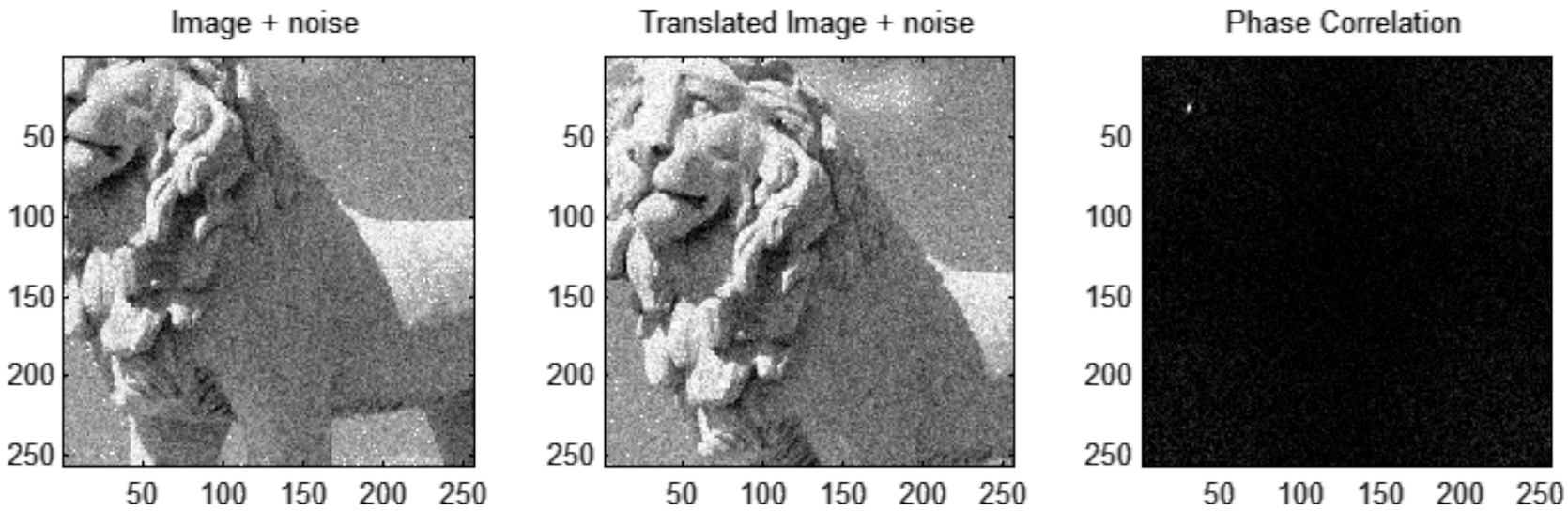


That means: Instead of computing the correlation for each possible shift, one can use the Fourier Transform which can be computed in a fast way.



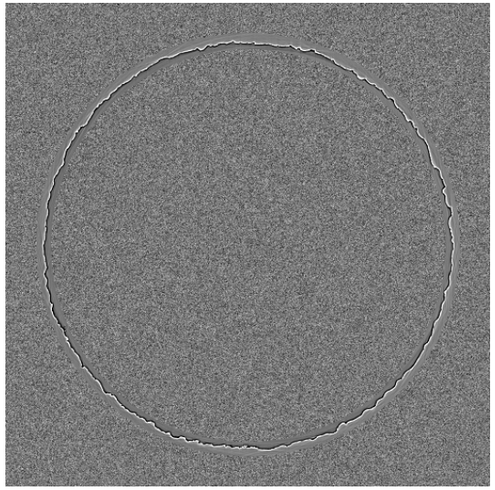
Fourier Transform for image registration

The same property applies across **multiple dimensions** and is **robust to noise**

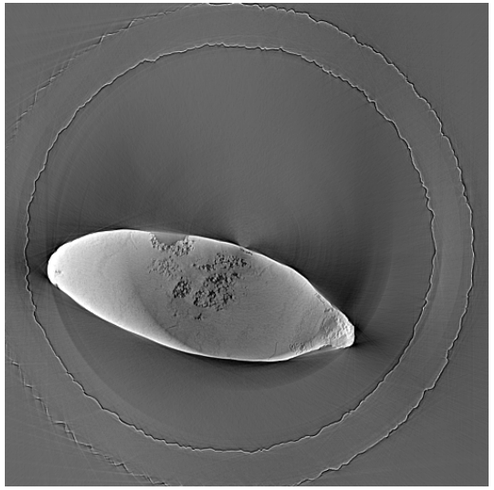


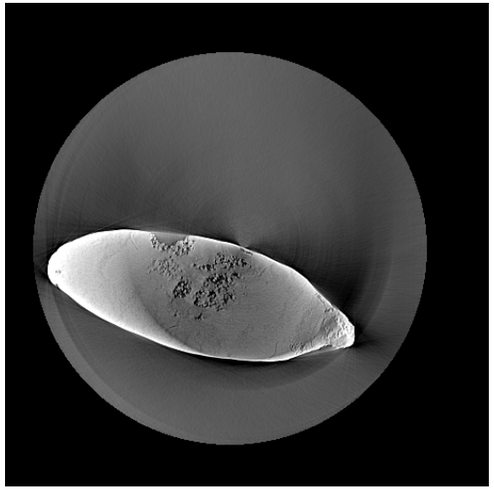
Fourier Transform for image registration

Detect and remove a cylindric sample holder in a CT scan



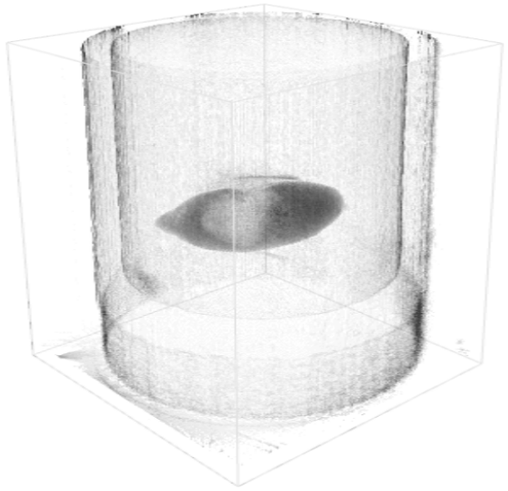
„Reference cylinder”

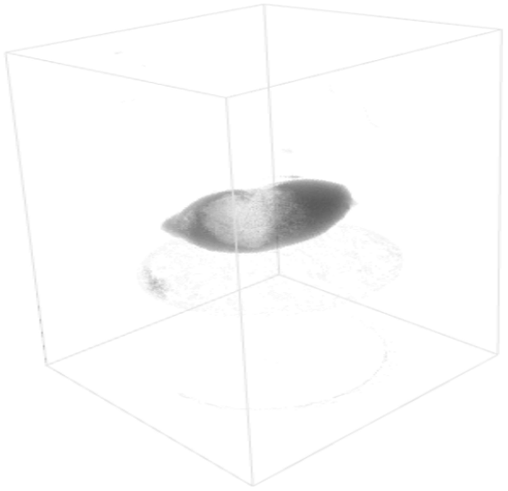




To match the image, the reference must be shifted by

$$x = -18$$
$$y = -3$$
$$z = 0$$



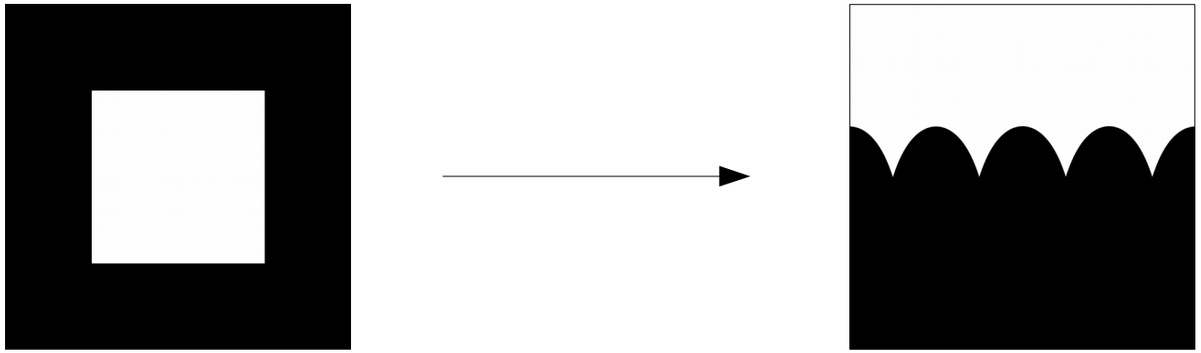


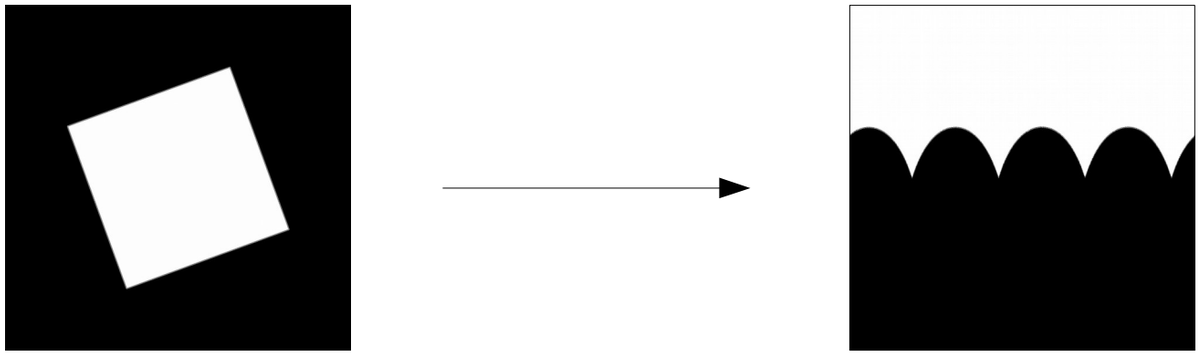
Removing frequencies?

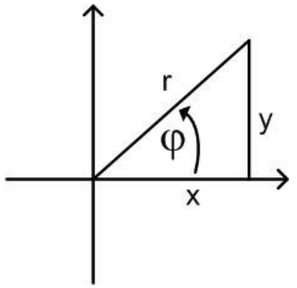
Fourier Transform for image registration

Q: What if images are rotated?

A: Projection in polar coordinates. Rotation corresponds to a shift in x-direction.





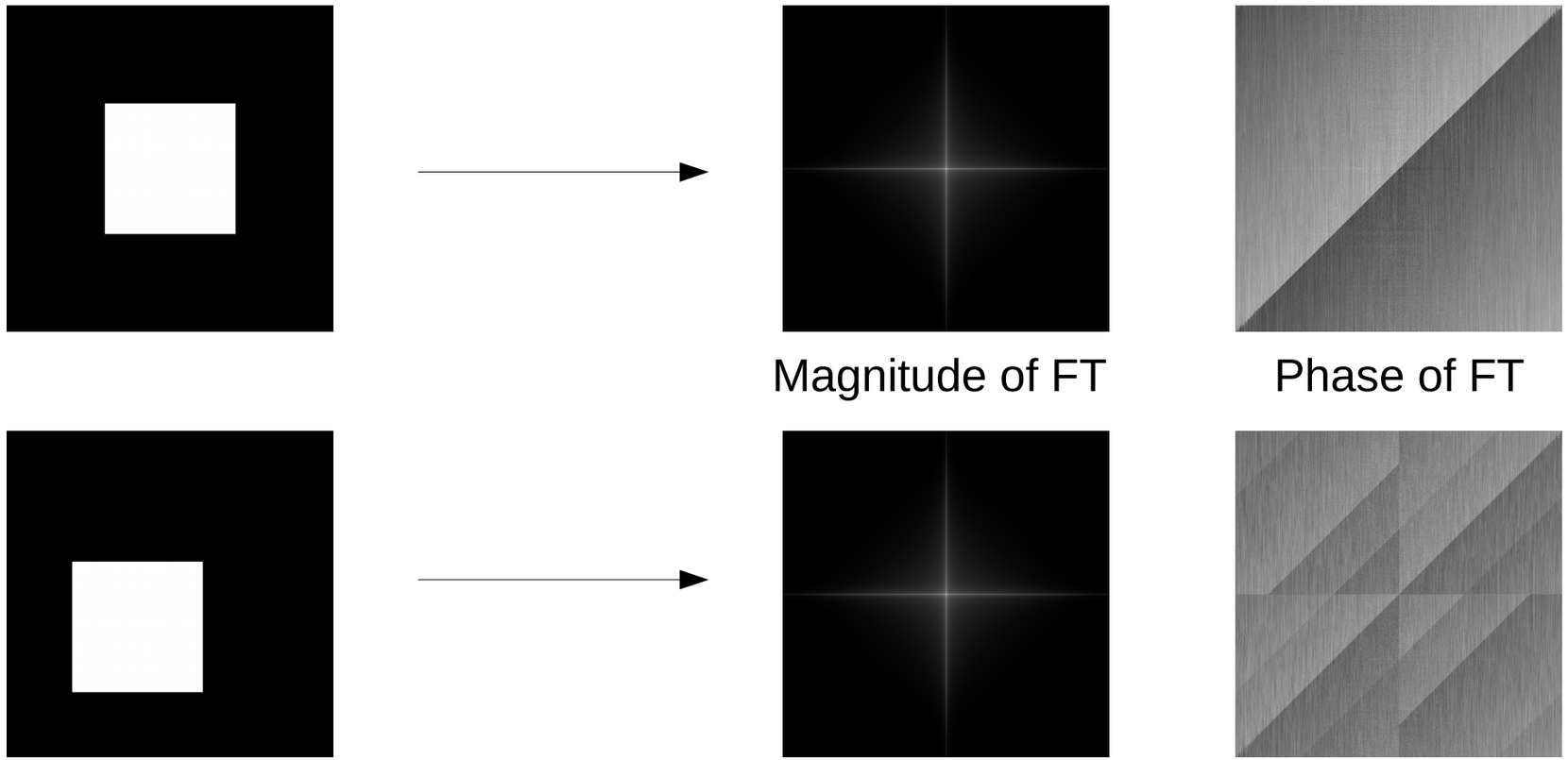


$$r = \sqrt{x^2 + y^2}$$

$$\phi = \arctan\left(\frac{x}{y}\right)$$

Fourier Transform for image registration

Q: What if images are rotated and translated?
A: (1) Translation only changes the phase of the Fourier Transform.

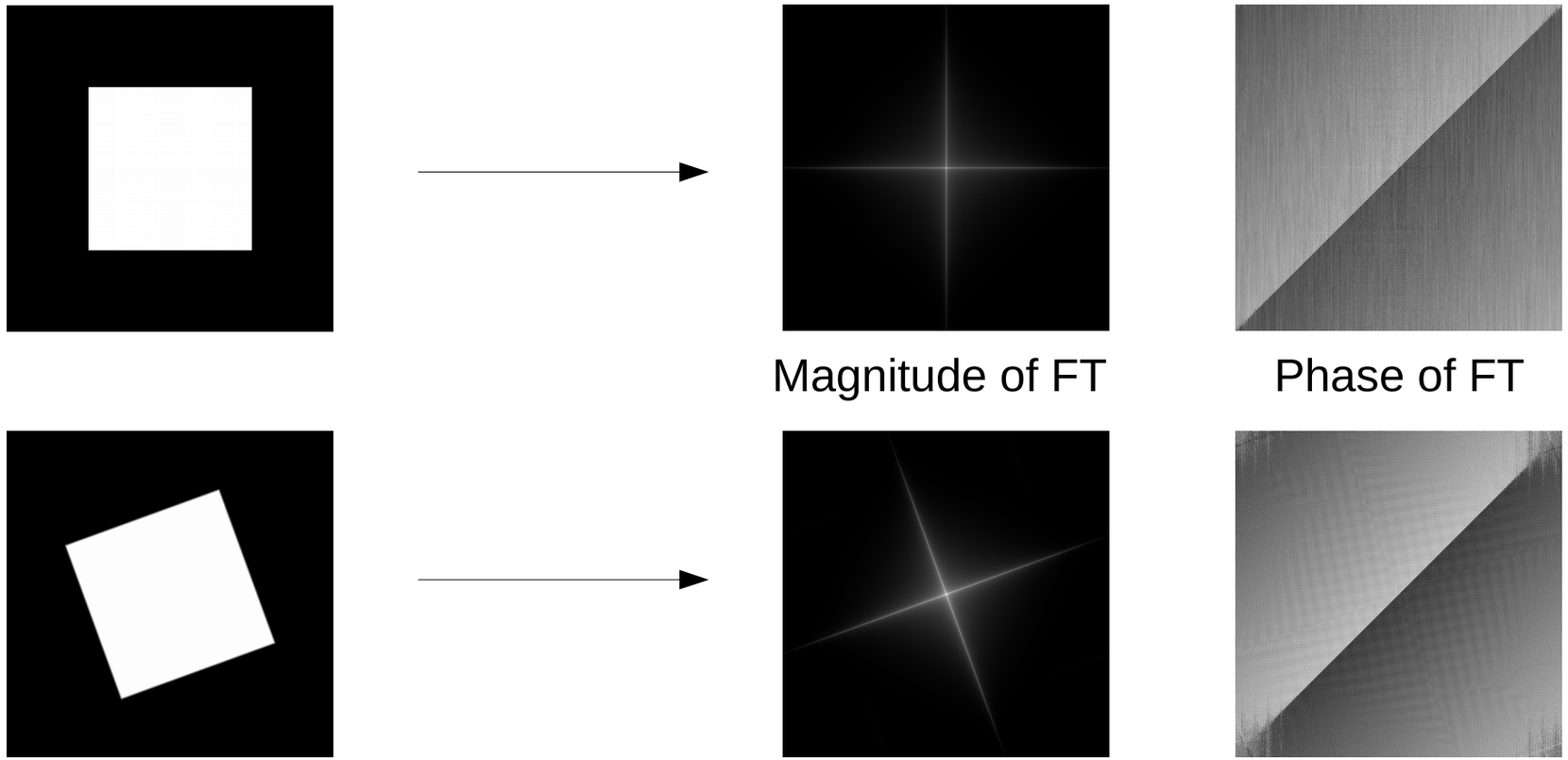


Fourier Transform for image registration

Q: What if images are rotated and translated?

A: (1) Translation only changes the phase of the Fourier Transform.

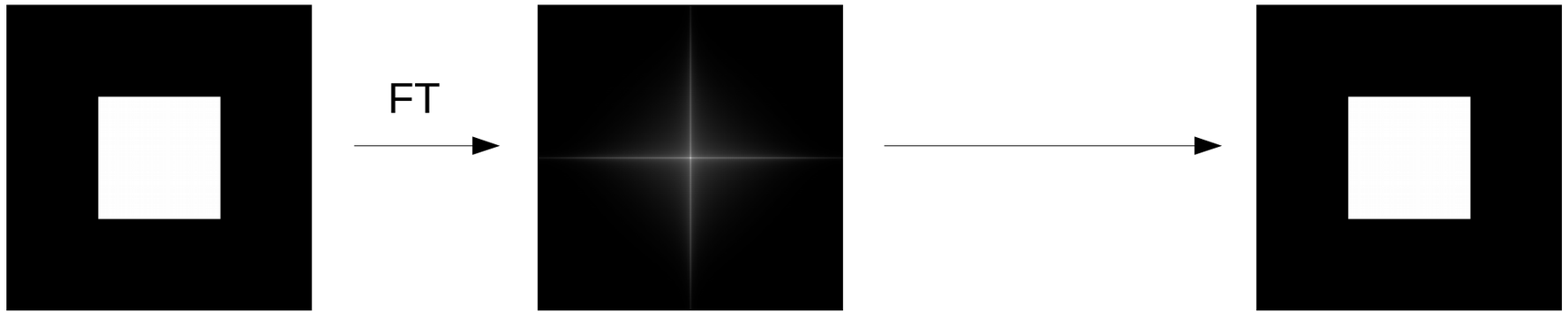
(2) Rotation of an image results in a corresponding rotation in its FT.



Fourier Transform for image registration

Bringing all together:

(1) Use the magnitude as a “new” image to find the rotation
(2) Using the magnitude of the Fourier Transform “removes” the translation
(3) Eliminate rotation and find translation



Magnitude as “new image”

Fourier Transform for image registration

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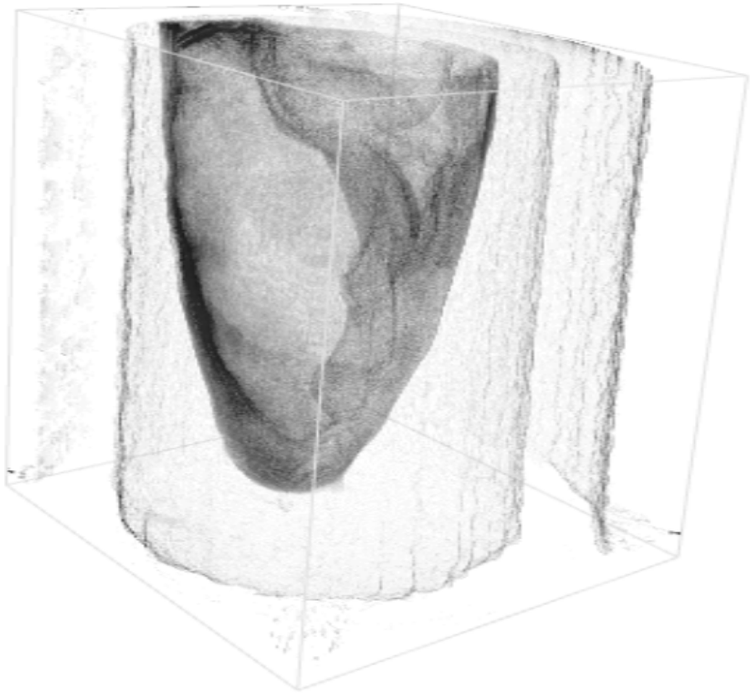
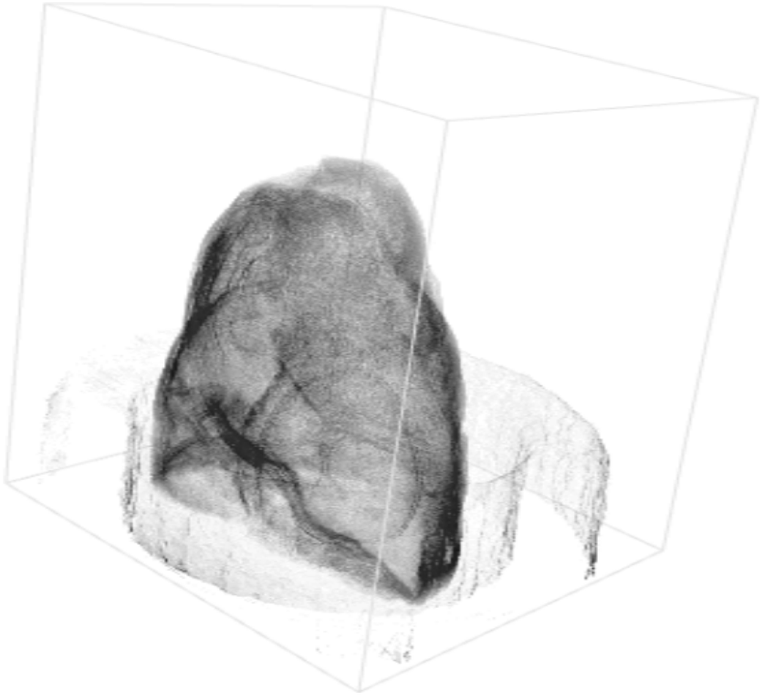
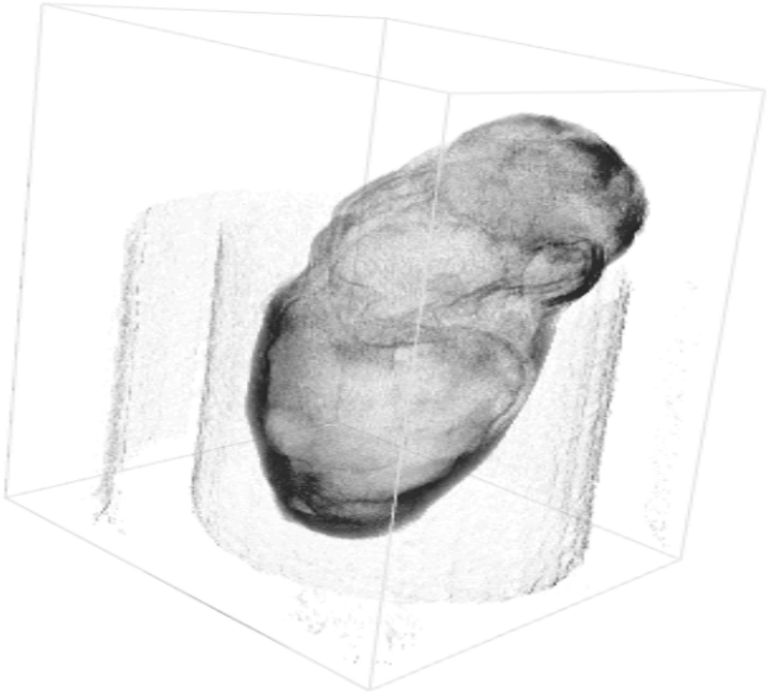
Find rotation and translation of two overlapping CT scans







To match the first image, the second image must be shifted by:

$$x = 2$$
$$y = 15$$
$$z = -2$$

and rotated by:

$$\phi = 4.84\ degrees$$

Fourier Transform for image registration

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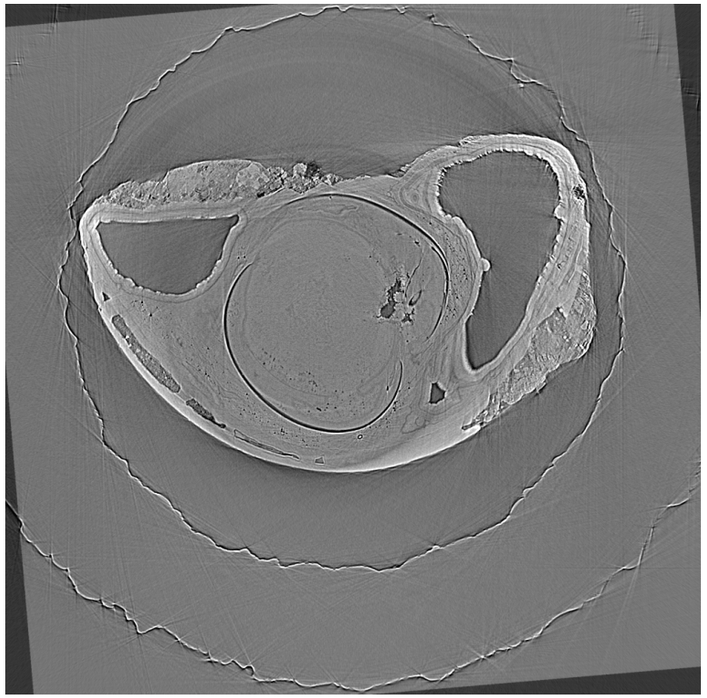
Find rotation and translation of two overlapping CT scans



To match the first image, the second image must be shifted by:

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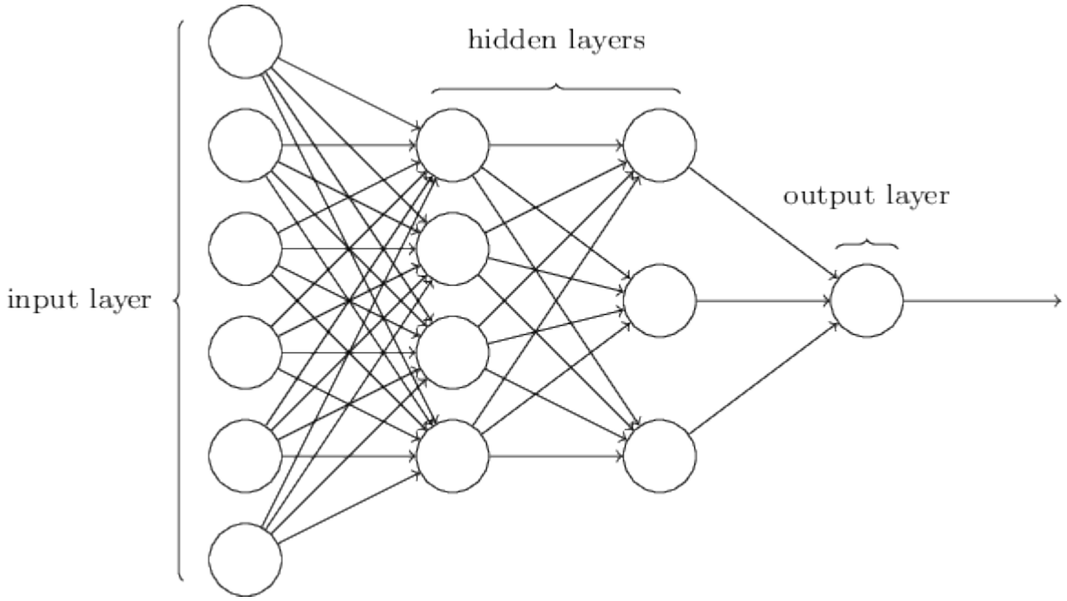
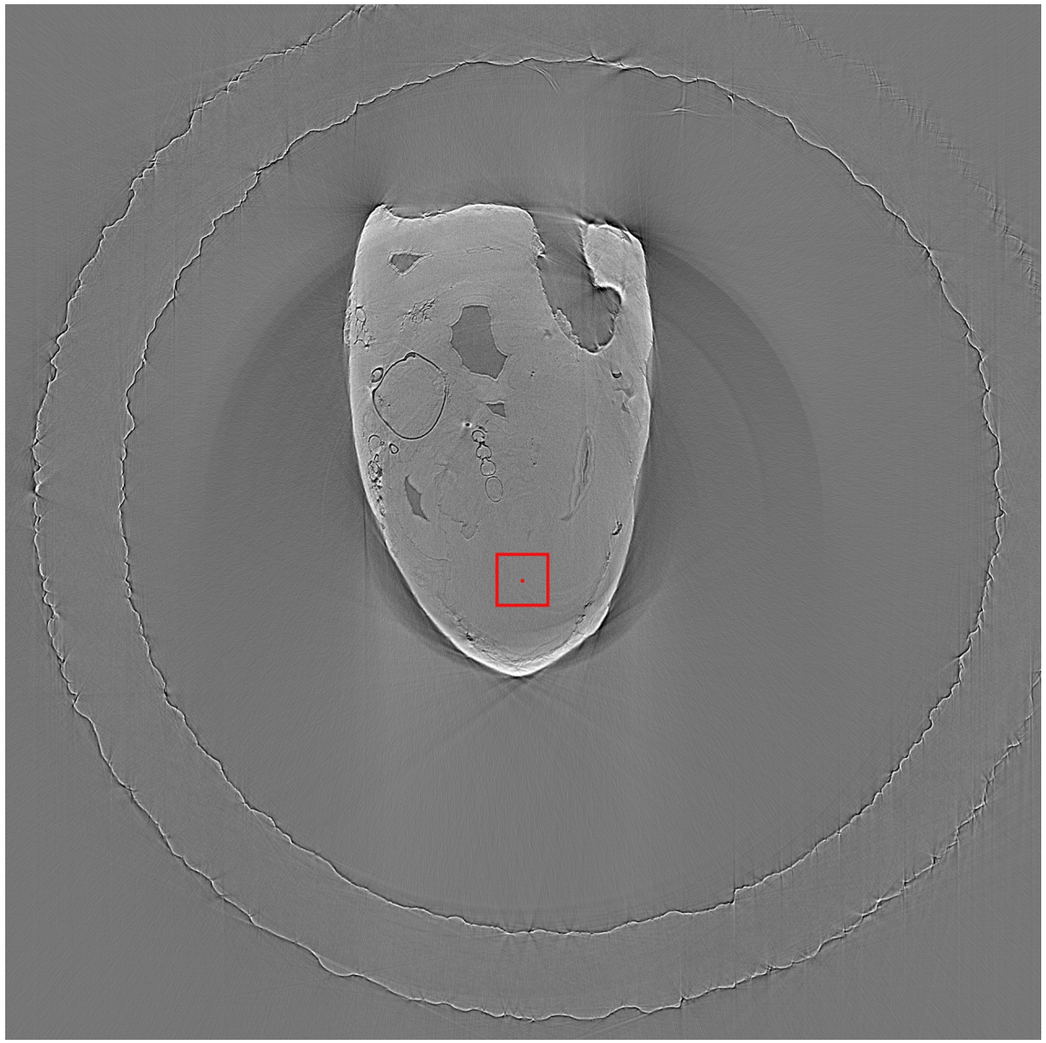
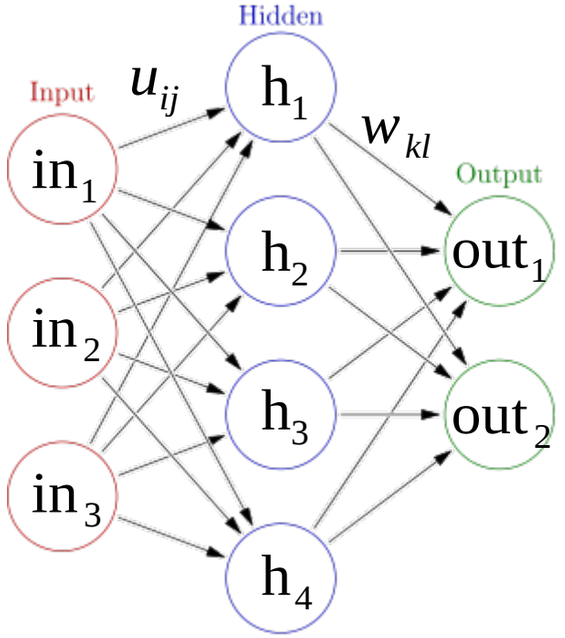
Deep learning for image segmentation

- **Input layer**: 2D patches
- **Output layer**: background / foreground





Deep learning for image segmentation



Having a training data set with images $\mathrm{Input}_1, \ldots, \mathrm{Input}_N$ and corresdponding classifications $\mathrm{R}_1, \ldots, \mathrm{R}_N$ (real output values).

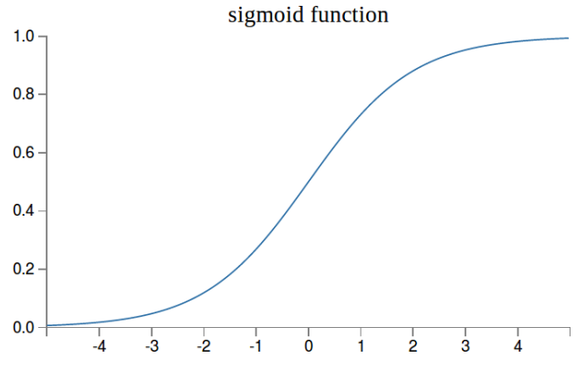
Then we want to find weights u_{ij} and w_{kl} in such a way that the function F is minimized for all our training data.

$$F(u, w) = \sum_{n=1}^{N} \left(\mathrm{out}_1 - r_1\right)^2 + \left(\mathrm{out}_2 - r_2\right)^2 \longrightarrow \min$$

where

$$\mathrm{out}_k = \sigma\left(\sum_{l=1}^{4} w_{kl}\, \mathrm{h}_l\right)$$

$$\mathrm{h}_i = \sigma\left(\sum_{j=1}^{3} u_{ij}\, \mathrm{in}_i\right).$$



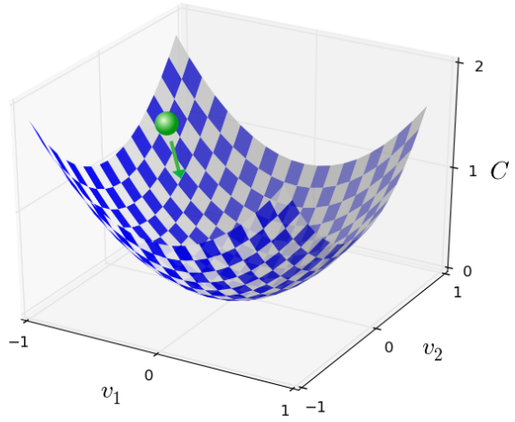
For Example:

$$\mathrm{Input}_1 = (23, 255, 0) \quad \text{and} \quad \mathrm{R}_1 = (1,0)$$
$$\mathrm{Input}_2 = (15, 38, 55) \quad \text{and} \quad \mathrm{R}_2 = (0,1)$$

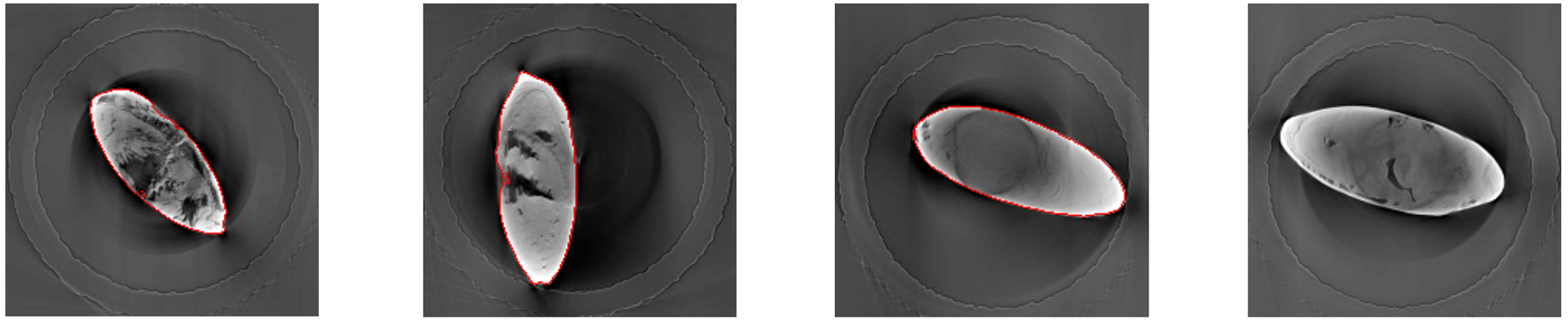
Deep learning for image segmentation

Minimization by means of stochastic gradient descent:

- Randomly select a batch of 10 input samples and take a small step towards the steepest descent.
- The so-called “Backpropagation” algorithm can be broken down to almost nothing as matrix-matrix multiplication.
- Can be calculated efficiently on GPUs.



Deep learning for image segmentation



Three out of nine virtual cross sections of different puparia used for training a neural network and automatically segment 10th puparia.

Deep learning for image segmentation

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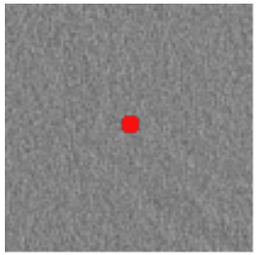
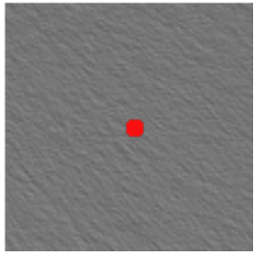
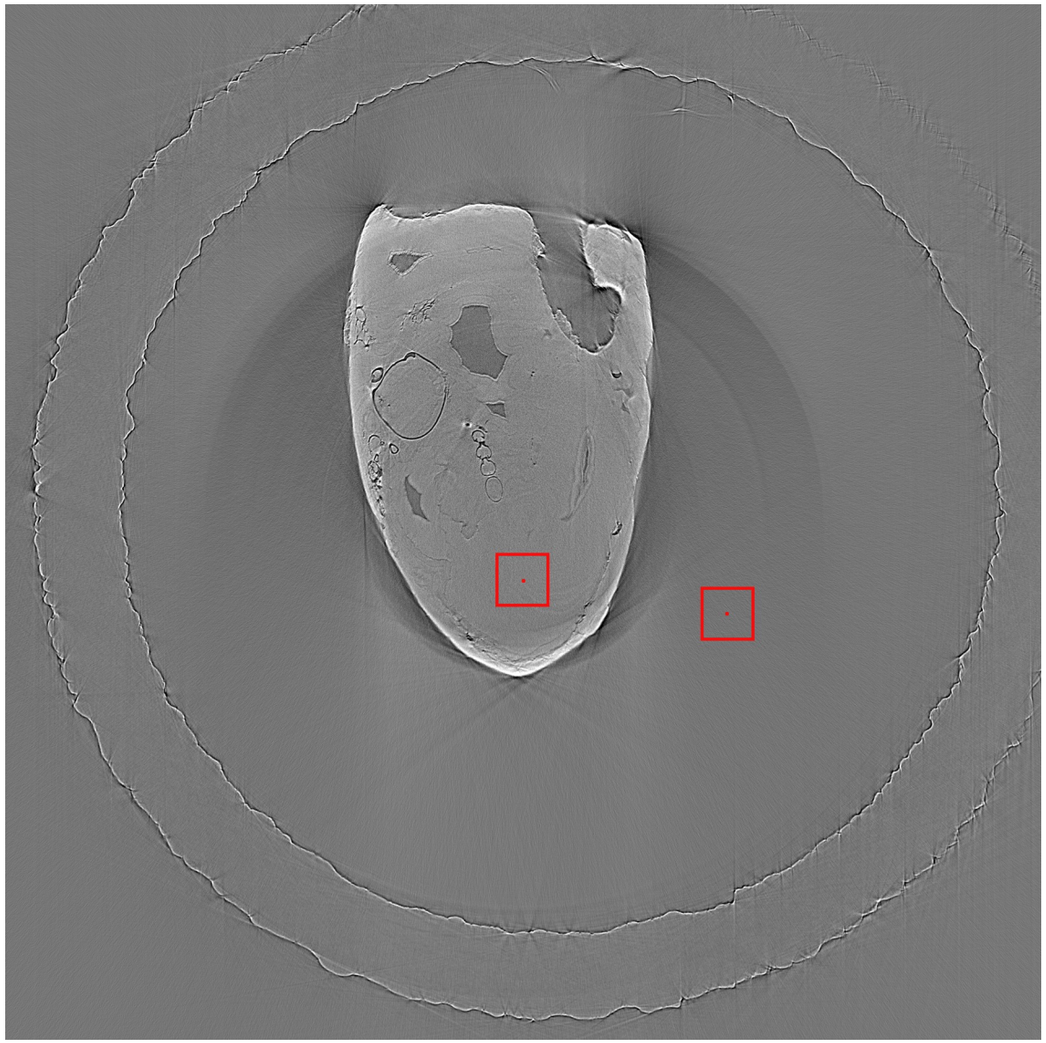
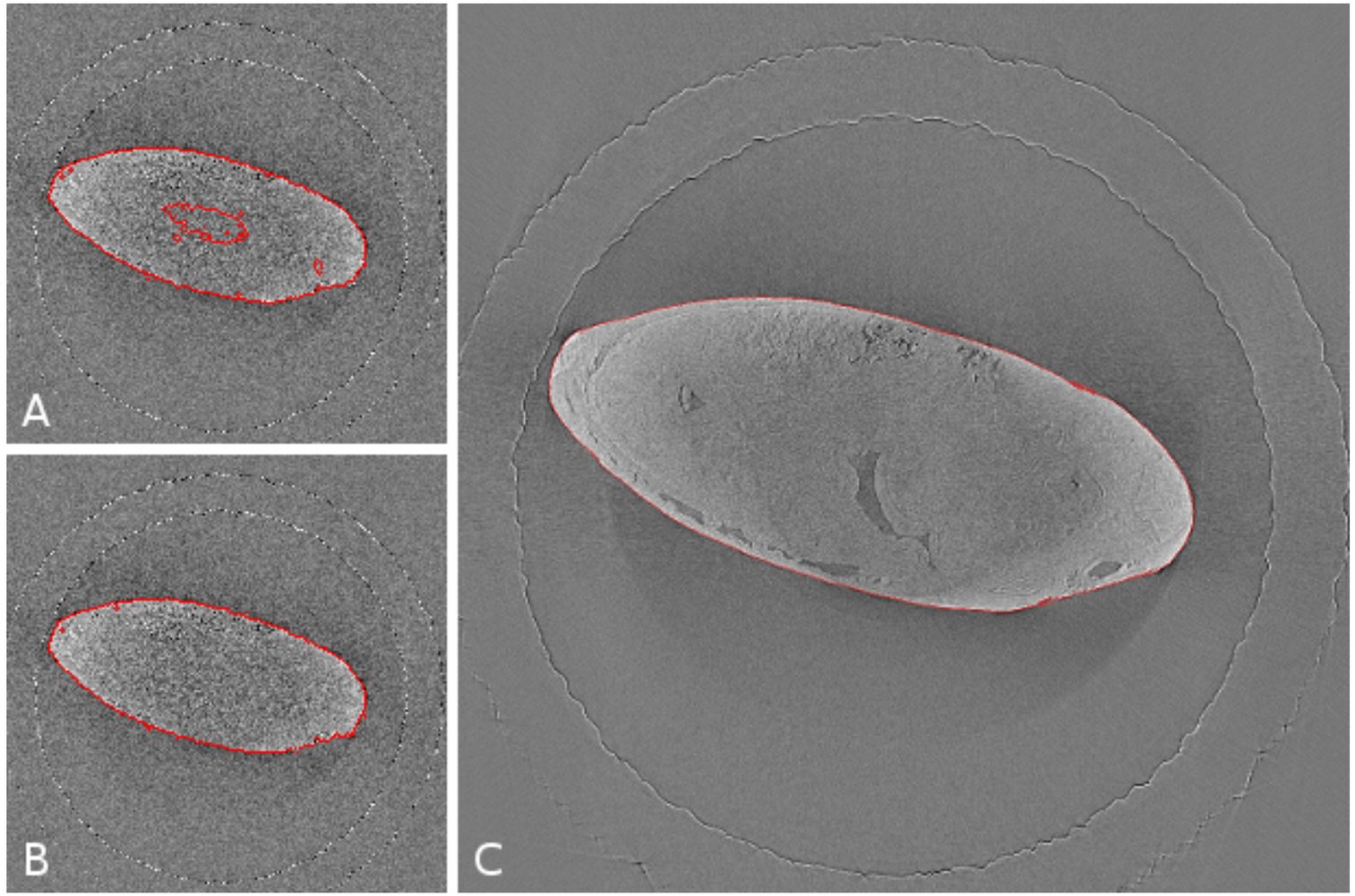
Foreground or background?







Deep learning for image segmentation



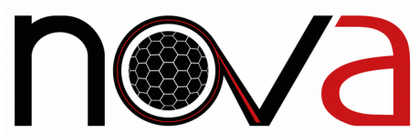
A - Result of the test image using a trained neural network.
B - Refinement of the result shown in (A) using Biomedisa.
C - Upsampling from resolution 202x202x202 (B) to full resolution 2016x2016x2016 using Biomedisa.

Outlook

1. Remote visualization
2. Subpixel image registration
3. Scale-invariant image registration
4. Fourier-based image segmentation using patches
5. Using random walks as input for a neural network

Thank you!

My special thanks go to:



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