A description of our approach to solving the

Multi-Centre, Multi-Vendor & Multi-Disease Cardiac Image Segmentation "M&Ms" Challenge

Presented by:

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Matteo Bonacini
Stefano Petraccini

Reference paper:

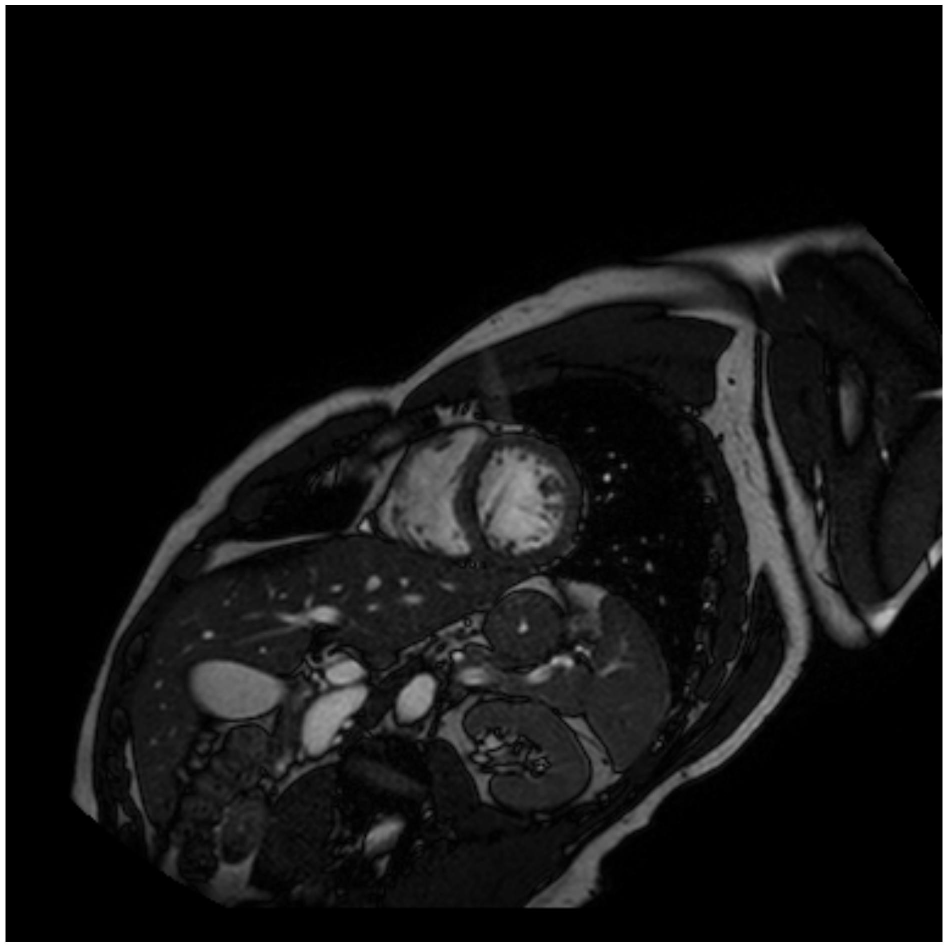
• V. M. Campello et al., "Multi-Centre, Multi-Vendor and Multi-Disease Cardiac Segmentation: The M&Ms Challenge," in IEEE Transactions on Medical Imaging, vol. 40, no. 12, pp. 3543-3554, Dec. 2021, doi: 10.1109/TMI.2021.3090082.

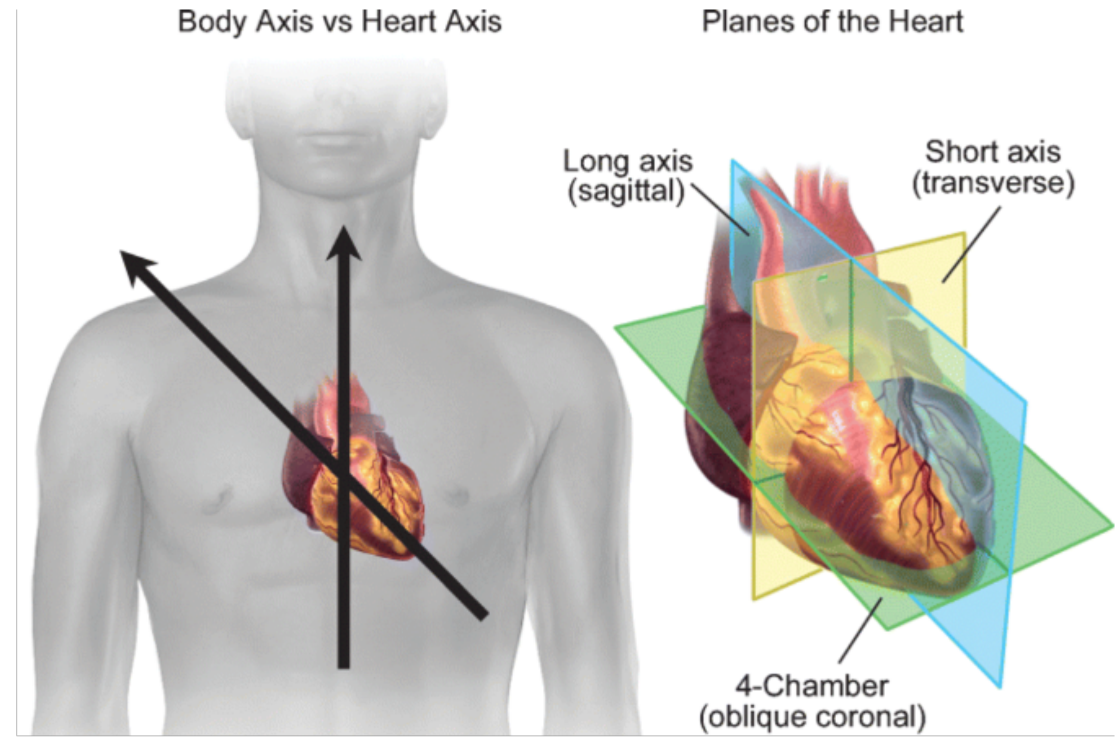
The challenge

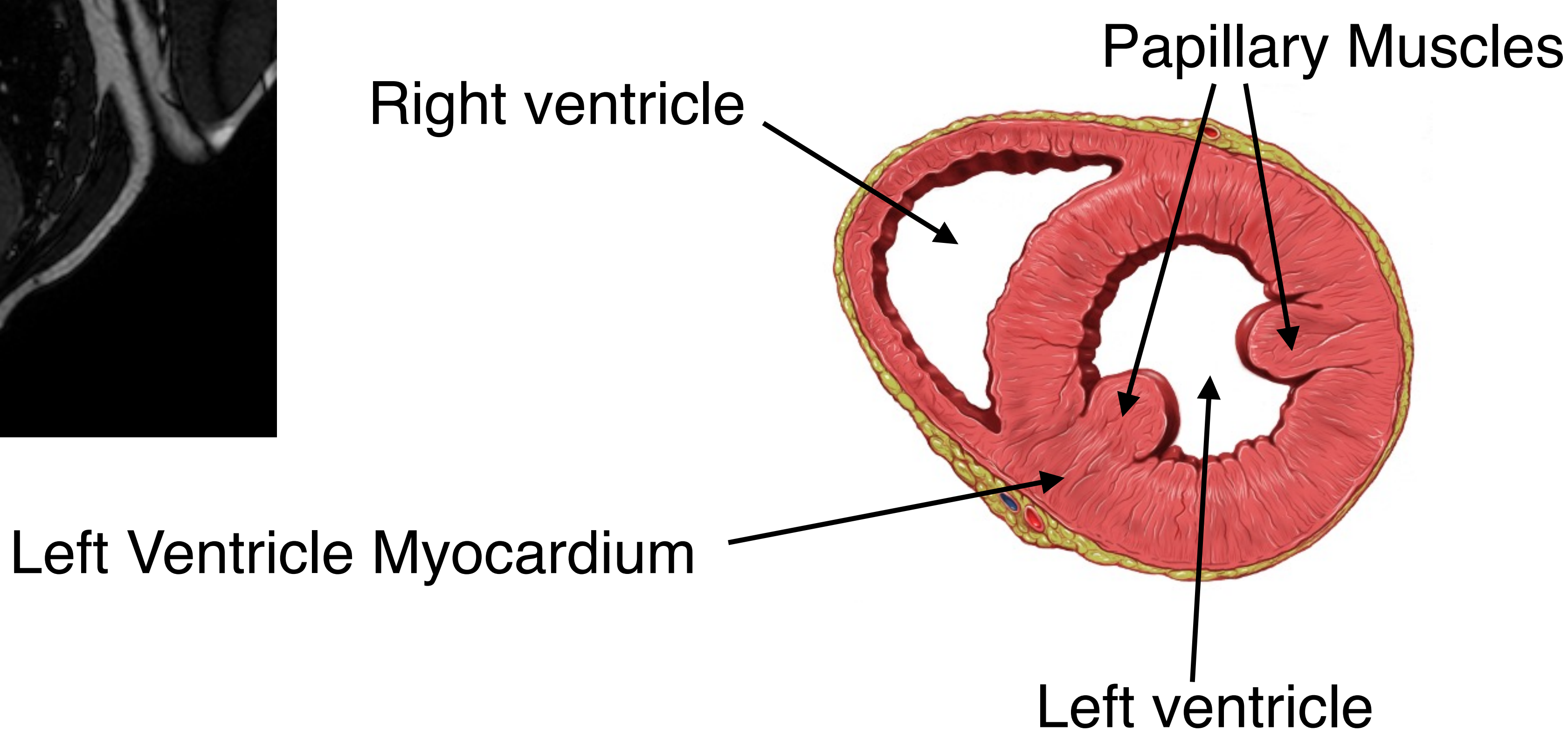
Participants are asked to improve automated CMR segmentation and generalize it towards different scanners vendors and imaging protocols:

- Multi-centre and multi-vendor: 6 clinical centers with Siemens, Philips, Canon and General Electrics scanner
- Subjects: ill people with various cardiovascular diseases, healthy volunteers
- Regions: left and right ventricle cavities, left ventricle myocardium

The images

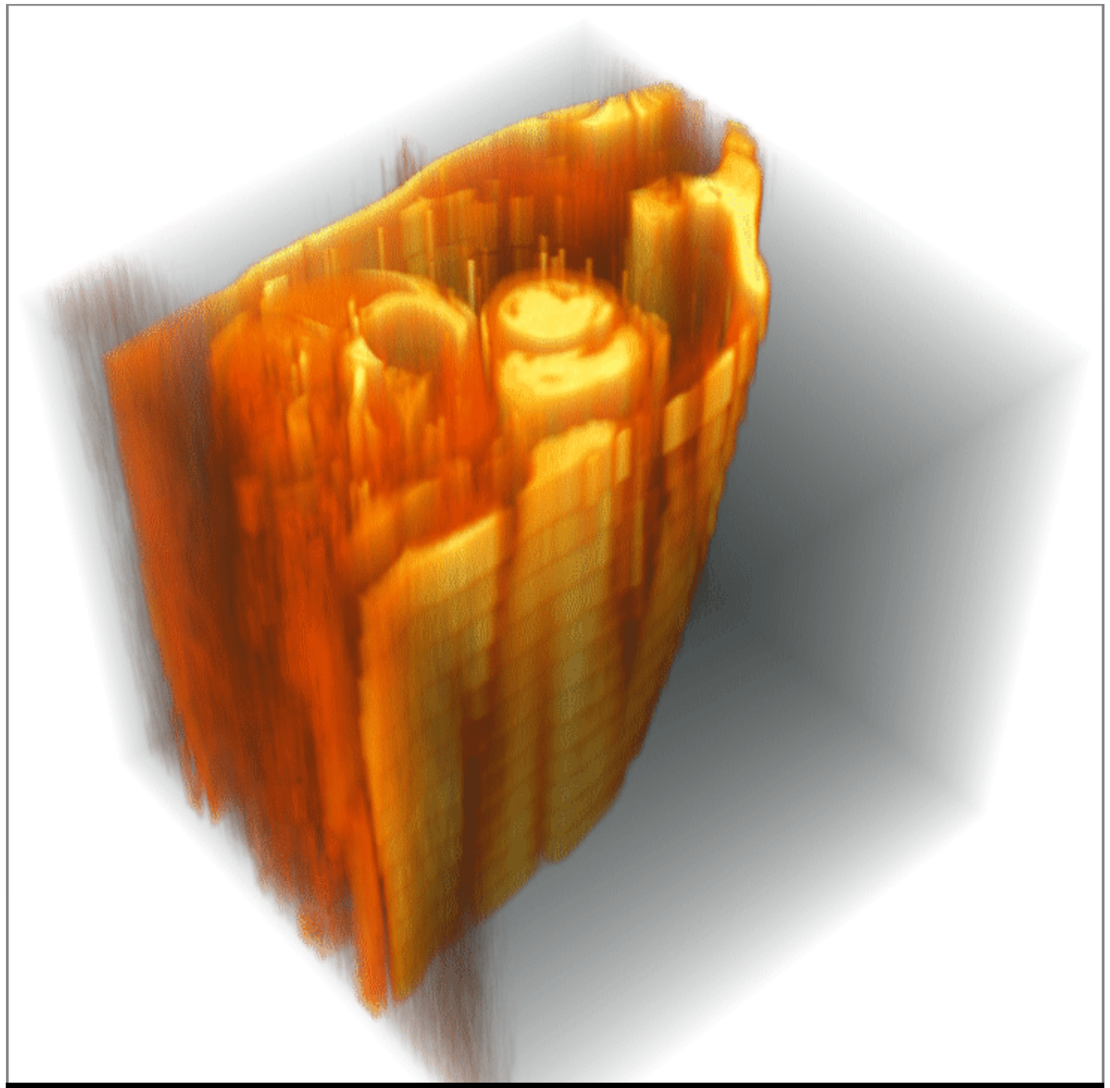



Body Axis vs Heart Axis
Planes of the Heart
Long axis
(sagittal)
Short axis
(transverse)
4-Chamber
(oblique coronal)


Papillary Muscles
Right ventricle
Left Ventricle Myocardium
Left ventricle

Preprocessing: finding the heart

- Finding the heart at first glance can be difficult.



3D+t MRI image from the M&Ms dataset.

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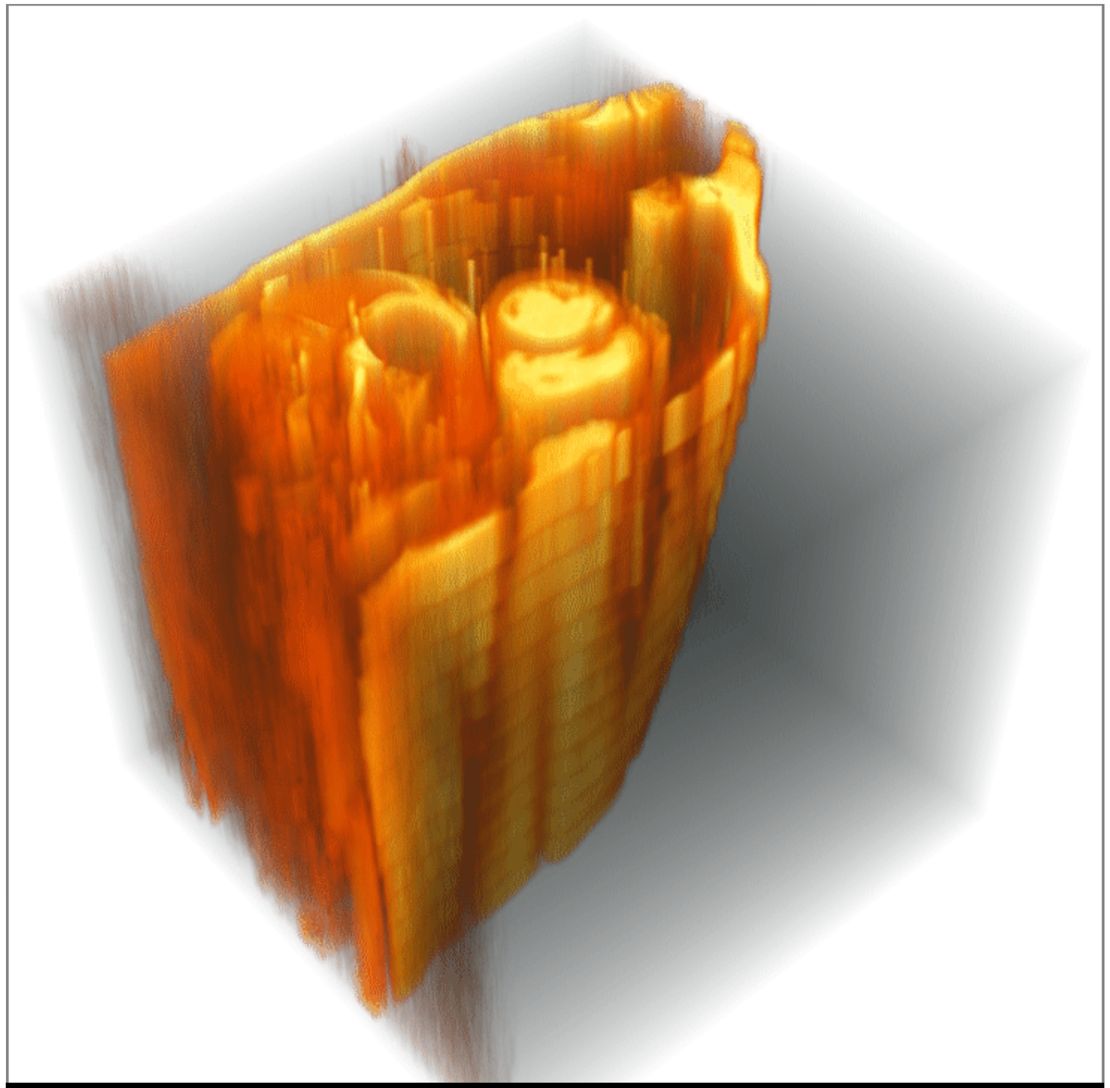

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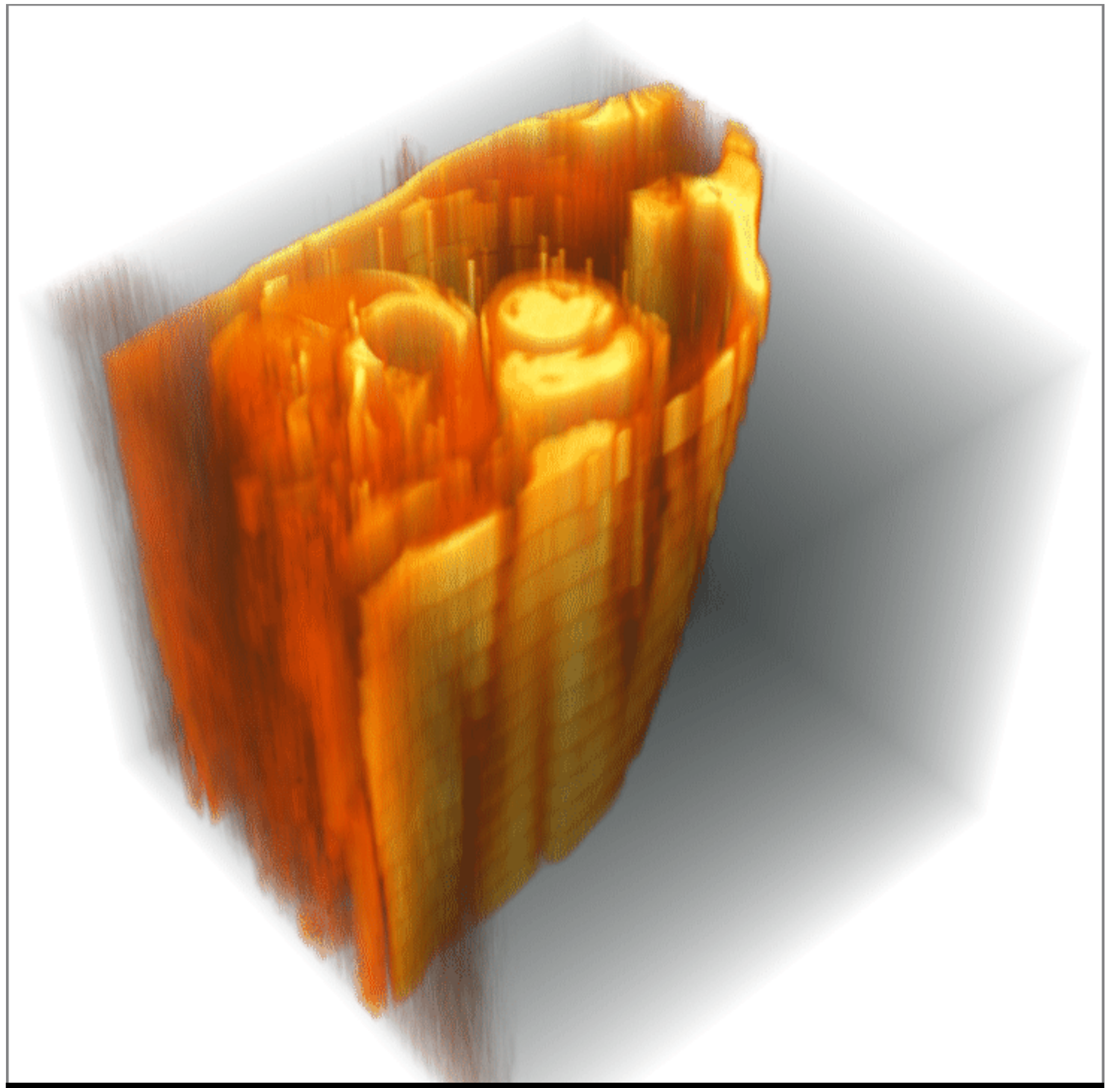

3D+t MRI image from the M&Ms dataset.

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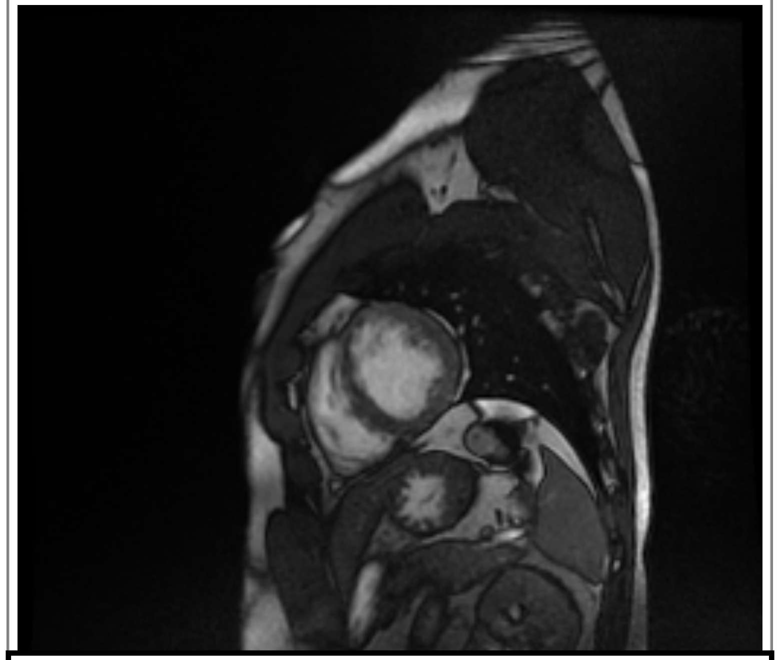
- We start with a sequence of 2D frames.



Short-axis slice of 3D+t MRI image from the M&Ms dataset.

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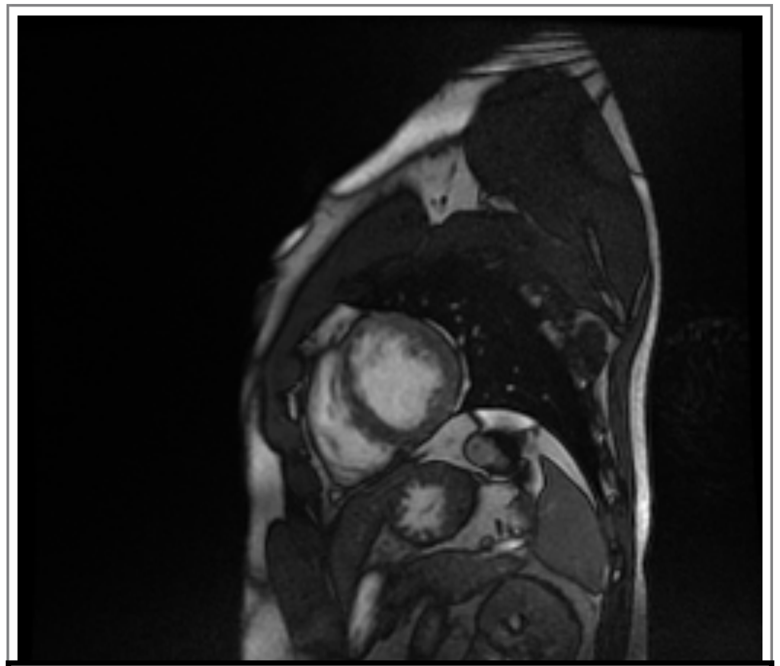
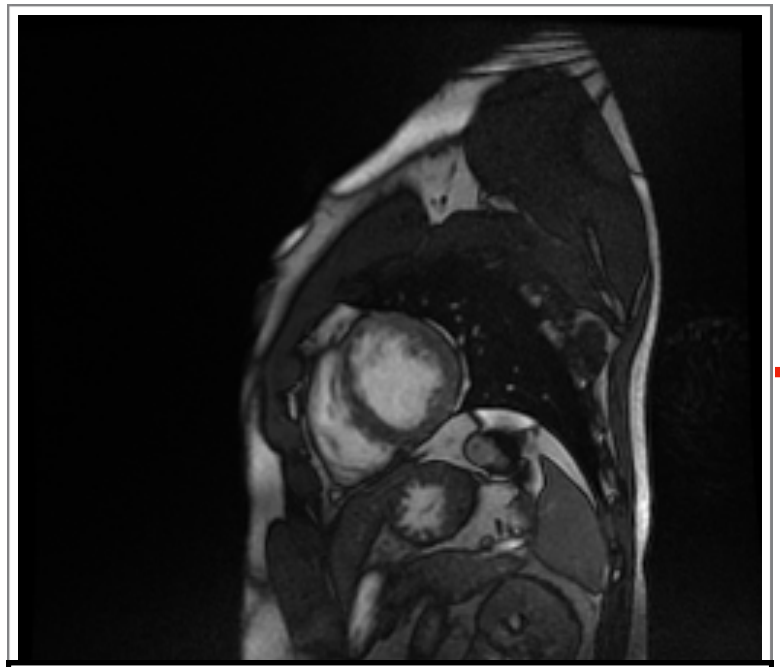


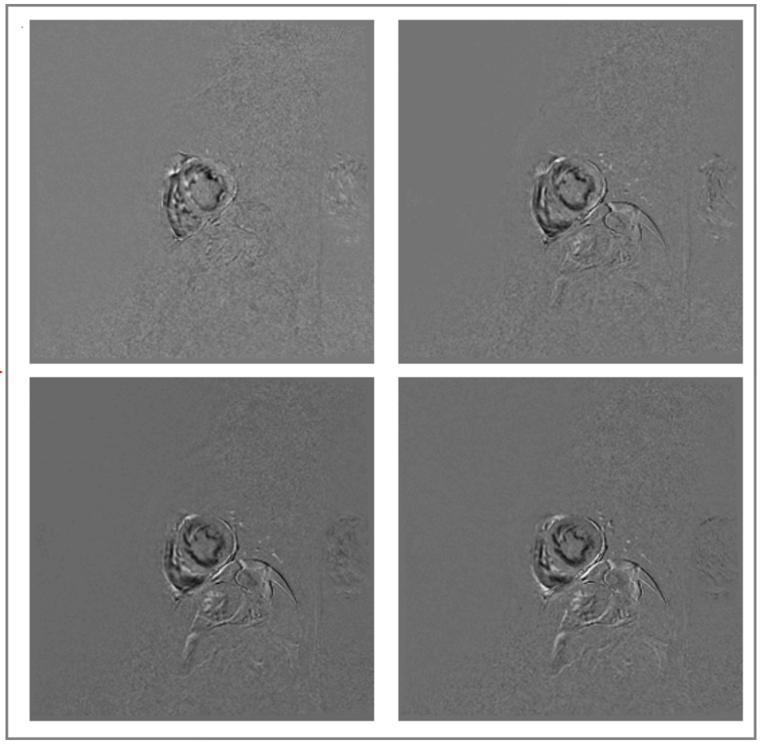
Short-axis slice of 3D+t MRI image from the M&Ms dataset.

Preprocessing: finding the heart

- We start with a sequence of 2D frames.
- We compute the differences between consecutive frames.



Short-axis slice of 3D+t MRI image from the M&Ms dataset.



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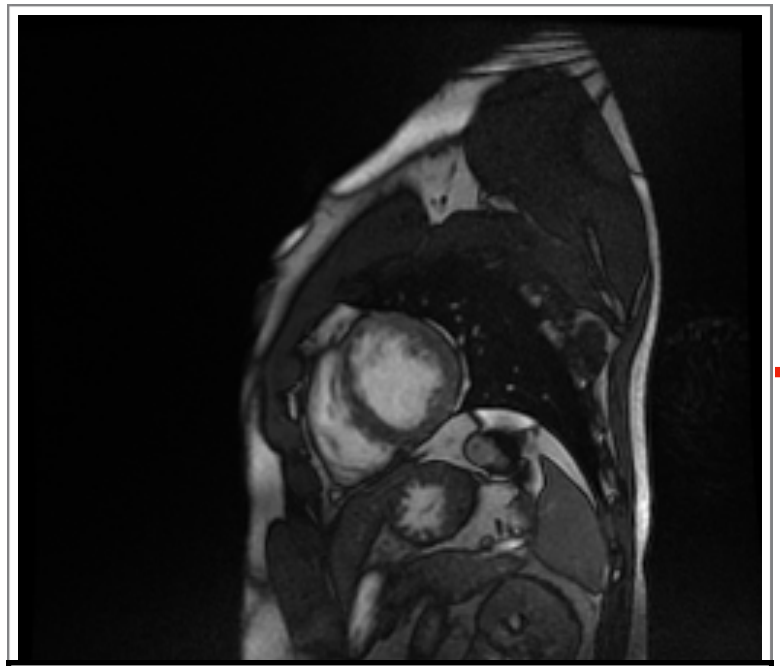
- We binarize and average the results.



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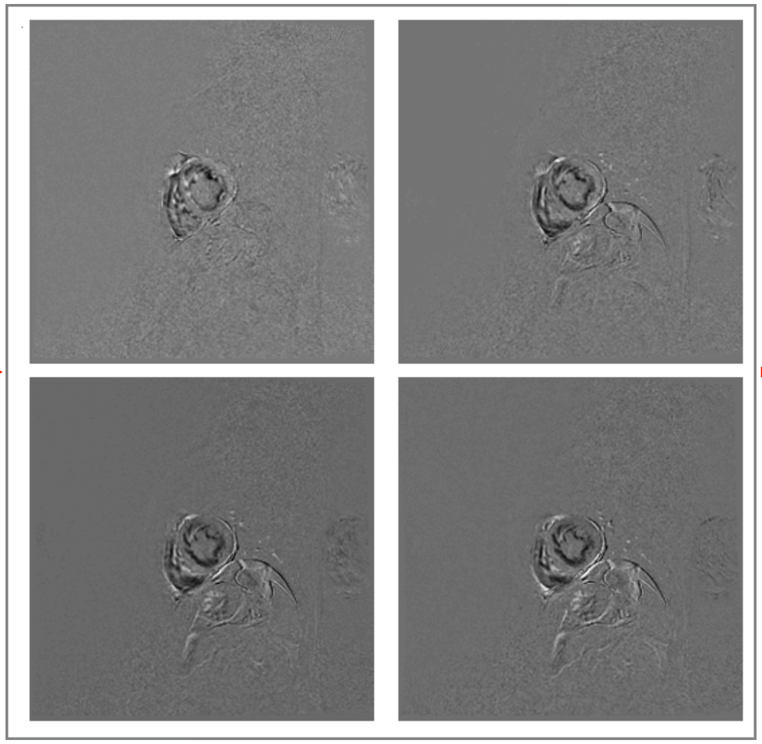

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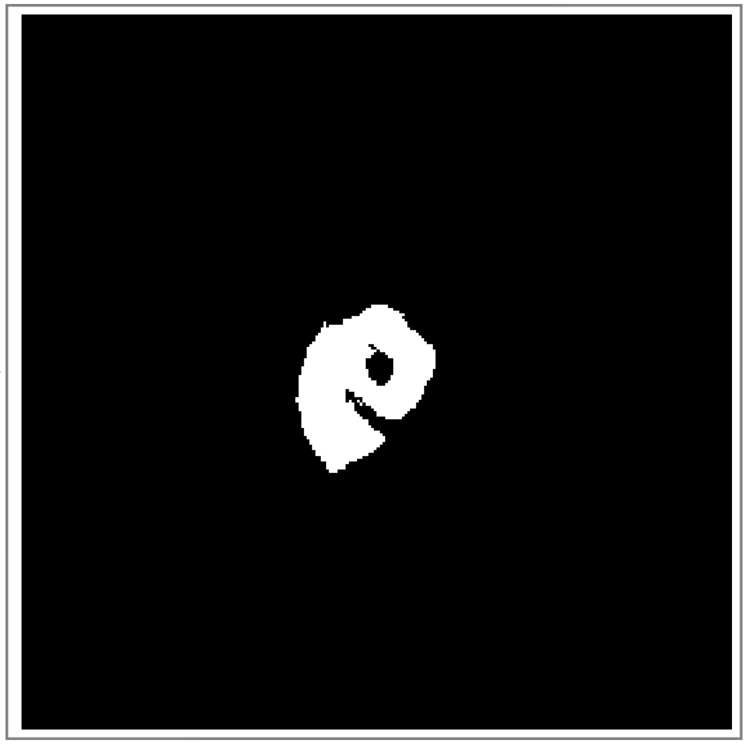
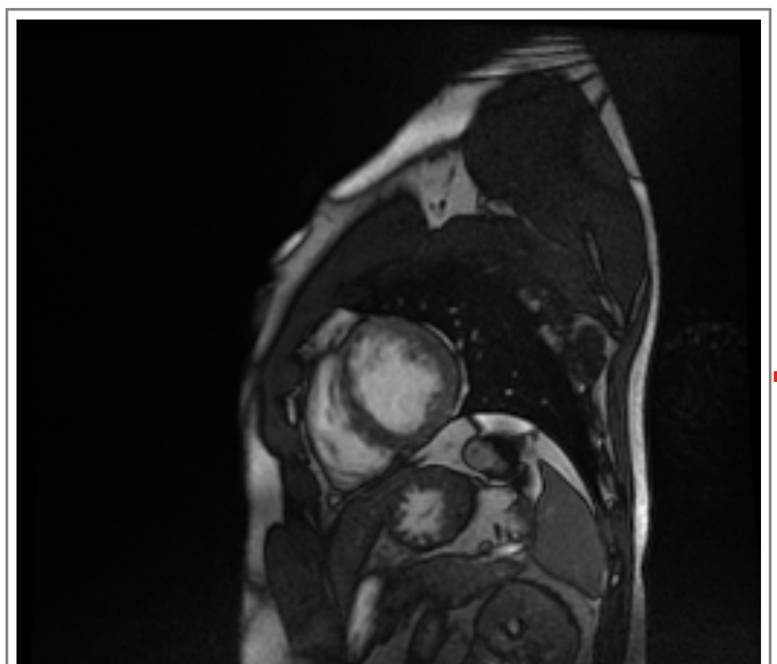


Preprocessing: finding the heart

- We start with a sequence of 2D frames.
- We compute the differences between consecutive frames.
- We binarize and average the results.
- We fit a 2D gaussian distribution to the image.



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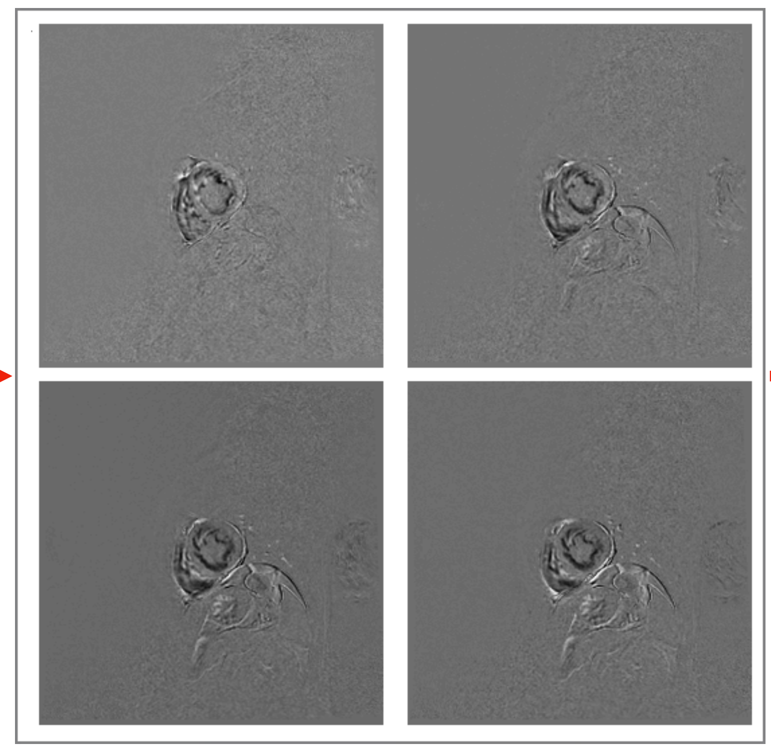

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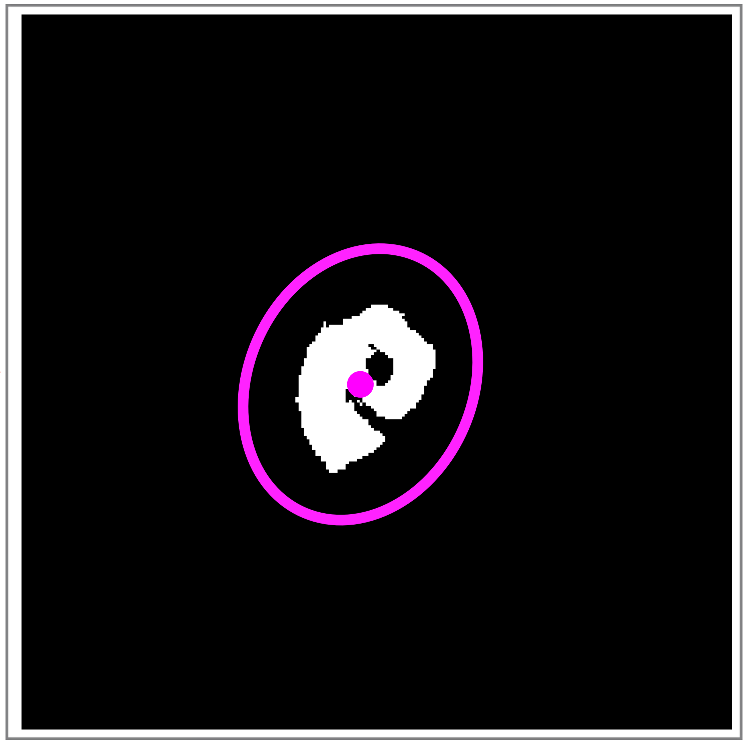

ImageJ

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- Preprocessing (contrast enhancement, noise removal, sharpening)

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- Statistical Region Merging

ImageJ

- Preprocessing (contrast enhancement, noise removal, sharpening)
- Statistical Region Merging
- Auto Local Threshold

MatLAB

- Edge enhancement, window/level corrections
- K-means clustering (3 clusters)
- Binarization of each channel

Original photo

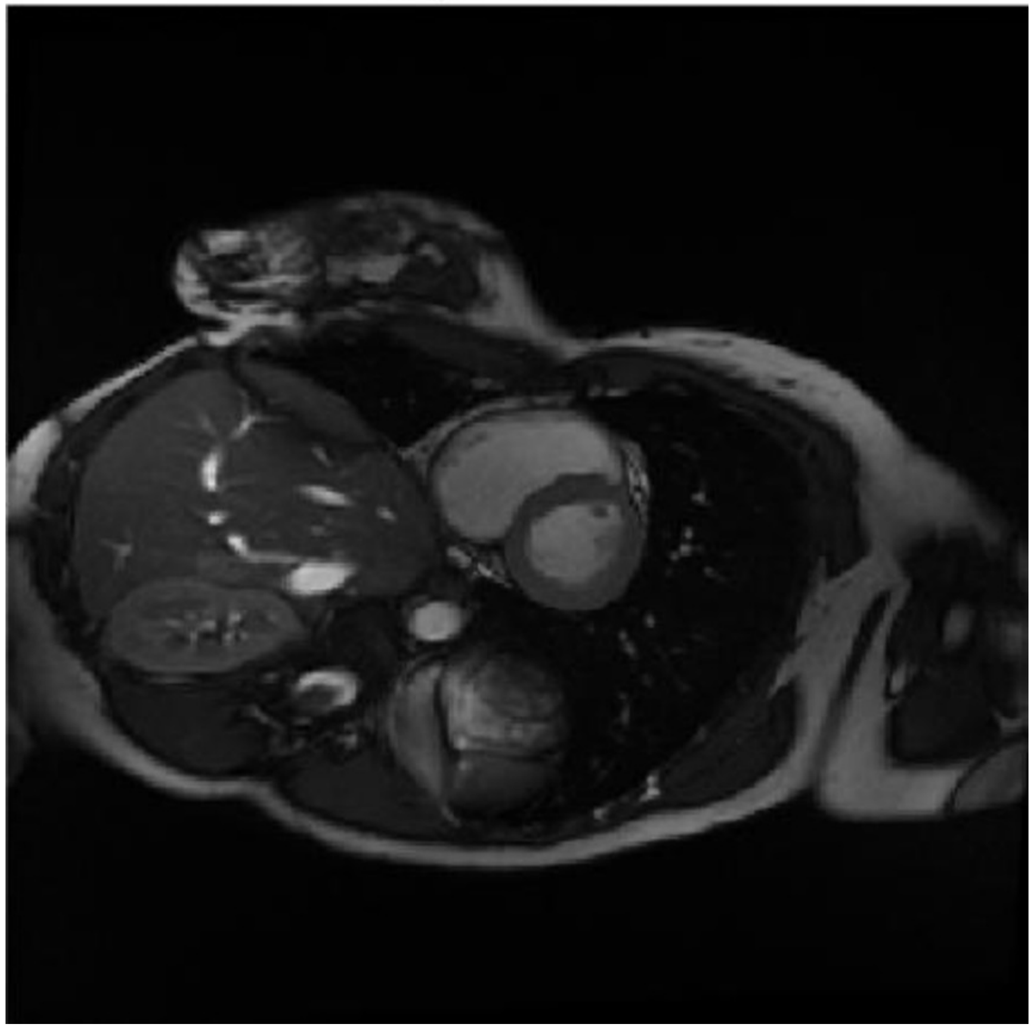
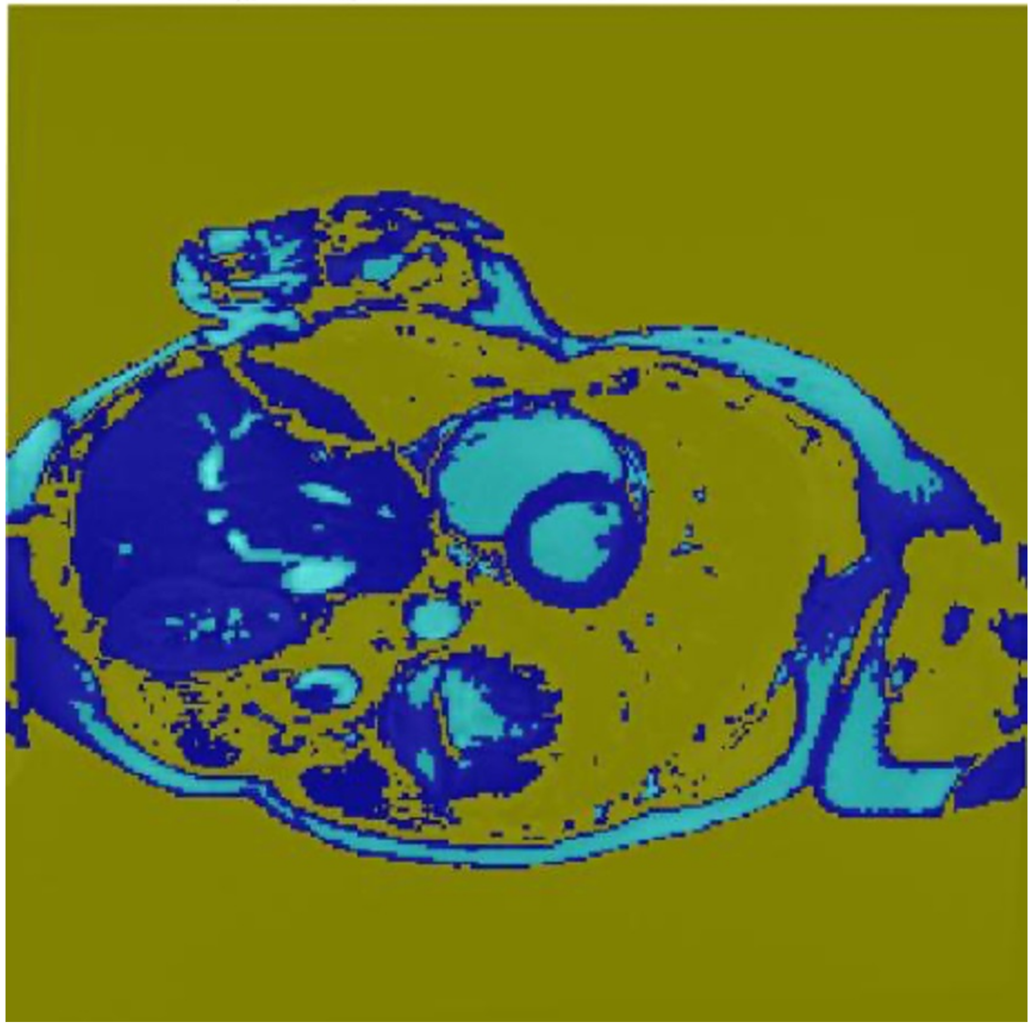
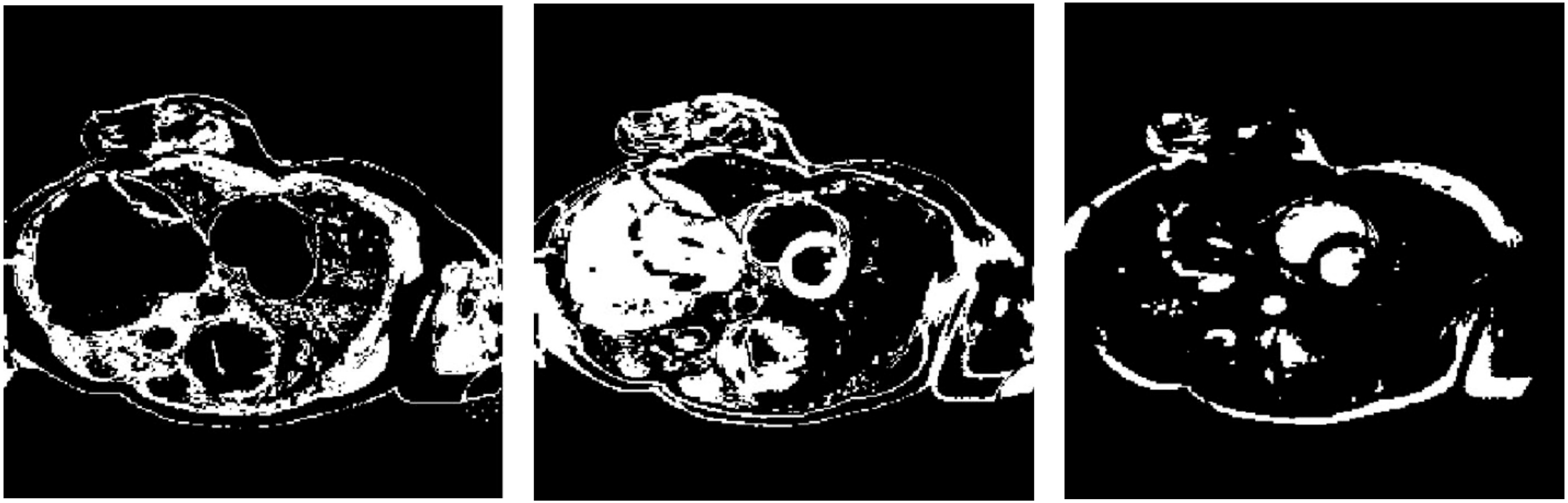


Image segmentation K-means



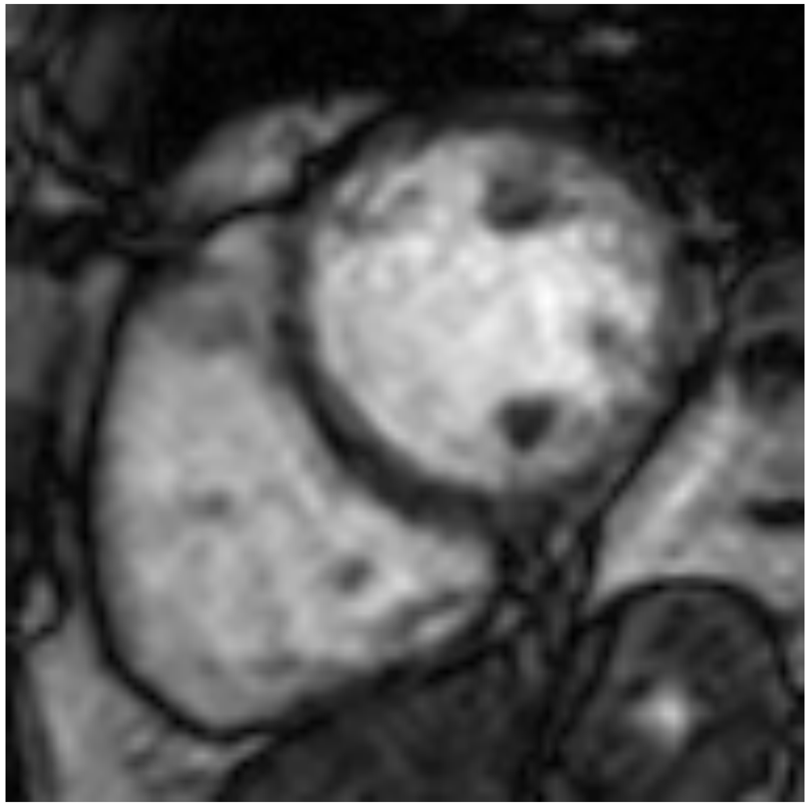
MatLAB



Cluster 1 Cluster 2 Cluster 3

Issues

- Edges not always being detected;
- Images coming from four different vendors scanners;
- Difficulty in separating the myocardium from the background.



Automated area recognition using the circularity ratio

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- Left and right ventricle have a different shape:
  - The **left** ventricle will have an approximately **circular** shape,
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- Left and right ventricle have a different shape:
  - The **left** ventricle will have an approximately **circular** shape,
  - The **right** ventricle tends to be more **elongated.**

- We can use the **circularity ratio** to classify the different areas of the image.

$$\boxed{C := \frac{4\pi A}{P^2} \qquad 1 \geq C \geq 0}$$

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- We start from a processed binary image.

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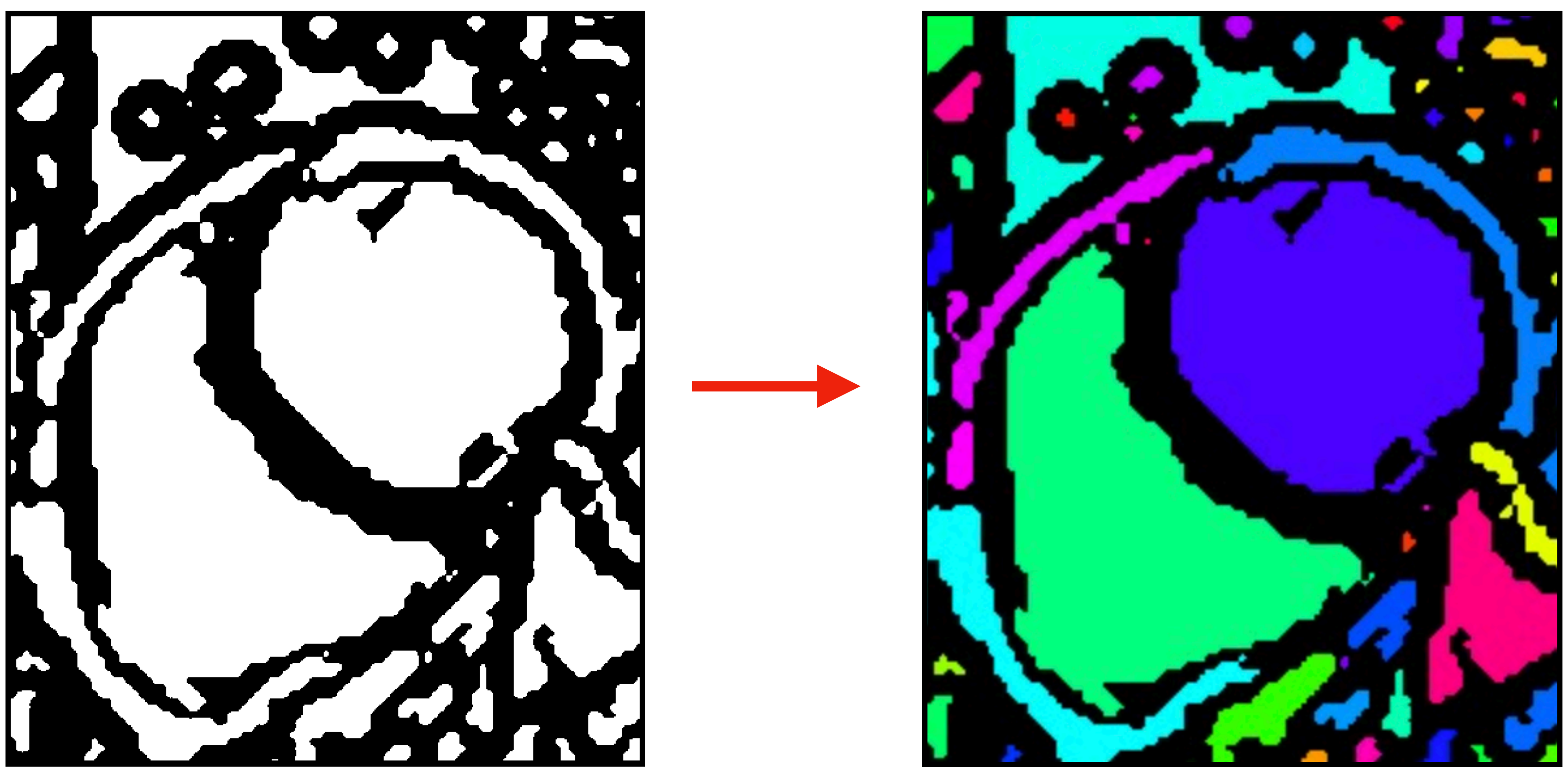
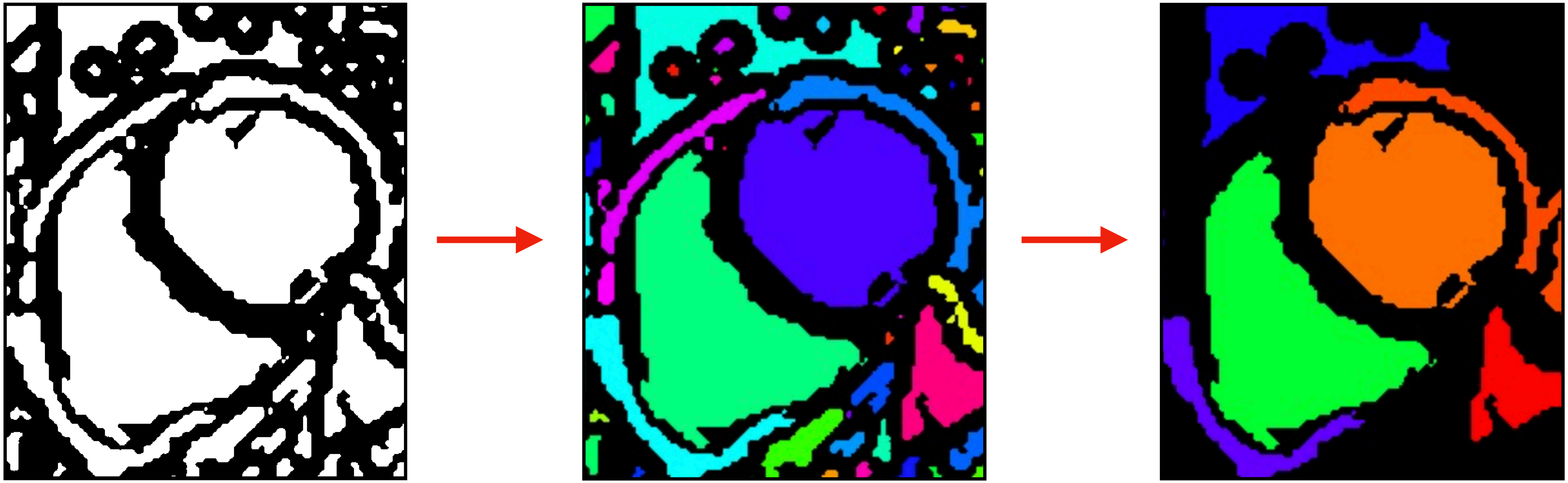


Automated area recognition using the circularity ratio

- We start from a processed binary image.
- We divide the image into its connected areas.
- We discard areas **smaller than 1/5 of the maximum area**.



Automated area recognition using the circularity ratio

- For the remaining objects we calculate the circularity ratio (equal to 1 for an ideal circle, less than 1 for any other shape).

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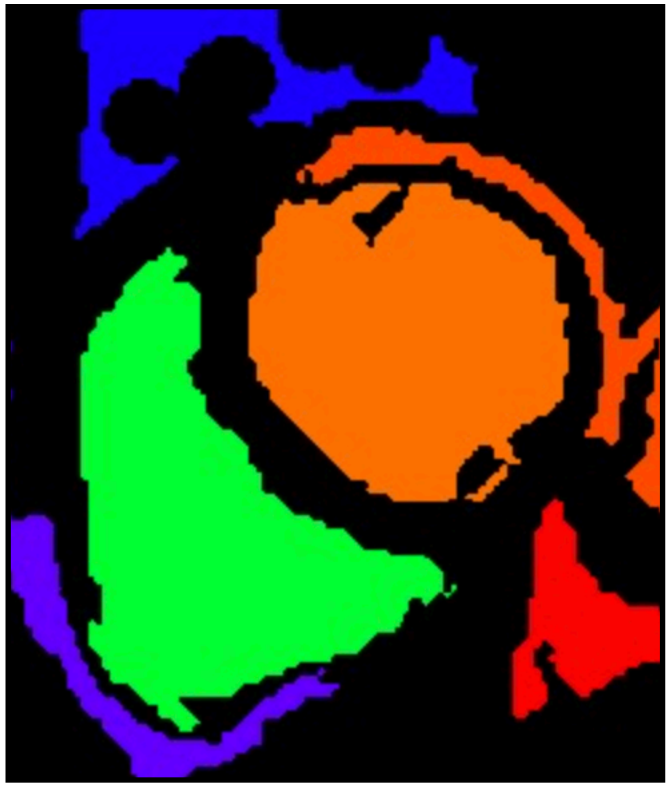

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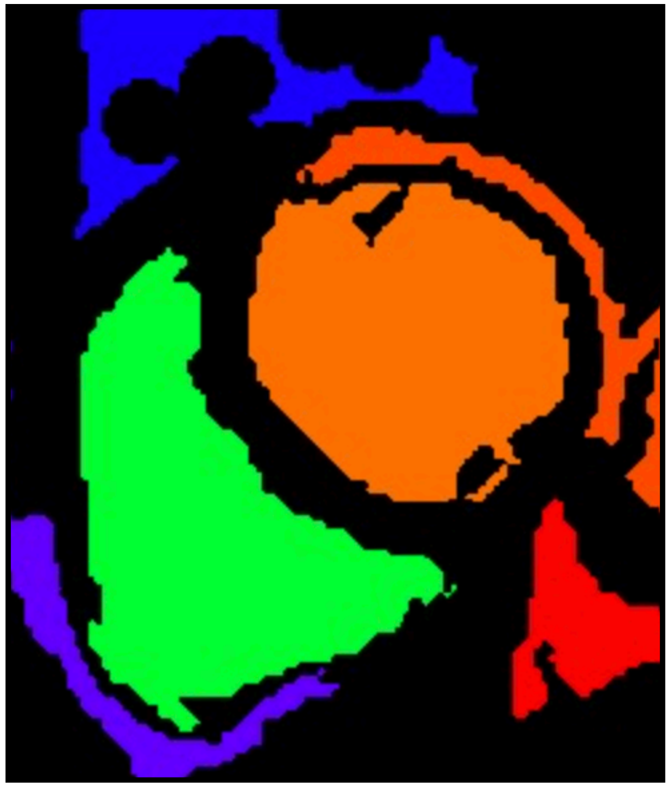
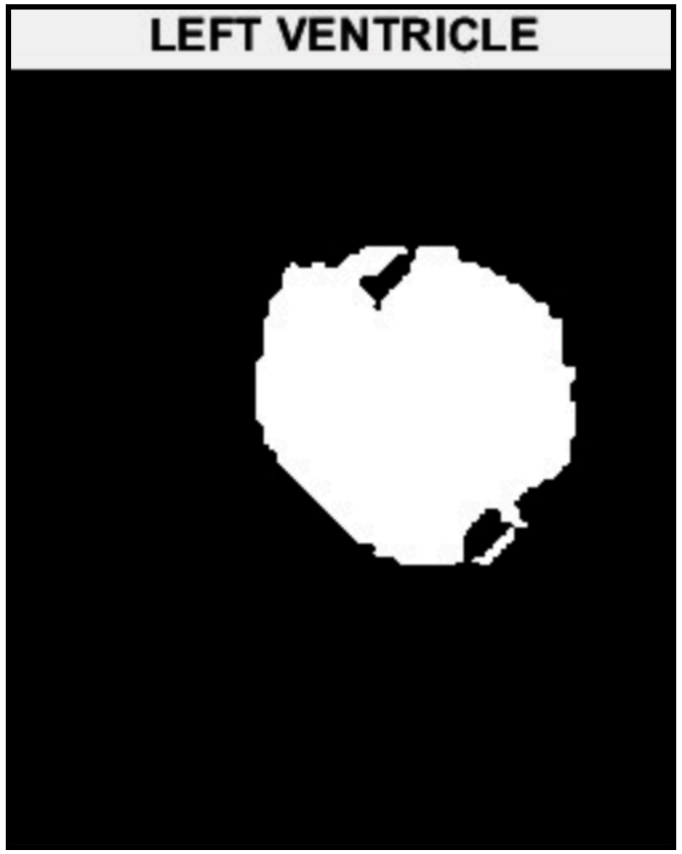
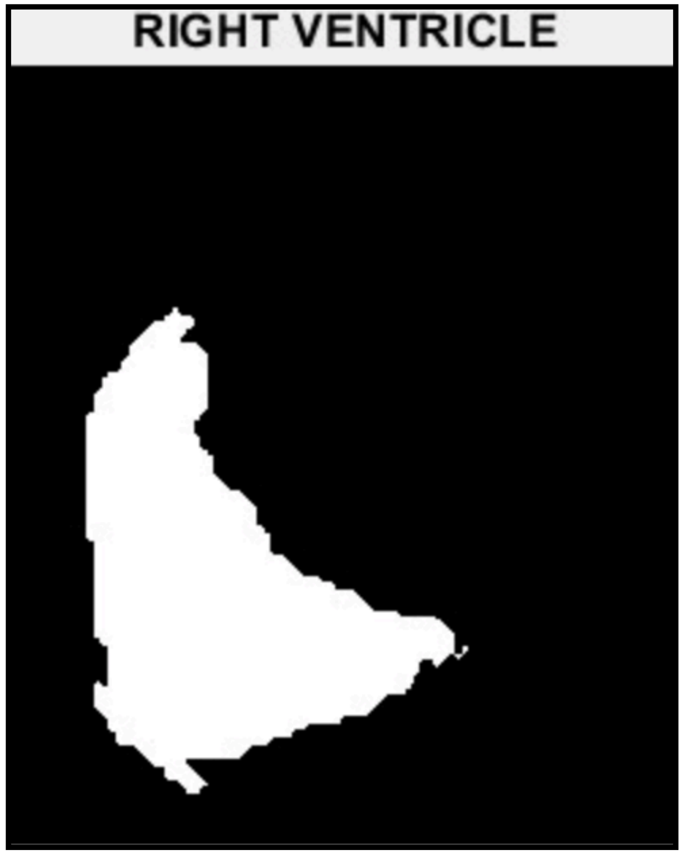
- We choose left and right ventricles as the first and second roundest objects in the image, respectively.







Automated area recognition using the circularity ratio

- **Limitations:**

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  - Left and right ventricle shapes have to be **connected**, **centered** and **clearly visible**.
  - The two areas should be reasonably big when compared to the other shapes containted in the image.
  - In some cases (like in the end-systole phase, where the ventricles are contracted), the circularity ratio may be similar.

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==> Human intervention is required!

Neural Network approach

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- **U-Net** is a convolutional neural network designed for medical image segmentation.

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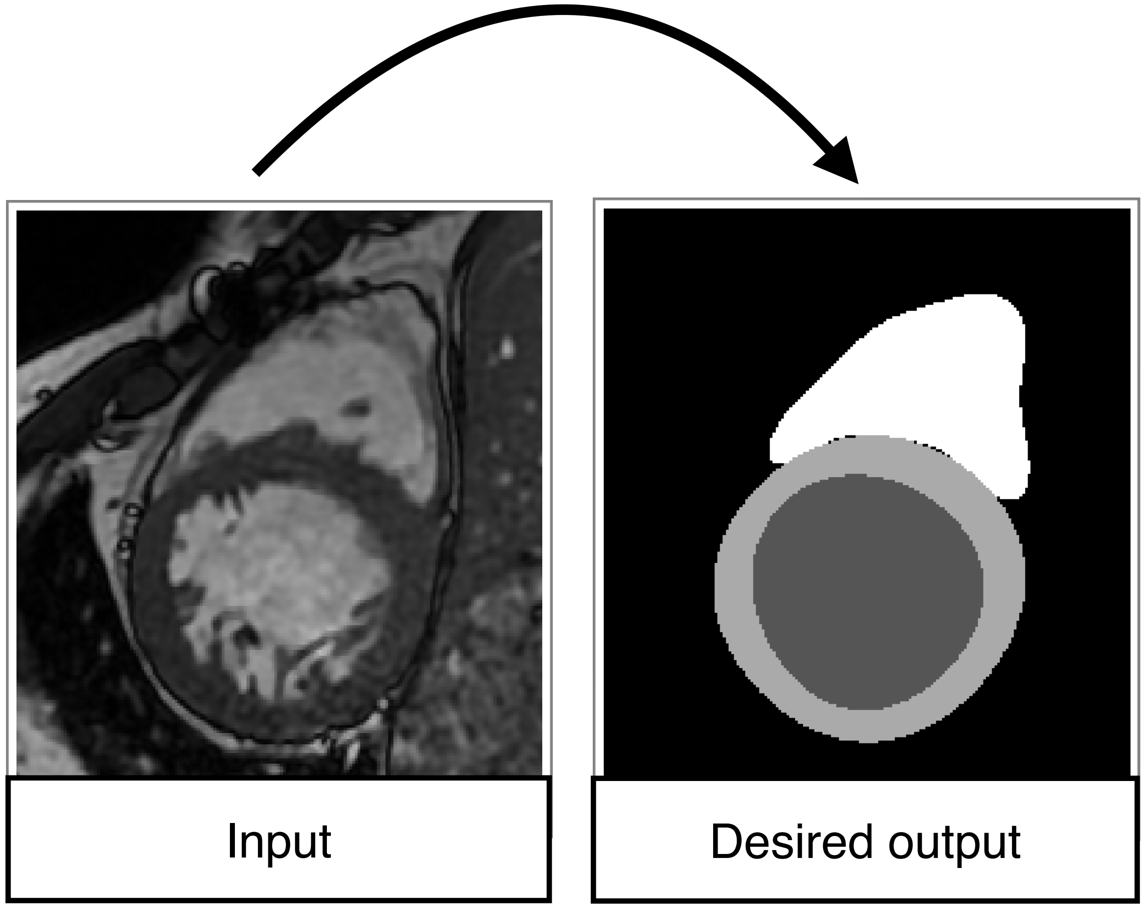
- Task: generate the mask of the heart from a given input.



Neural Network approach

- We trained the network using the human-made masks of the M&Ms dataset.

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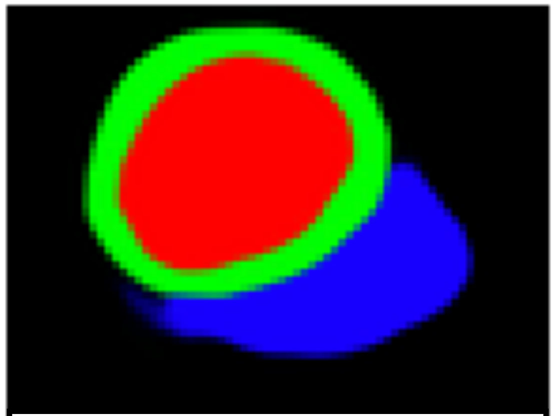
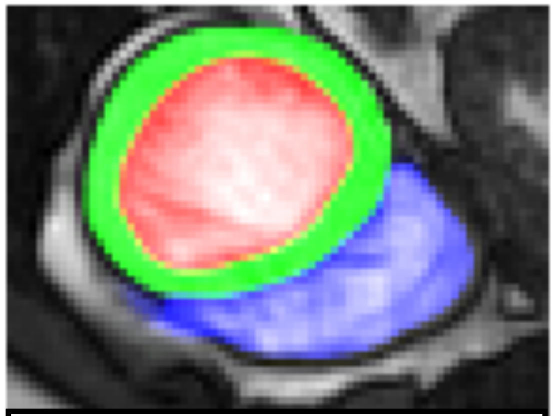
- **115 (x16) training** images, **49 validation** images.

- Results after **30 minutes of training** are great!
(**5% error rate** on validation, trained on a RTX2070)

Input



Output



Input+Output

Future works:
optimization and applications

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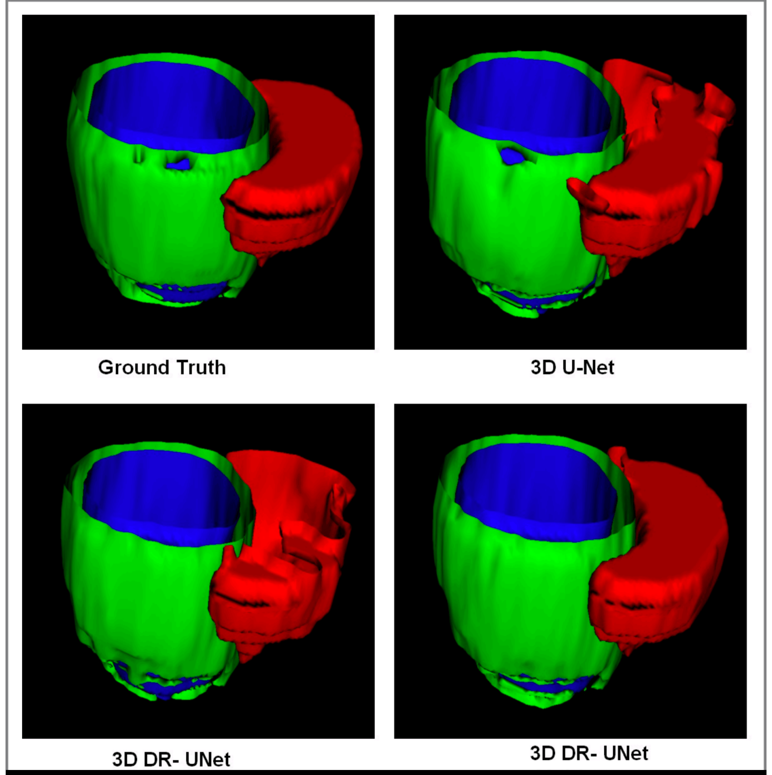
- Generalize our algorithms for 3D-images



Fully Automated 3D Cardiac MRI Localisation and Segmentation Using Deep Neural Networks,
https://doi.org/10.3390/jimaging6070065

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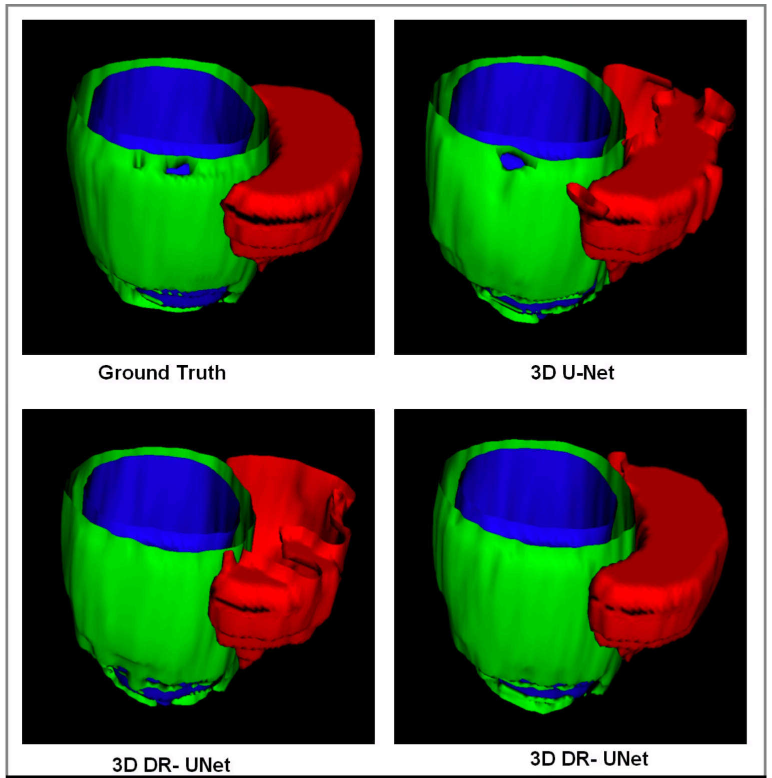

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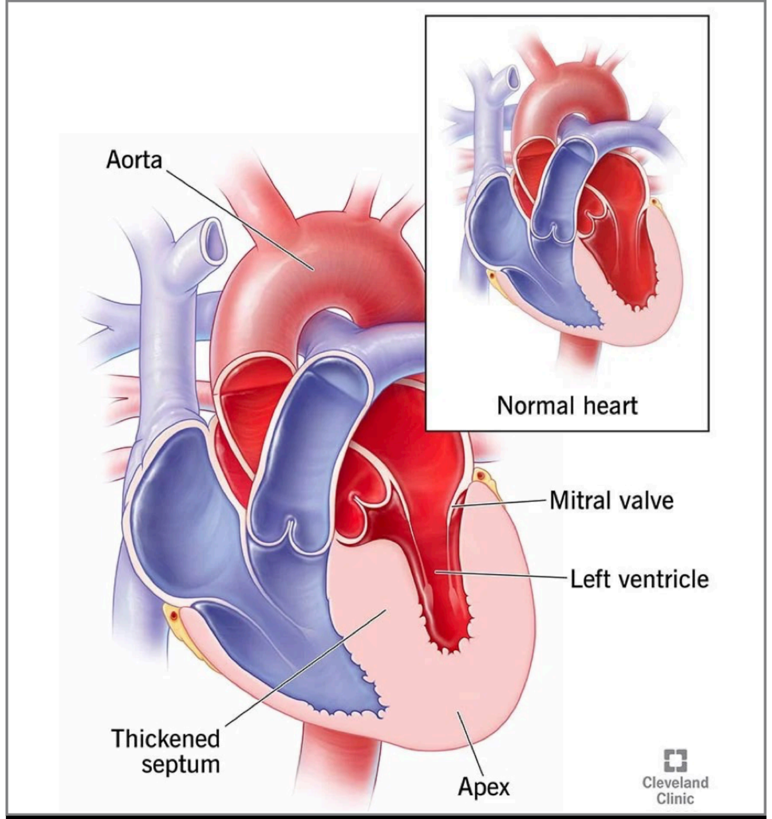
Ventricles and myocardium volumes comparation

Run simulations on the segmented heart

- Implement automatic malformation and disease recognition



Example disease: **Hypertrophic Cardiomyopathy**, *Cleveland Clinic ©2022.*

Thank you for your time,

we are happy to answer any further questions.

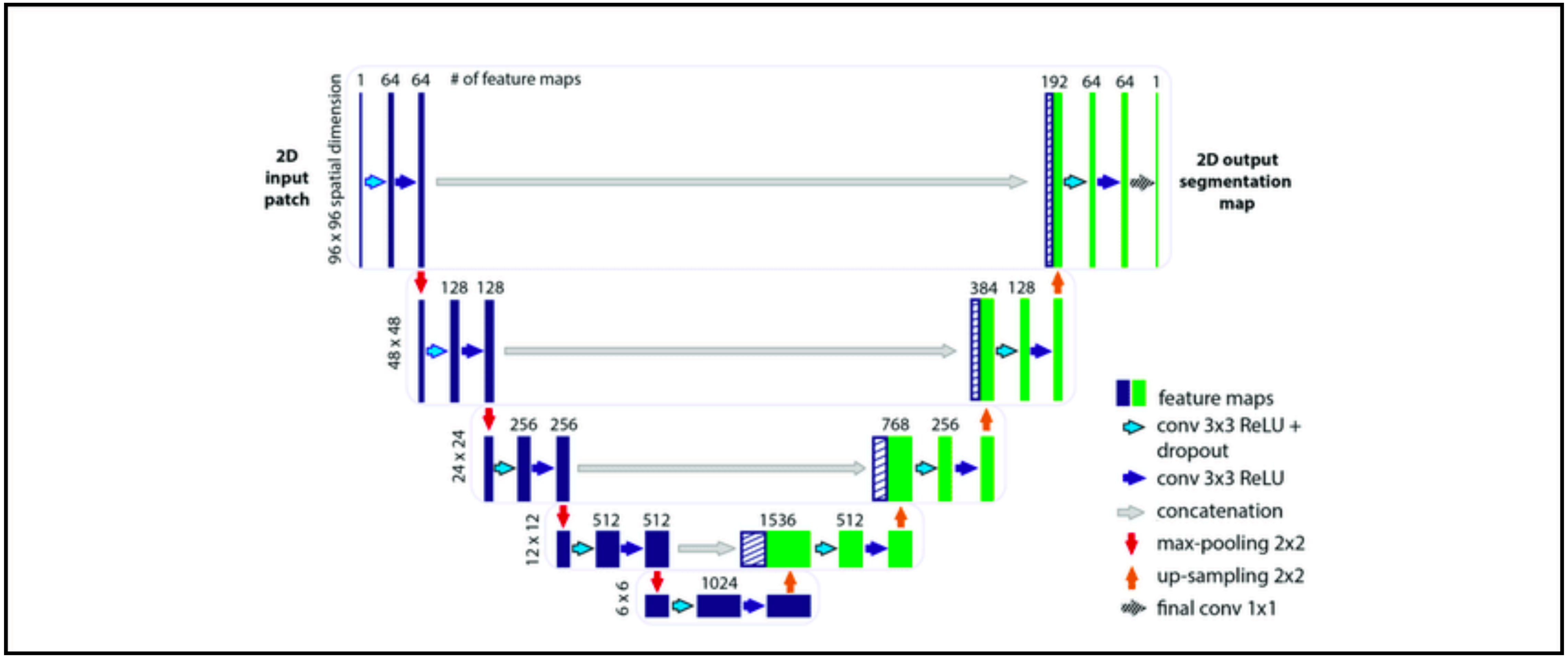
In our work, we used the following tools:

• Schindelin, J., Arganda-Carreras, I., Frise, E., Kaynig, V., Longair, M., Pietzsch, T., … Cardona, A. (2012). **Fiji**: an open-source platform for biological-image analysis. Nature Methods, 9(7), 676–682. doi:10.1038/nmeth.2019

• The MathWorks Inc. (2022). **MATLAB** Version: 23.2.0.2436196 (R2023b) Update 4, Natick, Massachusetts: The MathWorks Inc. https://www.mathworks.com

• Wolfram Research, Inc., **Mathematica**, Version 13.3, Champaign, IL (2023).

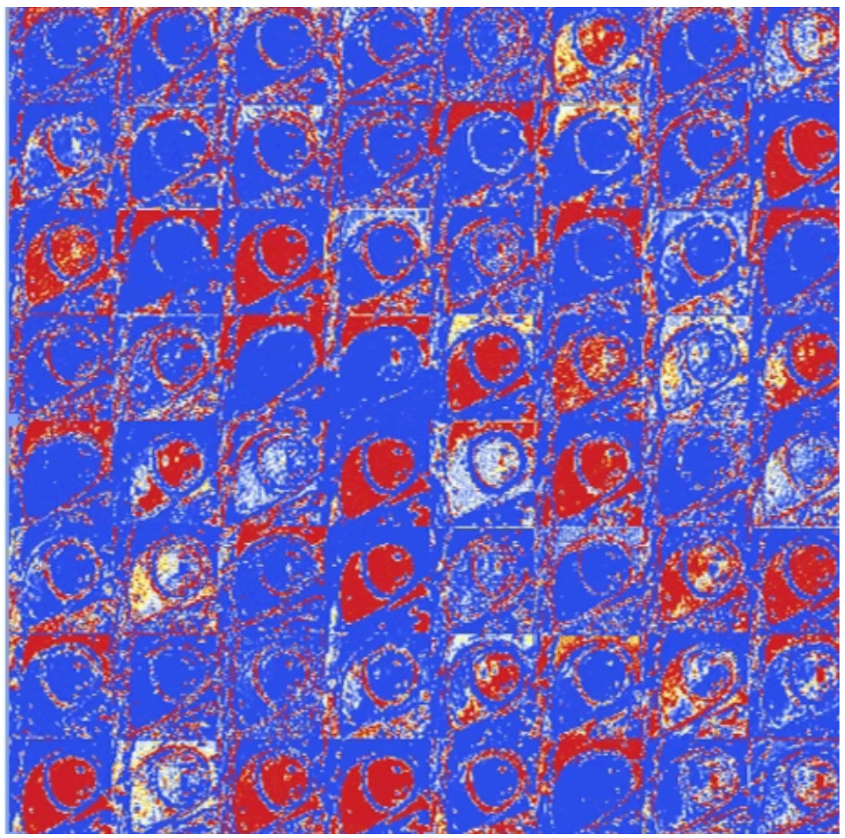
Appendix: neural networks



https://www.researchgate.net/figure/Illustration-of-the-U-net-architecture-The-figure-illustrates-the-U-net-architecture_fig2_331406702

Appendix: neural networks

Encoding layer



Decoding layer