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Mouse arterial wall imaging and analysis from synchrotron X-ray microtomography

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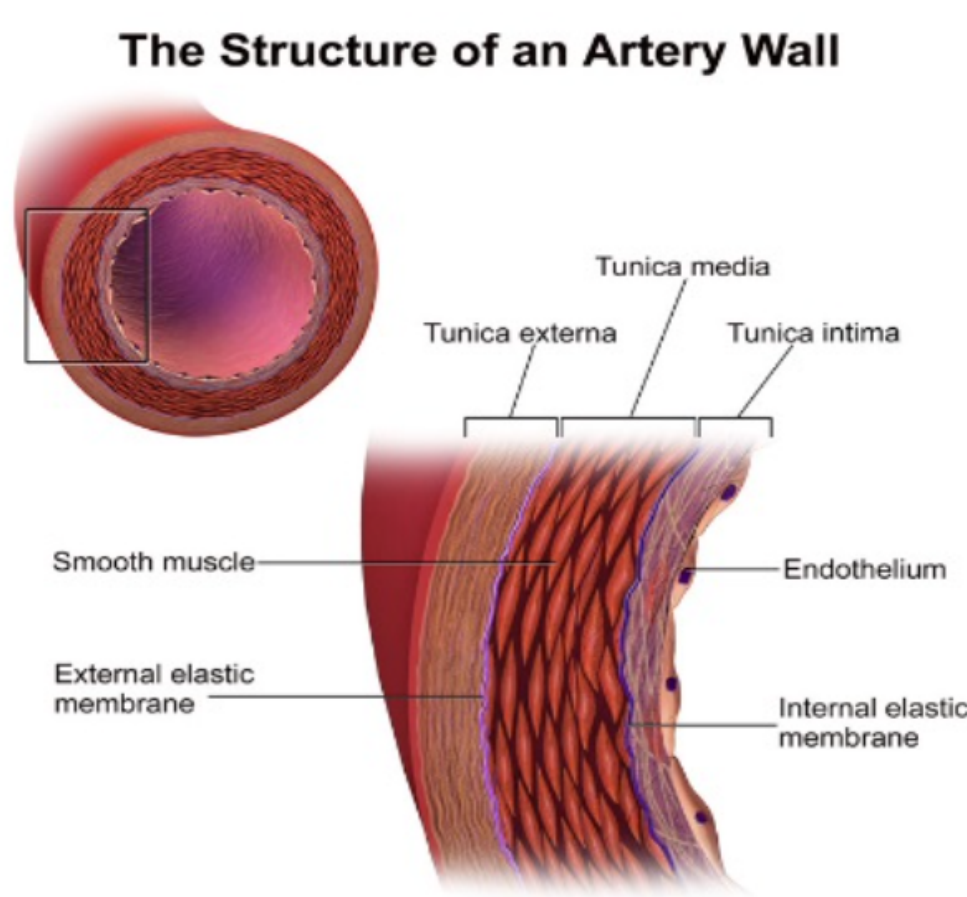
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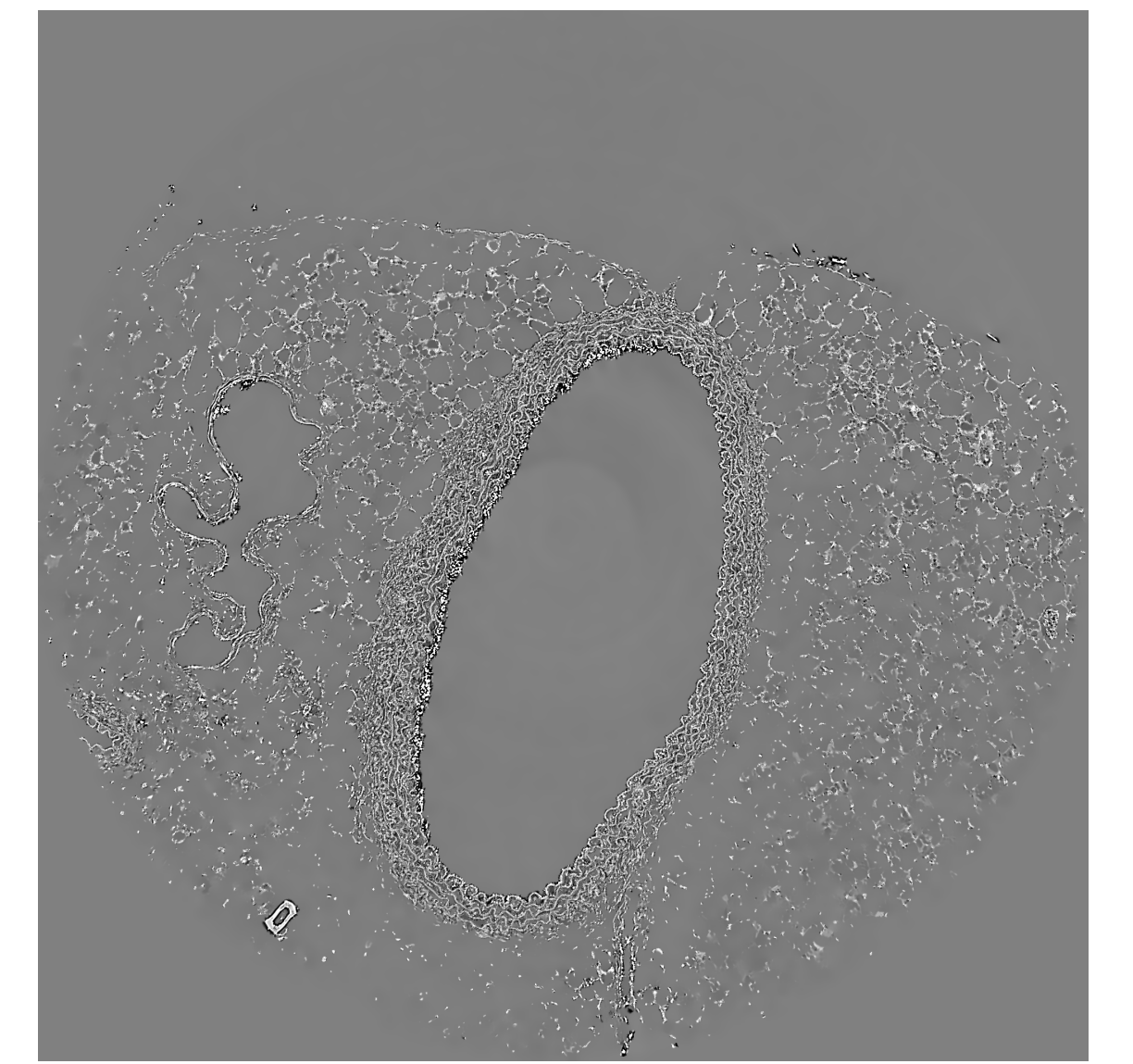


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Context



Vascular ageing is characterized by profound modifications of the large elastic arteries (mainly aorta), leading to consequences such as aneurysm formation. Age-related diseases can be precipitated by metabolic disorders, e.g. diabetes or chronic kidney diseases. Vascular diseases involve morphological changes of the arterial extracellular matrix, particularly remodelling of the elastic lamellae found in the wall. Synchrotron X-ray microtomography (μ CT) gives access to images with a micrometric resolution. In the context of vascular imaging, this allows the study of structural properties of arterial walls, even for small animals such as the mouse.



A methodological pipeline

- Preprocessing: to remove the noise and artifacts.
- Main step 1:
 - Segmentation of the lumen
 - Computation of the normal field and distance maps with respect to the lumen.
- Main step 2:
 - Deep learning-based texture classification.

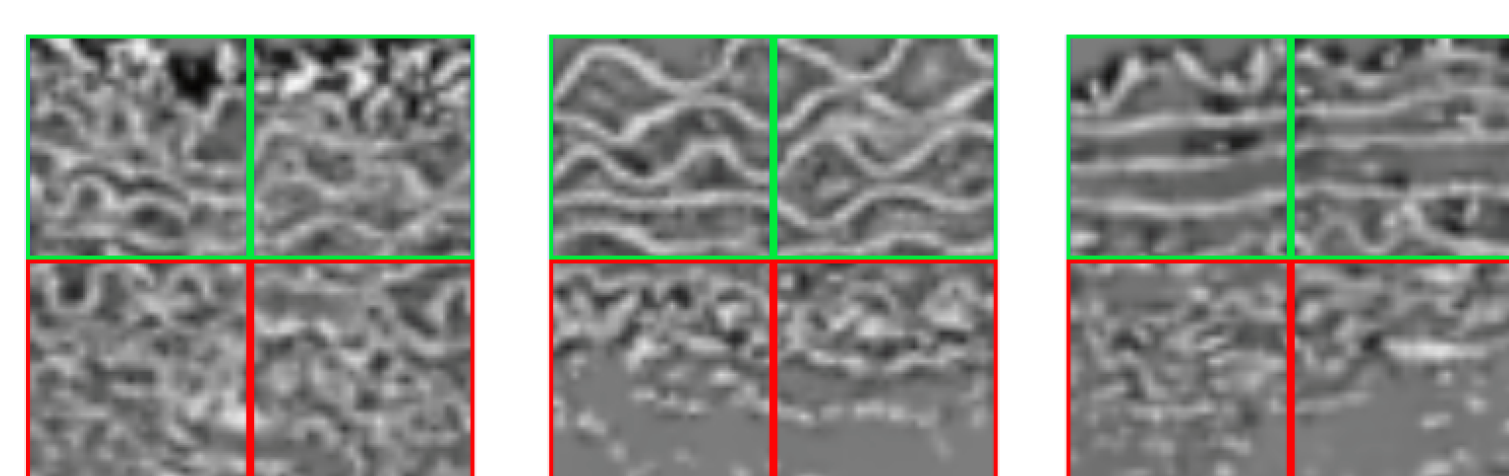
1 : Segmentation of the lumen & computation of the distance maps

- Segmentation of the lumen based on a co-occurrence texture analysis.
- Finding the contour of the lumen, which is the inner contour of the arterial wall.
- Computation of a distance map that shows the distance of a pixel to the lumen, in order to calculate a "contour line" at any distance.
- Calculating the normal vector at any point using "contour lines".

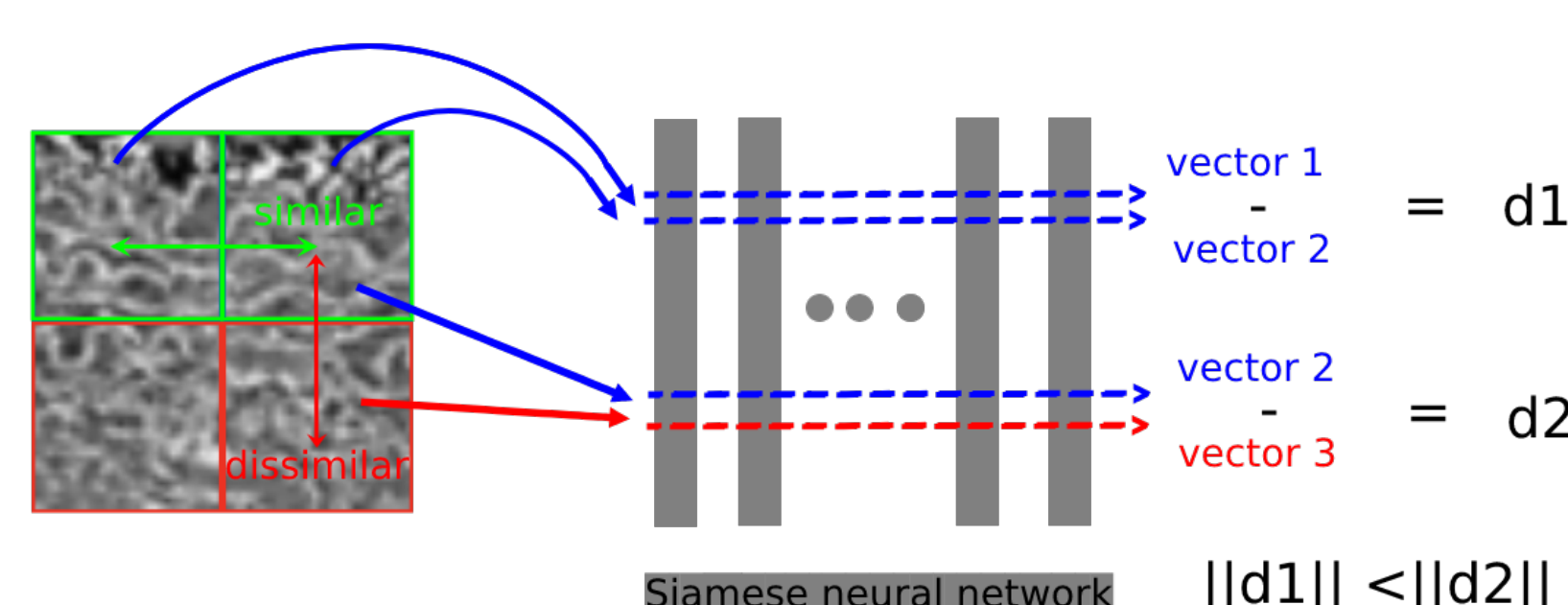


2 : Deep learning-based classification

- Rotating and cutting patches according to the calculated normal vectors.



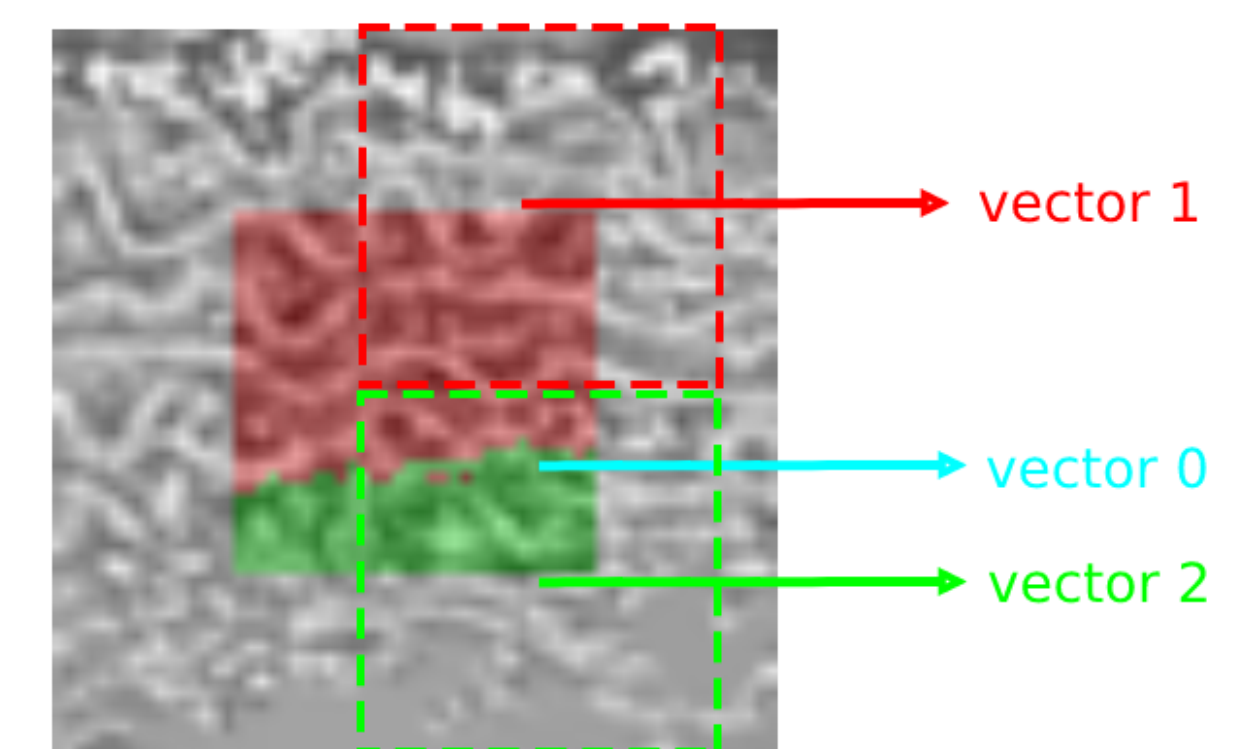
- Training a Siamese network to distinguish dissimilar sub-patches.



- Training on 1457 2D images that generate 47118 patches (20% for validation)

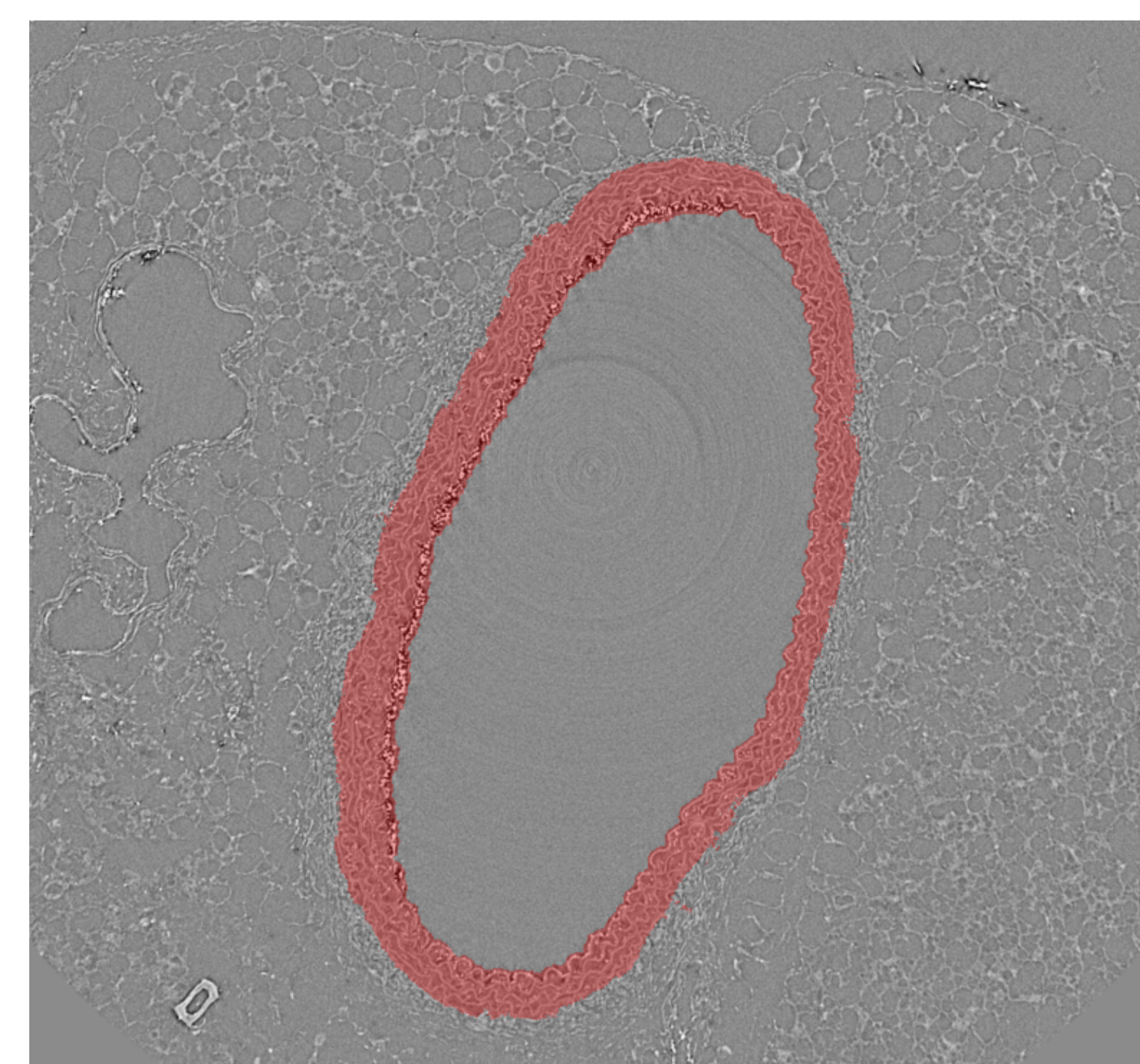
Results

- Classification at the pixel level by comparison between sub-patches.



- The Euclidean distance between *vector0* and *vector2* is smaller than the one between *vector0* and *vector1*, so the corresponding pixel is classified in the region of the surrounding tissues (the other region is that of the elastic lamellae).

- Segmentation on a whole image: extraction of the internal contour by the lumen segmentation + classification of the pixels at the border by the Siamese network.



Dice score = 0,926
(Ground truth obtained by manual annotation)

Conclusion

- Chronic cardiovascular diseases are often discovered when irreversible damage has already occurred, early identification of the very first stages of these diseases is therefore extremely important. Synchrotron imaging has shown its power to detect these very localized events with its high resolution. The proposed segmentation pipeline is a first step towards that goal, mixes conventional image processing and deep learning paradigms, and provides promising results.
- The next steps of that work will consist of improving the lumen segmentation step by reducing the parameter space to be handled and of exploring more thoroughly the deep learning part of the process.