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Vessel Extraction Using the Buckmaster-Airy Filter

Final presentation
November 23, 2015

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Outline

- Problem
- Airy function
- Buckmaster function
- Buckmaster-Airy function
- Results
- Conclusions

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Problem

- Extract vessels and other rizoma structures from biomedical images, to be clearly delimited in its filaments.
- It was necessary to obtain at first an appropriate enhancement of its filaments using filters capable to also provide smoothing and enhancement.
- Our problem consisted in finding an appropriate diffusive and coherent derivative which let us obtain a good vessel extraction using the combination of rizoma detectors with skeletonization.

Two-dimensional Airy function

$$\frac{\partial}{\partial t}P(x,y,t) = \eta_1\left(\frac{\partial^3}{\partial x^3}P(x,y,t)\right) + \eta_2\left(\frac{\partial^3}{\partial y^3}P(x,y,t)\right) \quad (1)$$

with the initial condition

$$P(x,y,0) = \delta(x-X) + \delta(y-Y) \quad (2)$$

Two-dimensional Airy function

Solving Equation (1) with the initial condition (2) and taking $\eta_1 = \eta_2 = \eta$

$$P(x,y,t) = \frac{3^{1/3} Ai\left(\frac{3^{2/3}(-x+X)}{3\sigma}\right) Ai\left(\frac{3^{2/3}(-y+Y)}{3\sigma}\right)}{3\sigma^2} \qquad (3)$$

where $\sigma^3 = \eta t$.

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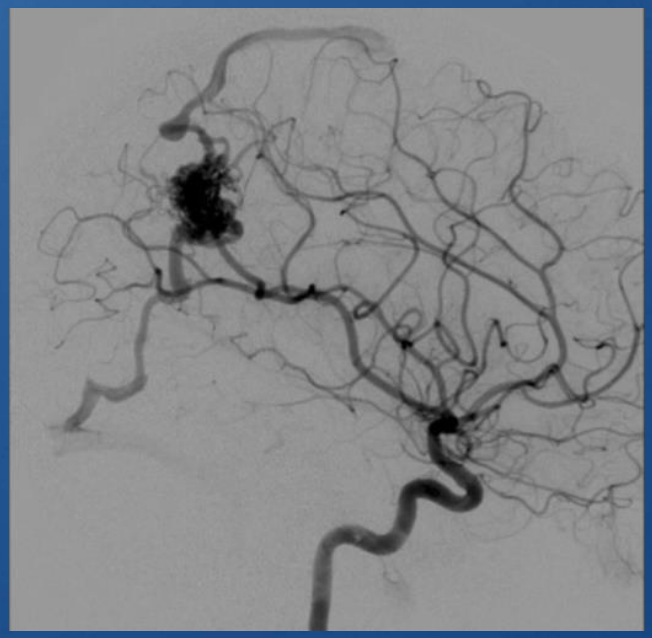
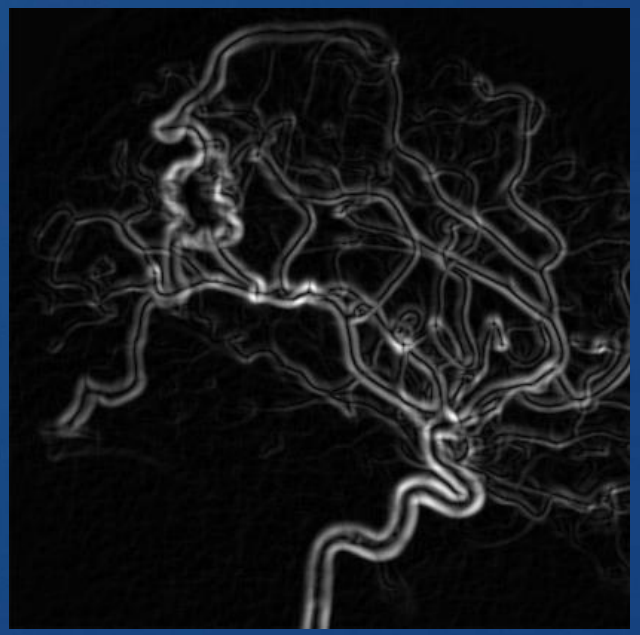
Experiment of detection of brain aneurysms



Original image



Processed image

Figure 1. Result of an experiment with the Airy filter as edge detector

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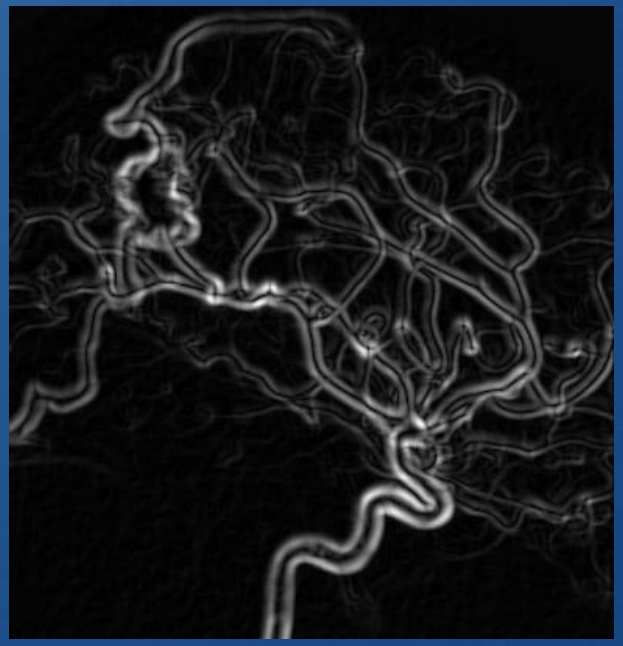
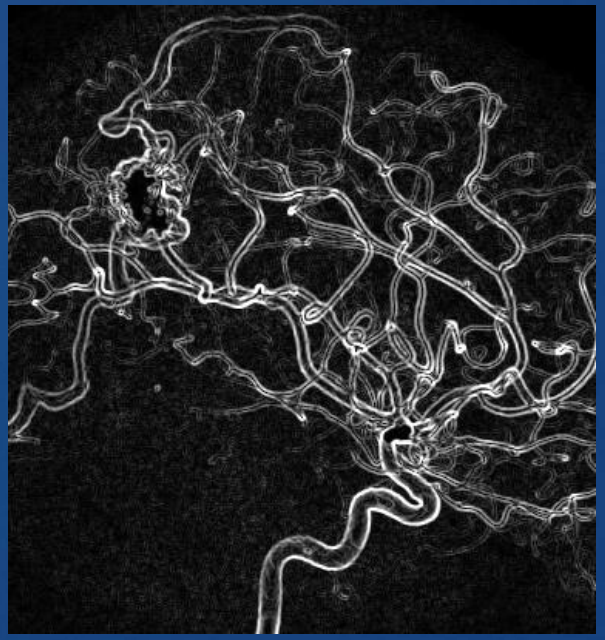


Result with Airy filter



Result with Sobel filter

Figure 2. Comparing the results of the Airy filter and the Sobel filter

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Image preprocessed with Airy filter

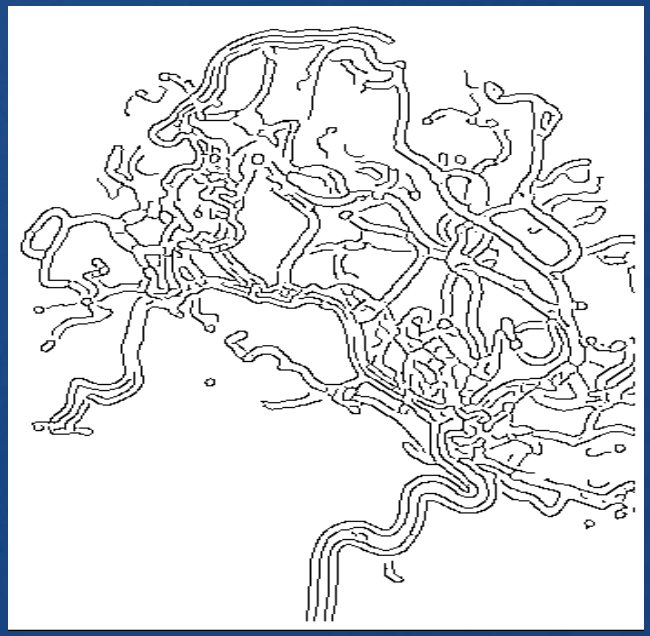

Image preprocessed with Sobel filter

Figure 3. Result from the application of the Canny edge detector to images in Figure 2.

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Image preprocessed with Airy filter

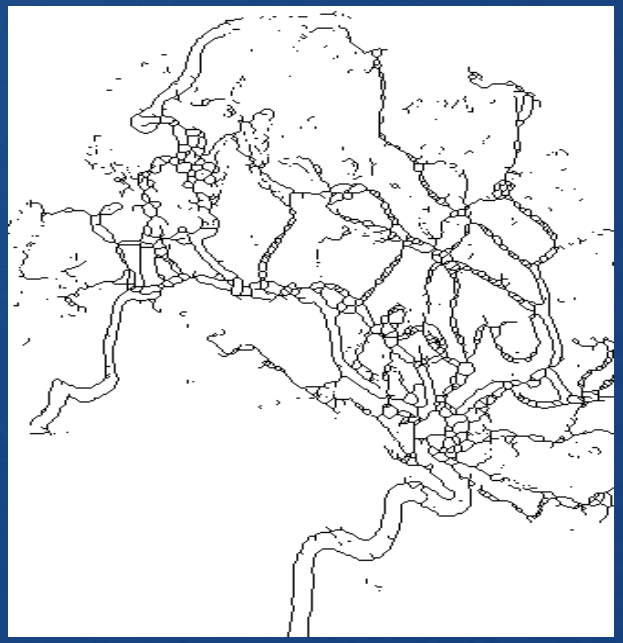

Image preprocessed with Sobel filter

Figure 4. Result from the application of skeletonization to the image in Figure 2.

Buckmaster function

$$\frac{\partial}{\partial t}u(x,y,t) = \left(\frac{\partial^2}{\partial x^2}u(x,y,t)^4\right) + \left(\frac{\partial}{\partial x}u(x,y,t)^3\right)$$
$$+ \left(\frac{\partial^2}{\partial y^2}u(x,y,t)^4\right) + \left(\frac{\partial}{\partial y}u(x,y,t)^3\right)$$

We construct a filter named here the Buckmaster-Airy filter applying the spatial operator Buckmaster to Equation 3.

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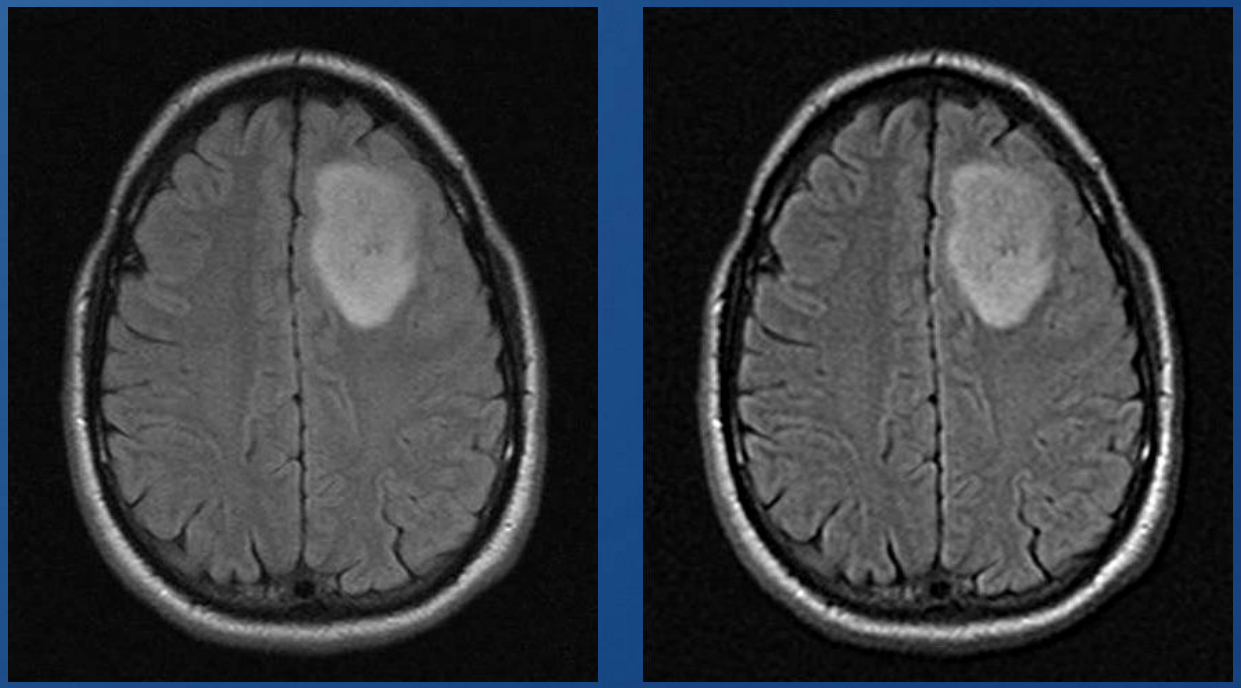
Buckmaster-Airy function

$$BA(x,y) = \frac{8}{27\sigma^{10}}\left(3^{2/3}Q^4\right) - \frac{18}{\sigma^7}\left(3^{2/3}Q^3\right)$$

$$+ \frac{4\left((-x+X)+(-y+Y)\right)}{81\sigma^{11}}\left(3^{1/3}Q^4\right)$$

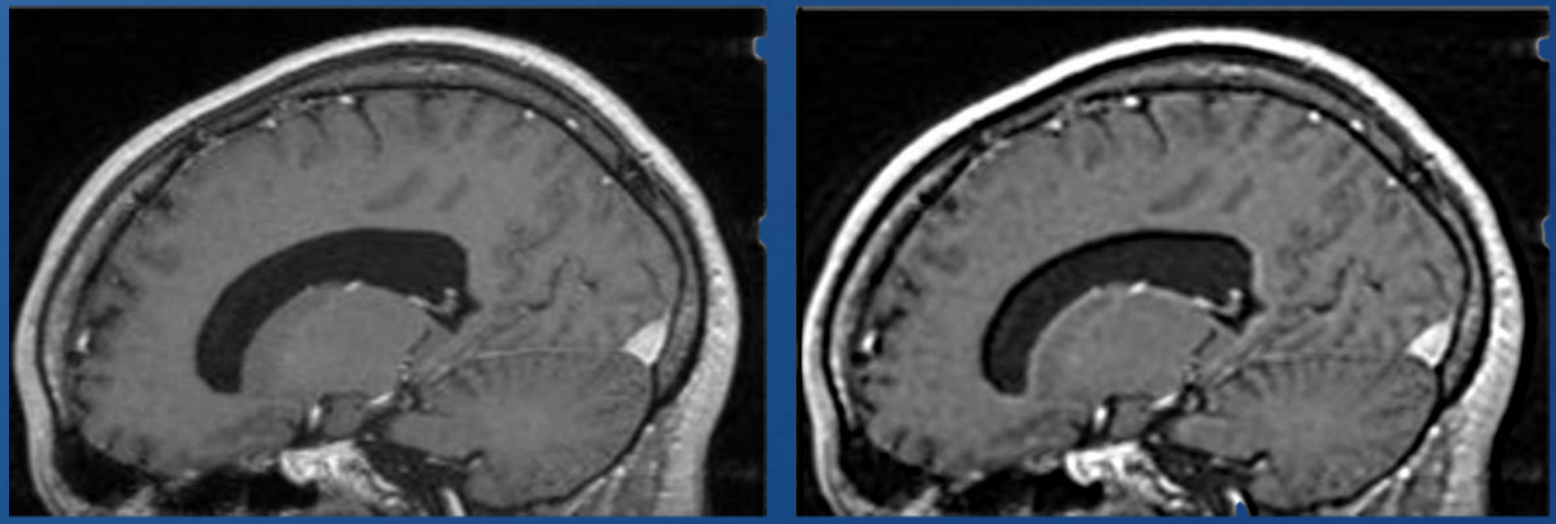
where

$$Q = Ai\left(\frac{3^{2/3}(-x+X)}{3\sigma}\right)Ai\left(\frac{3^{2/3}(-y+Y)}{3\sigma}\right)$$



Original image Processed image

Figure 5. Results of the first experiment with the BA filter.



Original image

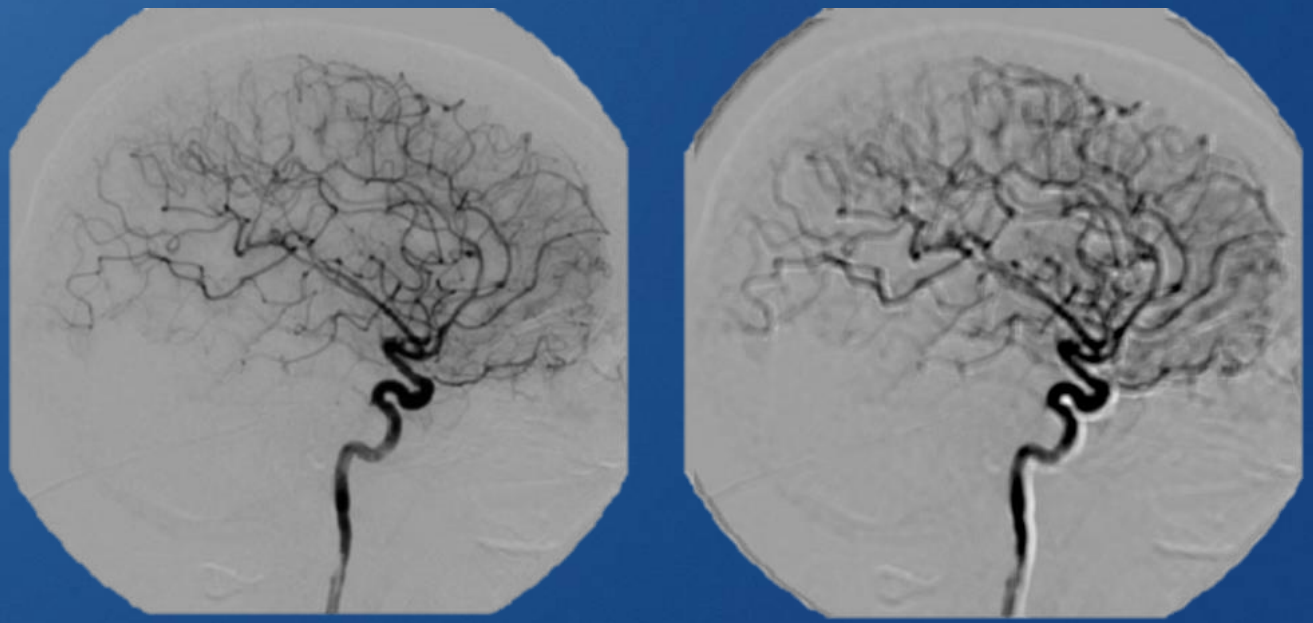
Processed image

Figure 6. Results of the second experiment with the BA filter.

Original image

Processed image

Figure 7. Results of the third experiment with the BA filter.

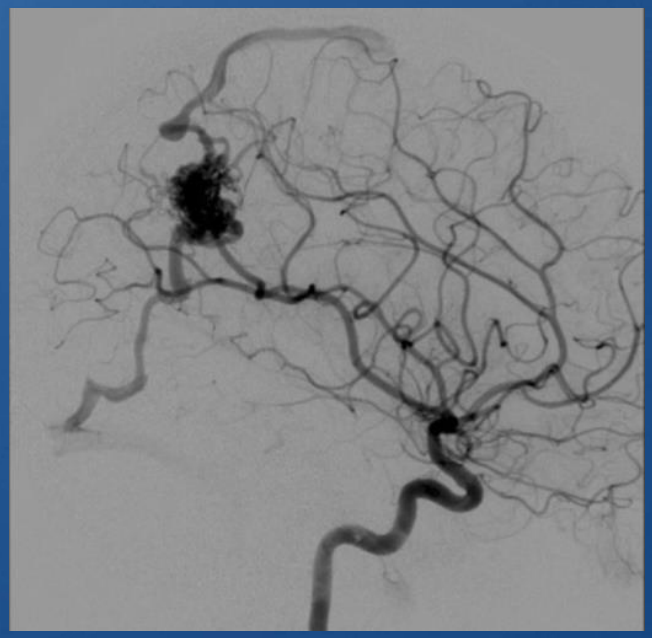


Original image

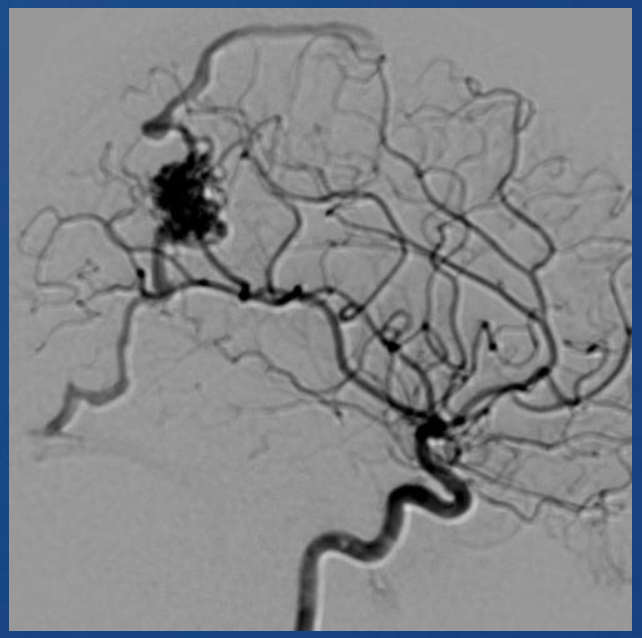
Processed image

Figure 8. Results of the fourth experiment with the BA filter.

Experiment of detection of brain aneurysms



Original image



Processed image

Figure 9. Processed angiogram of AMV with draining vein.

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Experiment of detection of brain aneurysms

Original image

Processed image

Figure 10. Skeletonization of Figure 9.

Experiment of detection of brain aneurysms

Original image

Processed image

Figure 11. Cany edge detection of Figure 9.

Experiment of detection of brain aneurysms

Original image

Processed image

Figure 12. Cany edge detection after anisotropic diffusion of Figure 9.

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Conclusions

- The Buckmaster-Airy filter is able to produce an enhancement of the dendritic structures of the image without producing alterations on the edges of the filaments.

- The combination BA filter + Anistropic diffusion + Canny filter will provide us a powerful vessel detector and extractor.

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Questions?