Image processing techniques and its impact on the computational hemodynamics of cerebral aneurysms

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ADVANCED COMPUTING

Introduction and Motivation

In **CT angiography** (CTA), a contrast material is injected into the arterial system to produce detailed images of blood vessels and tissues. CTA has become an accurate method to detect cerebral aneurysms. There are two types of CTA depending of the half-life of the contrast: Rotational has shorter half-life and Planar has longer half-life.

The relation between **hemodynamics** and **cardiovascular diseases** is still not fully understood, however fluid dynamic parameters on the vessel wall are typical correlators to disease. Fluid mechanics near the wall is critically influenced by the geometry definition.

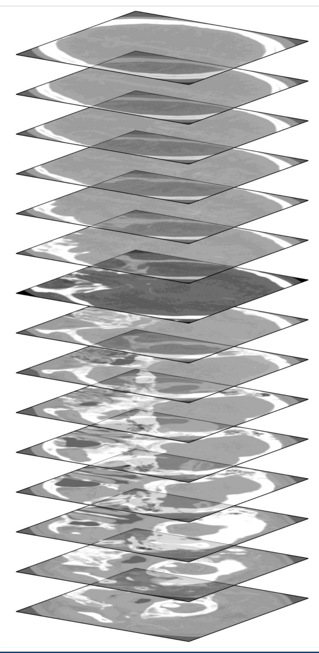


Image filtering is crucial in the preprocessing of medical images, allowing for robustness of segmentation and possibility of automatic approaches as well as on-the-fly clinical interpretation and feedback. However, care must be taken in order to chose optimal parameter that will not compromise important features

Different filtering methods, based anisotropic diffusion were chosen and compared with respect to image quality, segmentation robustness and visual aesthetics.

Optimal choice of parameters (stopping criteria and diffusion coefficient) were obtained through a minimization of both PSNR and MSE and maximization of SMSE Improvement.

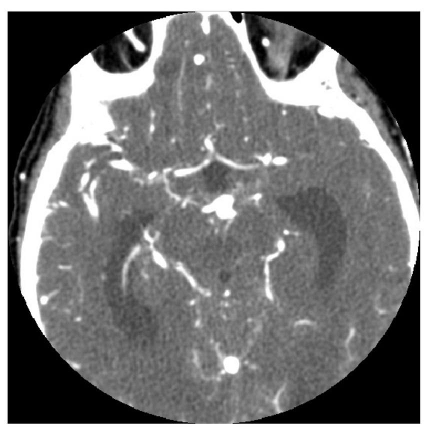
Preparation of the virtual model included selection of ROI, **segmentation**, **surface extraction** and **smoothing**.

Methods

Image Filtering (Anisotropic Diffusion)

The general non-linear (non-homogenous) diffusion process looks for the solution of:

$$\begin{cases} \dfrac{\partial I}{\partial t}(x,y,t) = \nabla.\left[c(x,y,t)\nabla I(x,y,t)\right] \\ I(x,y,t=0) = I_0(x,y) \end{cases}$$

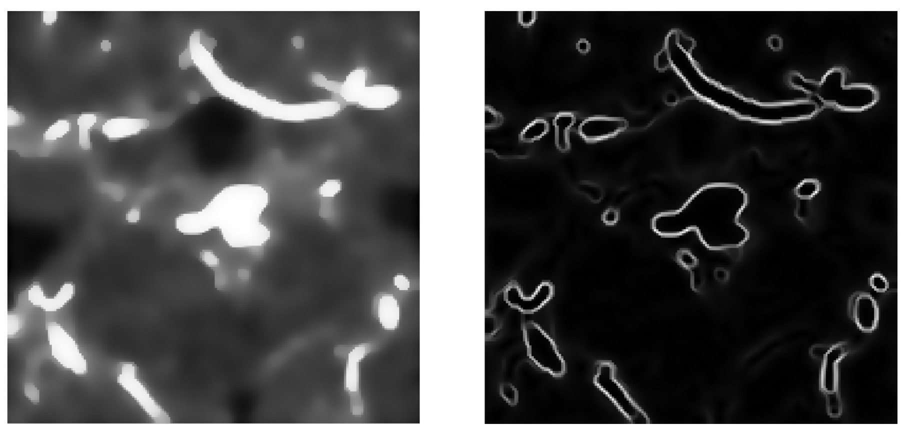


Perona-Malik Method

The diffusion coefficients are chosen to be a decreasing function of the signal gradient

$$c(x,y,t) = \frac{1}{\left(\frac{\|\nabla I(x,y,t)\|}{\beta}\right)^2}$$

Perona and Malik (1990)]{perona90} Perona, P., Malik, J. Scale-space and edge detection using anisortopic diffusion. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 12, 7 Jul 1990; 629-639.



Improved adaptive complex diffusion despeckling filter

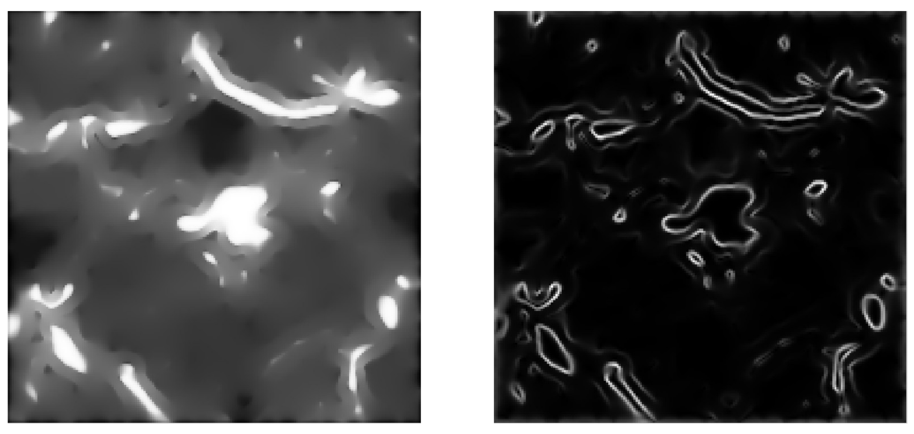
The regularisation proposed in this scheme includes an adaptive time step (Δt) and scaling factor (β).

$$c(x,y,t) = \frac{1}{1+\left(\frac{\|\Delta I(x,y,t)\|}{\beta}\right)^2} \Leftrightarrow c(x,y,t) = \frac{\exp(i\theta)}{1+\left(\frac{\mathrm{Im}(I)}{\beta\theta}\right)^2}$$

with

$$\beta = \beta_{MAX} + (\beta_{MIN} - \beta_{MAX})\frac{g-\min(g)}{\max(g)-\min(g)} \qquad \Delta t^{(n)} = \frac{1}{\alpha}\left[a + b\exp\left\{-\max\left(\frac{\left|\frac{\partial I^{(n)}}{\partial t}\right|}{I^{(n)}}\right)\right\}\right]$$

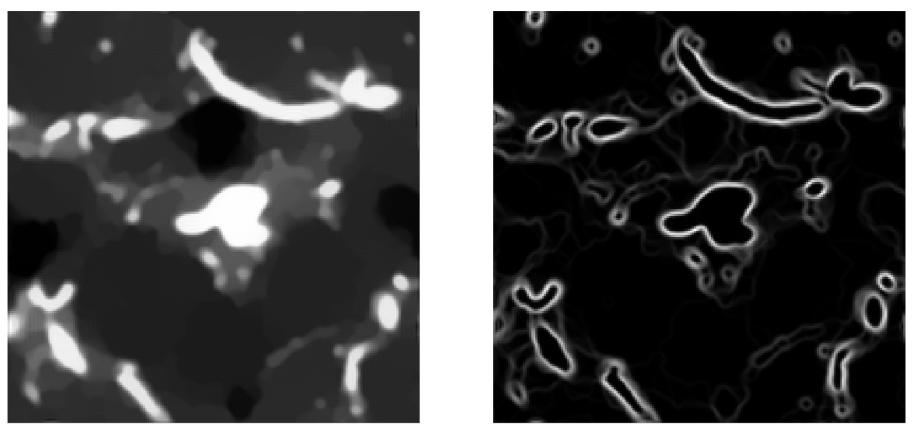
Bernardes, R.,Maduro, C., Serranho, P.,Araújo, A.,Barbeiro, S., Cunha-Vaz, J., Improved adaptive complex diffusion despeckling filter,*Opt. Express* 18, 2010, 24048-24059



Regularization of Backward and Forward Anisotropic Diffusion

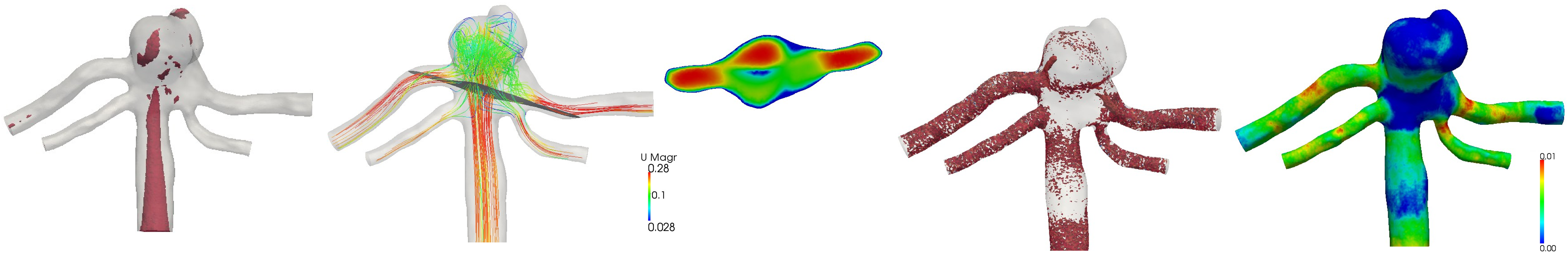
$$c(x,y,t) = \frac{1}{\left(\frac{\|\nabla^{1-\varepsilon} I(x,y,t)\|}{\beta}\right)^2}$$

Guidotti, P., Longo, K. Two enhanced fourth order diffusion models for image denoising *Journal of Mathematical Imaging and Vision*, 40(2), 188-198 (2011)

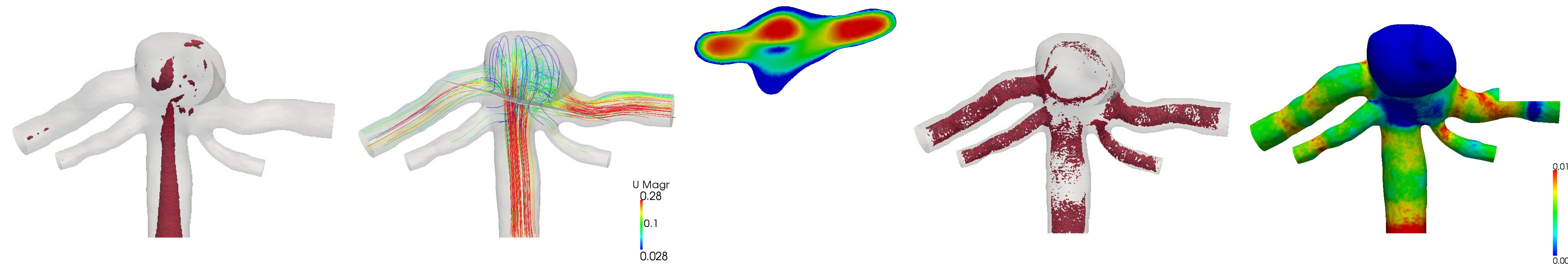


Results

Original



RBAF Geometry



μ = 0.004 PaS
(Bird Carreau Model)
Shear rate < 100 s⁻¹

Velocity (streamlines)

Q = 10000

WSS (Pa)

Conclusions

Results indicate that image processing and especially filtering can substantially alter the quality of the image and has great impact on the CFD. Nevertheless, care must be taken to choose appropriate and robust schemes. Further work will be to extend the filtering techniques described to 3 dimensions.