A non-local Chan-Vese model for sparse, tubular object segmentation

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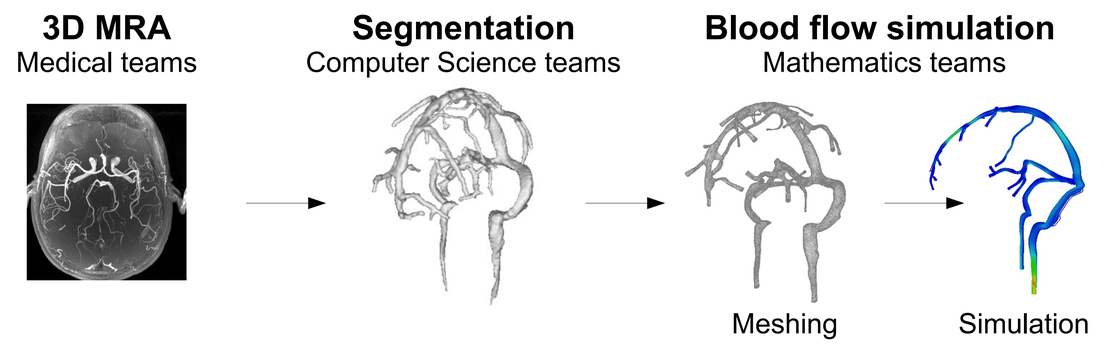
Context: ANR project VivaBrain[1]



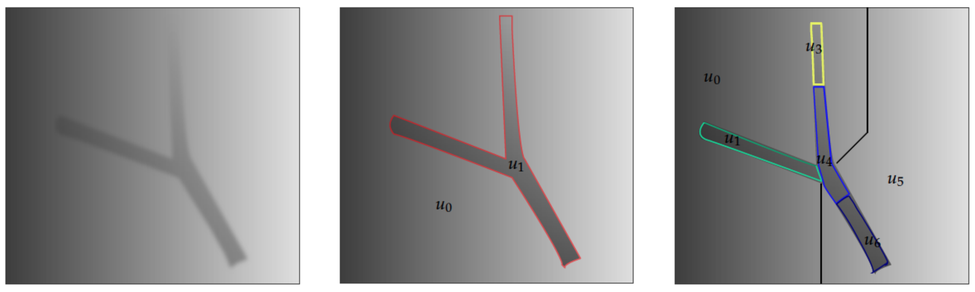
Segmentation: Angiographic Images

Difficulties: To extract some small tabular structures of lower intensity in the presence of:

- low contrast
- noise
- background/foreground inhomogeneity
- sparse object

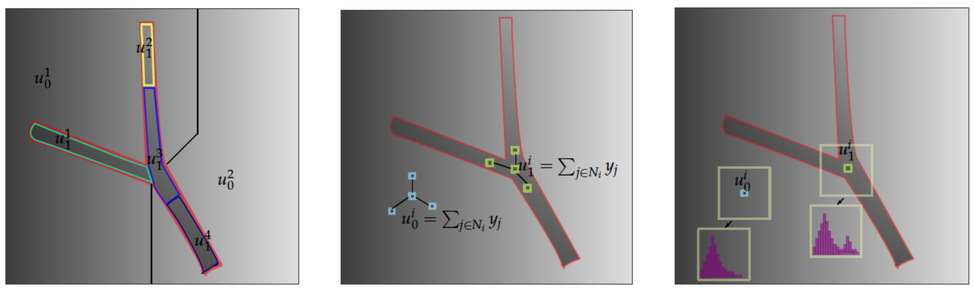
Inhomogeneity of object and background

u_0 = background and u_1 = intensity inside object



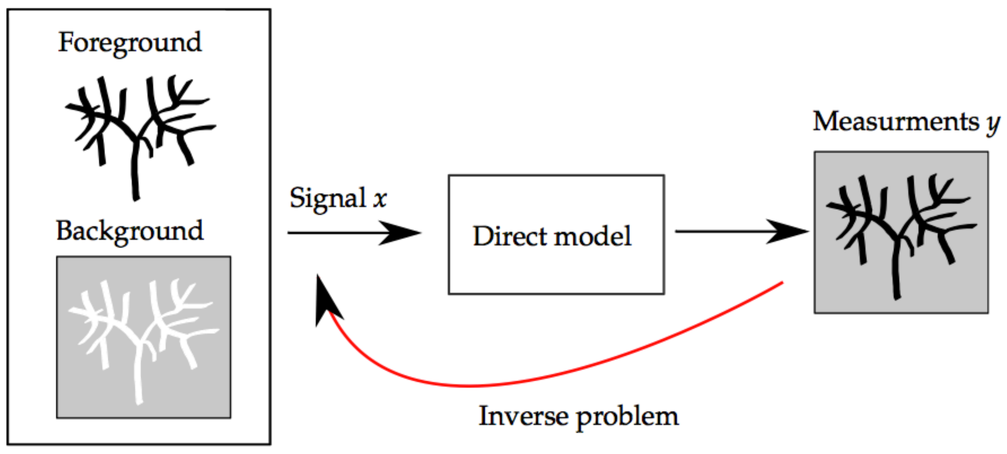
Original 2-phase image | Chan-Vese fitting term [Tai *et al.*, 2013] [Gooya *et al.*, 2007] | Multiple image segmentation [Tai *et al.*, 2013]

Non-local 2-phase segmentation



K-means clustering [Tao and Tai, 2011] | Non-local means centroid [Caldairou *et al.*, 2011] | Statistical centroid Ours work

Problem formulation



Problem: Find an optimal partition $(\mathbb{X}_0, \mathbb{X}_1)$ of $\mathbb{X}$ such that

$$\forall i \in \mathbb{X} \begin{cases} i \in \mathbb{X}_0 & \text{if } x_i < \tau \\ i \in \mathbb{X}_1 & \text{otherwise} \end{cases}$$

where $\mathbb{X}$ is the support, $\mathbb{X}_0$ the background and $\mathbb{X}_1$ the target signal.

Minimization problem: Find $\underset{x}{\operatorname{argmin}}\, f(x)$ where

$$f(x) = \Phi(x) + \sum_{r=1}^{R} \psi_r(V_r x) + \psi_{ROI}(x)$$

- $\Phi(x)$ a sum of data fidelity term

$$\Phi(x) = \sum_{i \in \mathbb{X}} \varphi_0(x_i)\, \phi(y_i - u_i^1) + \sum_{i \in \mathbb{X}} \varphi_1(x_i - 1)\, \phi(y_i - u_i^0)$$

  with u_i^0 =Quantiles$(\chi(\omega_i), \delta)$ and u_i^1 =Quantiles$(\chi(\omega_i), 1-\delta)$
- $\sum_{r=1}^{R} \psi_r(V_r x)$ a hybrid regularization term
- $\psi_{ROI}(x)$ an indicator function of a convex subset of $[0,1]^N$

Optimization approach

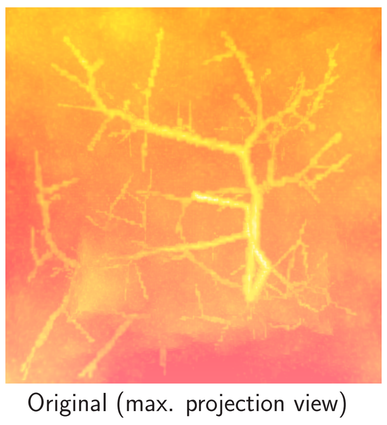
Let $f \in \Gamma_0(\mathbb{R}^N)$ (lower semi-continuous proper convex function). For every $x \in \mathbb{R}^N$, the minimization problem consists of finding

$$\operatorname{prox}_f(x) := \underset{y \in \mathbb{R}^N}{\operatorname{argmin}}\, f(y) + \frac{1}{2}\|x - y\|^2$$

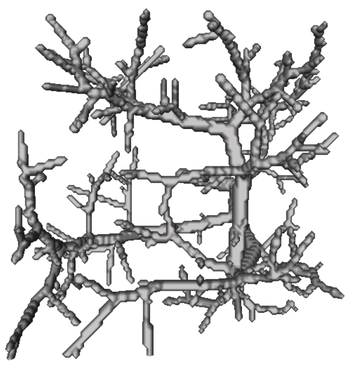
Proximal method: Primal-dual algorithm [Combettes and Pesquet, 2012]

- convergence guaranteed
- incorporating any Lipschitz differentiable function φ and arbitrary linear operators $V_r x$

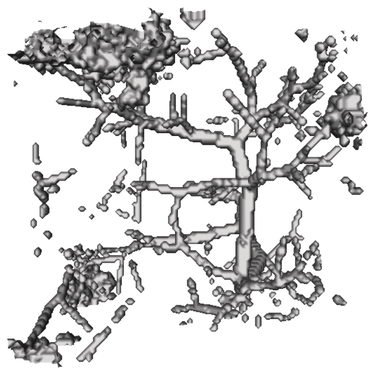
Experiments: VascuSynth and DRIVE database results



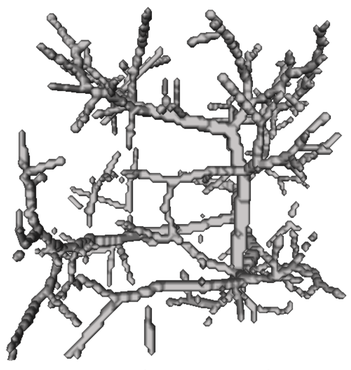
Original (max. projection view)



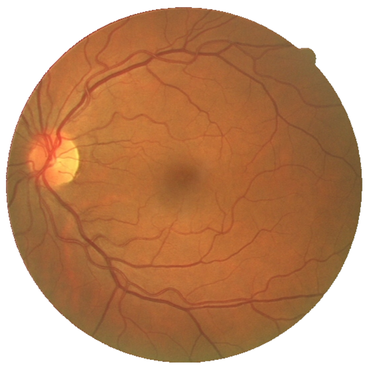
Ground truth



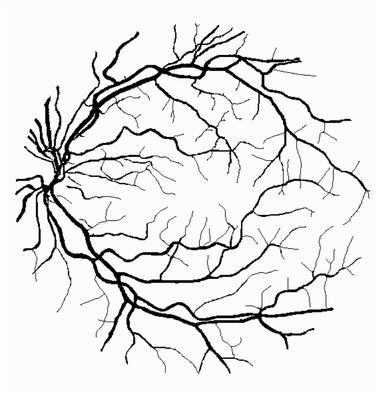
Piecewise const. (0.753,0.984)



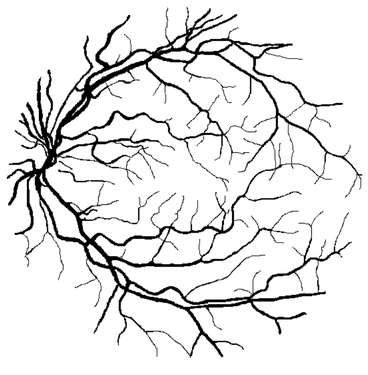
Ours (0.853,1.000)



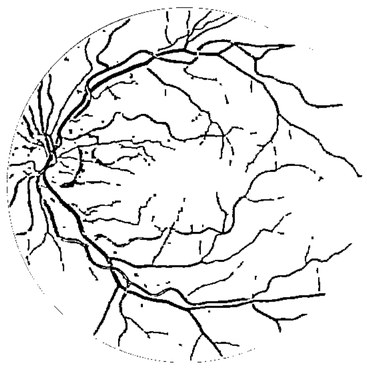
Original



Ground truth



Human (0.797,0.972)



Ours (0.800,0.936)

Drive database results (20 images)

TPR - sensitivity - and SPC - specificity -

	Human	Staal	Niemeijer	Perez	Fraz	Ours
TPR	0.780	0.719	0.679	0.709	0.715	0.725
SPC	0.972	0.977	0.980	0.949	0.976	0.925

Conclusions

Statistical non-local centroids:

- simplicity
- well adapted to angiographic images

Primal-dual algorithm:

- high flexibility
- robust to computational errors

Future work:

- efficient implementation of the proposed algorithm
- add connectivity and tubularity priors
- variational framework for multi-scale segmentation

[1] http://vivabrain.fr

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