Level set segmentation of extraocular muscles in MRI images for thyroid-associated-ophtalmopathy diagnosis

A. Histace[1], C. Portefaix[2], B. Matuszewski[3], Y. Zhang[3]

[1] ETIS, CNRS, ENSEA University Cergy-Pontoise F-95000 Cergy-Pontoise
aymeric.histace@ensea.fr

[2] CHU de Reims, 45 rue Cognacq Jay, F-51100 Reims

[3] Applied Digital Signal and Image Processing Research Centre University of Central Lancashire, Preston, U.K.

Purpose: In thyroid associated ophtalmopathy (TAO), the extraocular muscles are frequently enlarged. Classically, pharmacological treatment aimed at reducing this muscle enlargement can be monitored by measuring the size of the extraocular muscles from MRI acquisitions. Some methods have already been proposed in literature to automatically segment these muscles using dynamic contours. However, in order to have accurate and robust segmentation, the dynamic contours have to be initialized close from final result which remains a significant drawback for a fast and accessible application. In this contribution, we propose to tackle this segmentation by using level-set approach. The choice of this methodology choice allows clinicians to perform a fast and precise automatic segmentation with no need for complicated initialization constrains.

Methods:

Patient images acquisition: For our study, a typical coronal head sequence acquisition with a 512×512 matrix was performed on a Philips 3T MRI scanner (Achieva). 3 volunteers (1 healthy, 2 with TAO) were scanned using an eight channel sense head coil which allows up parallel imaging. A T1 acquisition (TR=425ms, TE=10ms) was used to image both orbits simultaneously. The images (dicom format) were transferred offline to a workstation for analysis.

Image processing: The segmentation is performed using a region-based level-set method. In contrast with other types of active contours (particle or parametric models), the level-set approach has significant advantages which include (1) the topological changes of the contour can be easily handled; (2) the concept and numerical implementation can be easily adapted to solve problems in arbitrary dimensional spaces; (3) the areas inside and outside an active contour can be easily determined; (4) the initial active contour curve does not need to be close to the target object. Theoretically speaking, the evolution law associated with the active contour in the proposed framework is based on an iterative minimization of the functional given by:

$$\varepsilon(\phi) = -\alpha \int_{\Omega} (I-\mu) H(\phi) d\Omega + \beta \int_{\Omega} g \left|\nabla H(\phi)\right| d\Omega ,$$

where I is the image to be segmented, H the classical Heaviside function, $g = g(|\nabla I|)$ is boundary feature map related to the image gradient ($|\nabla I|$), Ω represents the image domain and α and β are predefined weights to balance two terms. The first term of the functional is region based where μ is a predefined parameter indicating an expected lower bound of the gray-level of the target object. In our case, we make the assumption that the target object has relatively high gray-level values. If that is not the case, simple gray-level re--mapping can be applied to achieve it. It can be seen that the first term encourages the contours to enclose the regions with gray-levels greater than μ. The global minimum of this term alone is given by boundaries of the binary image resulting from simple thresholding of the image I with threshold μ. The second term of the functional is the geodesic active contour functional specified in the level-set formulation. The role of this term is to encourage the contours to attach to the areas with high image gradients. For the application described here, this term not work directly on classical image gradient (which is too noisy) but on gradient computed from an adaptive binarisation of *I*, followed by a morphological opening. This preprocess allows us to generate better gradient attractor for the level-set approach.

Image segmentation: The extraocular muscles segmentation is divided into 3 main steps: (1) segmentation of the whole ocular globes (left and right), (2) segmentation of the fat of the ocular globes, and (3) segmentation of the extraocular muscles. Initialization is performed manually by clicking near the center of ocular globes (left or right). The same algorithm is used in each step but with different values of α and β: for step (1), a strong constrain on the shape is imposed in order to avoid topological changes during the contour evolution to the boundaries of the ocular globe; for step (2) this strong shape constrain is not being used and as a consequence topological changes can occur allowing segmentation of optical nerve and extraocular muscles; for step (3), same parameterization as for step (2) is performed, but with an initialization which avoids the optical nerve. For each of this segmentation step a corresponding binary mask is generated. This makes possible quantitative analysis of the segmented data. More precisely, muscle surface, fat surface, and orbit surface can be quantified and compared.

Results: Fig. 1 shows segmentation results obtained for a TAO patient whereas Fig. 2 shows the corresponding binary masks used for quantitative evaluation.

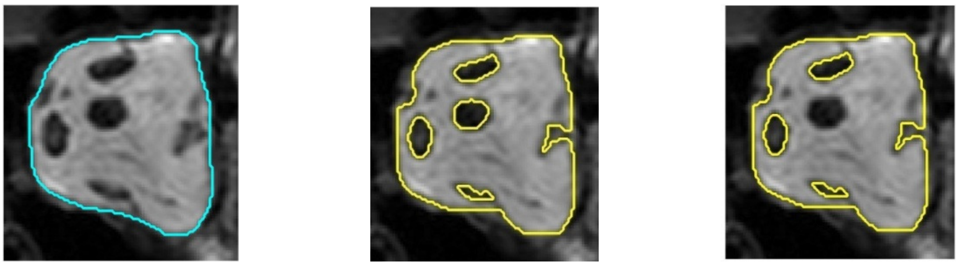

Fig. 1 Example of segmentation obtained on the left ocular globe of a TAO patient. Left image shows segmentation results obtained for step (1), middle image for step (2) and right image for step (3).

Fig. 2 Segmentation masks. Images from left to right permit quantitative assessment of whole ocular surface, fat tissue, and muscle surface.

Computation time is very fast: only a few seconds (about 5 seconds including initialization step) are needed to perform the whole segmentation per ocular globe on an Intel® Core Duo (2.2Ghz, 2Go of RAM) equipped with Matlab R2008®.

Conclusion: In this abstract, we present, as an initial study on automatic method for extraction of extraocular muscle using level-sets technique. The proposed method is fast, and easy to initialize (a simple click in the center of the ocular globe is needed). The initial segmentation results have been considered very satisfying by experts in that field. At the moment, more patients are going to be scanned in order to give a statistical meaning to future quantification results. A comparison with ground-truth quantification is also foreseen as a study of reproducibility and robustness.

Acknowledgements: The work done in this paper has been supported by the ECSON project (EPSRC grant No. EP/F013698/1, www.ecson.org) and the CHU of Reims (France).