

Minimum Intensity Snake Algorithm (MISA) for segmenting brain tissues in MR TBE images

Eleonora Maggioni^{1,2}, Mauro Costagli^{2,3}, Gianluigi Reni⁴, Anna Maria Bianchi¹, and Michela Tosetti³

¹Department of Electronics Information and Bioengineering, Politecnico di Milano, Milano, Italy, ²IMAGO7 Research Center, Pisa, Pisa, Italy, ³IRCCS Stella Maris Scientific Institute, Pisa, Pisa, Italy, ⁴Bioengineering Lab, Scientific Institute IRCCS E.Medea, Bosisio Parini, Lecco, Italy

Target Audience: Researchers and clinicians interested in brain morphometry and segmentation.

Purpose: This contribution introduces a new algorithm for the extraction of minimum intensity curves within images. It was specifically developed for detecting brain tissue interfaces in MR images acquired with the Inversion Recovery (IR) Tissue Border Enhancement (TBE)¹ technique. Brain morphometry often relies on T1-weighted or T2-weighted structural images, which are segmented by algorithms that assign to each voxel a tissue label on the basis of the image intensity histogram. These techniques are generally successful, however they may fail when applied to images acquired on ultra-high field systems, where the employed radiofrequency wavelength is comparable to the size of the Field of View, and therefore images exhibit undesired variations in intensity and tissue contrast^{2,3,4}. The recently introduced TBE technique is an IR sequence that enhances the interfaces between two structures of interest (Fig.1), and it appears to be a valuable tool in both basic research and clinical applications for highlighting anatomical structures that are not clearly visible with other acquisition techniques. In TBE, the Time of Inversion (TI) is chosen in a way that the longitudinal magnetization of two tissues has equal magnitude but opposite sign, thereby allowing the immediate visualization of the border between them. The TBE technique can be applied both at standard (1.5T) and ultra-high (7T) field; it can be used to identify small structures and to extract the borders between Gray Matter (GM) and White Matter (WM), or between GM and CerebroSpinalFluid (CSF). The automatic segmentation of tissues in TBE cannot rely on the most common intensity-based algorithms: therefore we developed a new method, the Minimum Intensity Snake Algorithm (MISA), which extracts tissue borders by following minimum intensity lines within the image.

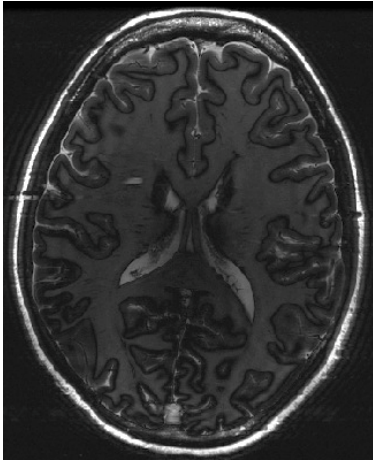


Figure 1. Original TBE image

and edges connect adjacent voxels; the weight of each edge is given by the mean value of voxel intensities. The curve with minimum intensity is extracted by using the Dijkstra's algorithm⁵, which calculates all the shortest paths from a node to any other node reachable from it. The shortest paths going from the starting central node to each of the nodes at the border of the square are compared; then, the border node associated to the path with minimum total weight is chosen as ending node of the iteration and the corresponding path is added to the curve. The ending voxel of each iteration becomes the starting voxel of the next iteration, around which a new graph is constructed. Four consecutive iterations of the algorithm are shown in Fig.2, together with the result over an image portion. Some constraints were introduced to guarantee a coarse regularity of the resulting curve: to avoid curve overlapping, the previously selected voxels are excluded from the considered paths, together with their immediate neighborhood. Unless the

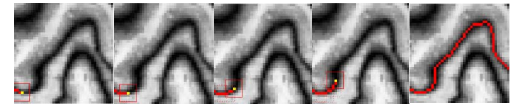


Figure 2. Performance of the algorithm over four consecutive iterations and in the image portion.

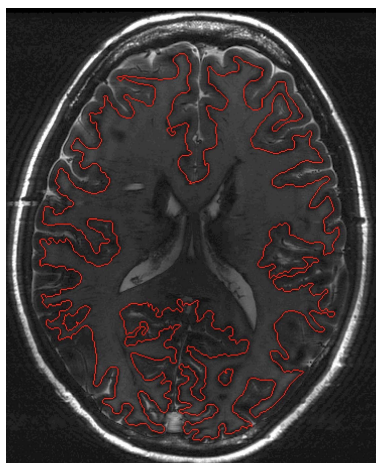


Figure 3. Borders between GM and WM identified by MISA

user chooses an ending point, the curve is forced to return to the starting point, i.e. the one initially selected by the user. In image portions affected by significant intensity inhomogeneities, the minimum intensity path may not correspond to the actual tissue border; in this case the user marks the point where the processing should be resumed, allowing the algorithm to take a different path. By default, the iterations are performed in blocks (default is n=300); the intermediate results of each block are displayed to the user, who can inspect the algorithm performance.

Results: The borders extracted by MISA on one TBE representative image are shown in Fig.3. The slice was recorded from a patient using a GE MR950 7.0 T system (GE Healthcare, Milwaukee, WI, USA) equipped with a 2-channel transmit / 32-channel receive coil (Nova Medical, Wilmington, MA, USA). The FastSE-IR TBE sequence parameters were the following: Repetition Time (TR) = 4875ms, Echo Train Length = 9, effective Echo Time (TE) = 8ms, Bandwidth (BW) = 62.5kHz, Field of View (FOV) = 220x220 mm², slice thickness = 2 mm, matrix size = 512x512. In this protocol, the optimal TI for enhancement of GM/WM border was 700ms. In this image, MISA correctly extracted the main WM borders, together with the smaller WM portions.

Discussion and conclusions: In this study we presented an algorithm for the extraction of curves of minimum intensity within an image. The new method was specifically developed to process brain MR images acquired with the TBE technique, with the aim of extracting a singular thickness border between two tissues of interest. The new algorithm provided promising results that satisfy the requirements of further quantitative analysis. The method is still under development to minimize its sensitivity to image intensity variations, maximize its performance and reduce user's intervention.

References:

- ¹ Costagli M. et al., Tissue Border Enhancement by Inversion Recovery Acquisition, *Proc. ISMRM 2013*
- ² Vaughan J.T. et al., 7T vs. 4T: RF power, homogeneity, and signal-to-noise comparison in head images, *Magnetic Resonance in Medicine 2001*
- ³ Van de Moortele P. F. et al.: B₁ destructive interferences and spatial phase patterns at 7 T with a head transceiver array coil, *Magnetic Resonance in Medicine 2005*
- ⁴ Belaroussi B. et al., Intensity non-uniformity correction in MRI: existing methods and their validation, *Medical Image Analysis 2006*
- ⁵ Dijkstra E.W., A note on two problems in connexion with graphs, *Numerische Mathematik 1959*.