Automated phase-based segmentation of the cerebral cortex in 7T MR images of the elderly

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INTRODUCTION: The cerebral cortex has become an area of great interest for neuro-radiologists since its geometry provides relevant information about the disease stage in various forms of dementia and iron deposition related to Alzheimer's Disease (AD) [1]. Most automated cortical segmentation methods involve the use of T1 magnitude images, which show good GM/WM contrast [2]. GM/WM contrast is however decreased in T2* images, especially in the elderly population as shown in Figure 1. This low contrast seriously hampers the efficiency and accuracy of magnitude-based methods. Recent advances in high field MR have increased the use of phase information, which is very sensitive to small differences in tissue susceptibility [3] and appears not to suffer as much from the reduced contrast shown in magnitude images. The purpose of this work was to investigate segmentation of the cortex in low GM/WM contrast data by combining magnitude and phase information of T2*-weighted scans at 7T.

METHODS:

Segmentation of the outer cortical surface; The outer cortical surface was segmented based on magnitude images. A k-means clustering algorithm was used with 4 different classes, corresponding to dark (background and bone), bright (outer CSF) and medium (2 classes, WM/GM/CSF) grayscale values.

Segmentation of the GM/WM interface: The GM/WM interface was determined based on phase data with the hypothesis that cortical thickness can be considered constant as a first approximation. Normals to the detected external contour were extracted and concatenated. Subsequently a minimum cost approach was used to determine the best contour fitting of a cost function based on the local maximum phase gradient norm. The cost function was designed so that the influence of smooth local variations as well as phase wraps was removed. An example of GM/WM interface segmentation can be seen in Figure 2.

In Vivo Studies: The phase-based cortical segmentation algorithm was evaluated on in vivo studies performed on elderly patients (n=4, mean age=79.25 yrs). A high resolution T2*-weighted gradient echo sequence [3] with a scan duration of 10 minutes (TR/TE/flip angle = 800ms/25ms/45°, voxel size = 0.24x0.24x1mm³, FOV=240x180mm²) was used to acquire 20 slices. A navigator echo correction technique (TE=9.5ms) was used to correct for resonance frequency fluctuations.

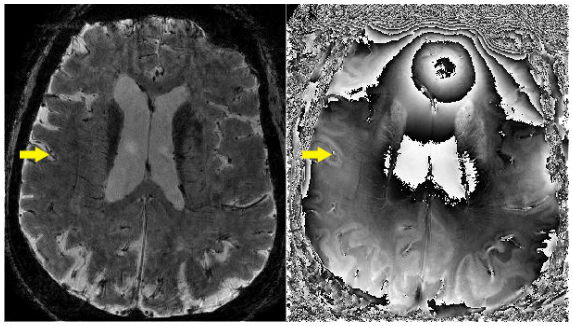

Figure 1: Example of GM/WM contrast in T2*-weighted magnitude (left) and phase (right) images for elderly subjects. GM/WM contrast is visible in the phase data, but is completely absent in the magnitude data (arrow).

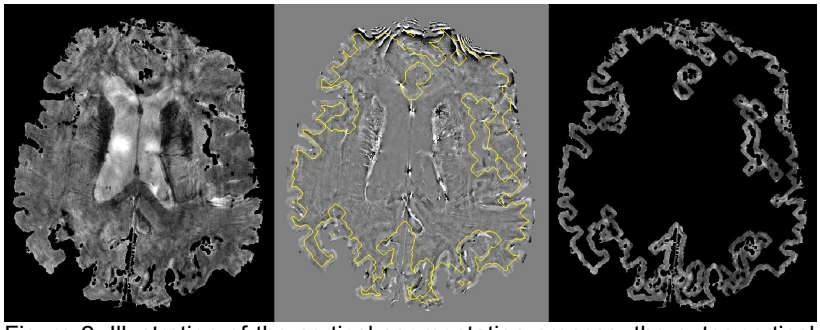

Figure 2: Illustration of the cortical segmentation process: the outer cortical boundary is determined using magnitude data (left), and the inner cortical boundary is computed based on phase data (center). (right) Final magnitude image of the segmented cortex.

RESULTS: Figure 1 illustrates the lack of GM/WM contrast in magnitude images of a T2*-weighted sequence performed on an elderly patient (83 years). Phase data however do show some measurable contrast. Figure 2 illustrates the different steps involved in the segmentation method. Once the parenchyma has been extracted, the lack of GM/WM contrast in magnitude data is obvious. Application of any magnitude-based approach failed completely, essentially giving nonsensical results. The obtained GM/WM segmentation using the phase data does rely on an initial global criterion of constant cortical thickness, but this proved to be fairly accurate. Phase-based segmentation of the cortex seems to be a valid alternative for cortical segmentation in the elderly population. Further research will focus on refining the segmentation to reflect more accurately local variations in cortical thickness.

REFERENCES: [1] Nakada et al, J Neuroimaging 18, 125-9 (2008);[2] Dale et al, Neuroimage 9, 179-194 (1999) ; [3] Duyn et al, Proc Natl Acad Sci 104,11796-801 (2007)

ACKNOWLEDGEMENT: This research was supported by the Center for Translational Molecular Medicine (CTMM).