Fast and Accurate Brain Tissue Segmentation with Polarity Categorization (POLCAT)

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TARGET AUDIENCE: Researchers and clinicians that apply tissue segmentation to parcellate brain volumes.

PURPOSE: Intensity-based brain tissue segmentation algorithms rely on post-hoc image intensity at a single point along the relaxation recovery curve of MPRAGE[1] exams, making them very sensitive to unexpected signal variations including the considerable spatial heterogeneity of radio-frequency (RF) coil sensitivities[2,3]. *The purpose of this work is to develop a novel, robust and efficient method POLCAT (Polarity Categorization) for brain tissue segmentation that relies on intrinsic properties such as T1 and is insensitive to variations in RF receiver coil bias.*

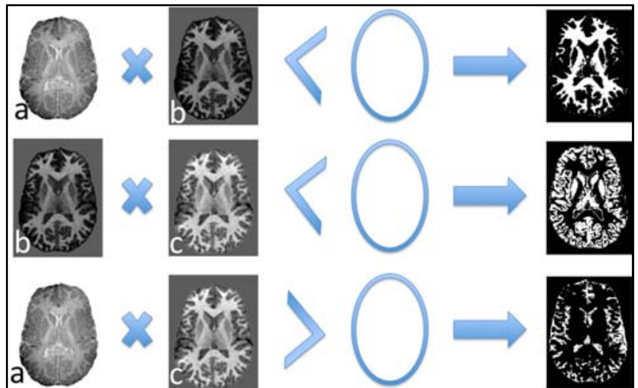


Figure 1: Automatic polarity based method for segmentation, POLCAT, utilizing three images with different inversion times. The three source images (a,b,c) are automatically co-registered since they are acquired in a single 7.5 minute exam using the MP-nRAGE

THEORY: An MP-nRAGE method[4], an inversion recovery (IR) sequence with radial k-space sampling was recently shown to produce 100s of co-registered high resolution, volumetric images with different T1 contrasts in a single exam about as long as a fully sampled Cartesian MPRAGE acquisition. MP-nRAGE images may be divided into four groups based on their position with respect to the null points of WM, GM, and CSF. POLCAT assigns the tissue class of each voxel by the sign of the real signal intensity after voxel-wise complex-multiplication of images from different regions as shown in Fig. 1. Only three images are needed, with one image between the WM and GM null points (image b in Fig. 1) and another between the GM and CSF null points (image c in Fig. 1). The third image can be either before the WM null point (image a in Fig. 1) or after the CSF null point.

METHODS: POLCAT segmentation was compared against intensity-based segmentation results from both MPRAGE and MP2RAGE images. Two images from the MP-nRAGE exam were combined according to Eq. 3 of reference **5** to produce a single MP2RAGE image (Fig. 2a) with high T1 contrast and no RF receiver-bias. A Cartesian MPRAGE acquisition was also acquired (Fig.2b). MPRAGE and MP2RAGE images were segmented with FSL FAST. Intensity correction was only used for the MPRAGE image. Since the MP2RAGE image has no RF receiver-bias, its segmentations were used to form difference images with the segmented MPRAGE and POLCAT.

PARAMETERS for the MP-nRAGE exam were: FOV=256 mm x 256 mm, slab thickness 180 mm, acquired resolution = 1.0 mm x 1.0 mm x 1.0 mm, TR = 4.89 ms, TE = 1.8 ms, 224 inversion pulses played out 2000 ms apart. N=302 gradient echo TRs acquired after each TR using 4 degree flip angle. Images were reconstructed using a sliding window of width 60 and spacing 1,i.e. image 1 uses data during gradient echo TRs 1 through 60, image 2 used data during gradient echo TRs 2 through 61, and so forth, forming 242 different T1 weighted images. The Cartesian MPRAGE acquisition had FOV = 256 mm x 256 mm, pFOV = 0.91, slab thickness 180 mm, acquired resolution = 1.0 mm x 1.0 mm x 1.0 mm, TR = 8.2 ms, TE = 3.2 ms, inversion time = 450 ms, and flip angle 15 degrees. A 32-channel receive-only head coil (Nova Medical) was used for both MP-nRAGE and MPRAGE.

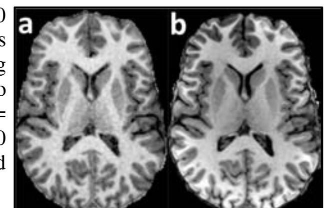
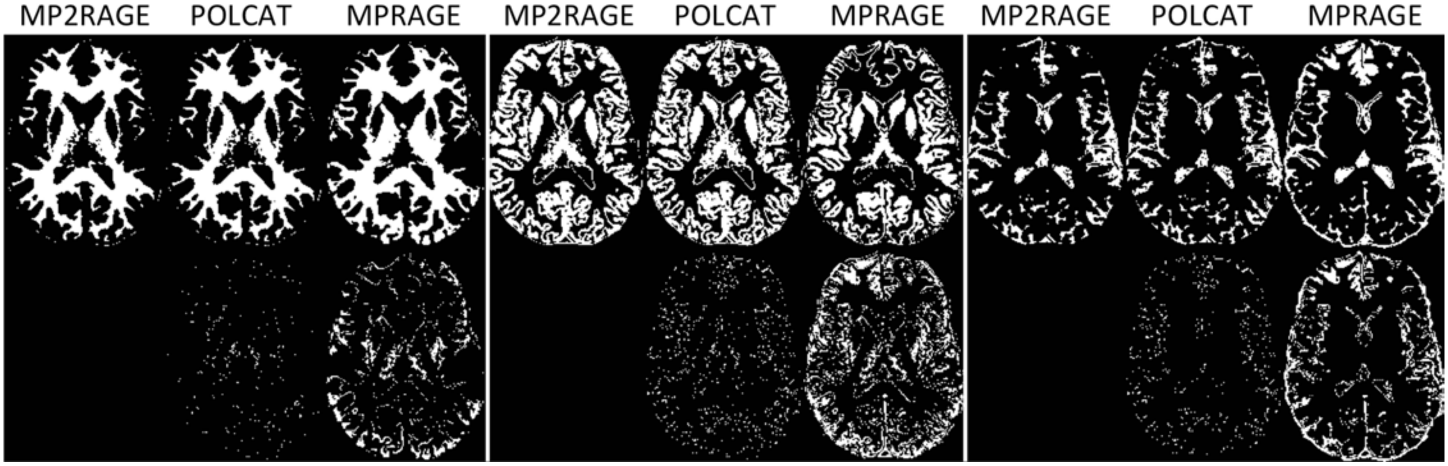


Fig 2: (a) MP2RAGE image formed from radial MP-nRAGE acquisition and (b) Cartesian MPRAGE image.

RESULTS: Example segmentations of WM, GM, and CSF are shown below for MP2RAGE, POLCAT, and MPRAGE. The difference images (bottom row) are referenced to the MP2RAGE segmentations. The new automated polarity-based method, POLCAT, yielded similar results to the MP2RAGE segmentation with FSL FAST with subtle differences primarily located at the tissue boundaries. Note that POLCAT does not use any spatial/intensity regularization like that in FSL and is entirely automated. FSL FAST had trouble segmenting the MPRAGE image accurately in the anterior and posterior regions due to the large degree of RF coil inhomogeneities of the 32 channel receive coil used.

MP2RAGE POLCAT MPRAGE MP2RAGE POLCAT MPRAGE MP2RAGE POLCAT MPRAGE



DISCUSSION AND CONCLUSION In this preliminary work, we demonstrated a novel technique, POLCAT, to automatically segment brain tissue directly using 3 IR images with different inversion times. Although the polarity based method needs more study, its ease and speed has the promise to provide efficient and accurate online brain segmentation in combination with an efficient MP-nRAGE acquisition.

REFERENCES 1. Mugler, J.P. et al, Magn Reson Med, 1990, **15**(1); p.152-7 **2**. Ashburner, J et al, Neuroimage, 2000. **11**(6 Pt 1): p. 805-21 **3.** Belaroussi, B., et al. Med Image Anal, 2006. **10**(2): p.234-46 **4**. Kecskemeti SR, et al. ISMRM 2013 Meeting #0452 **5**. Marques, J.P. at al, Neuroimage, 2010. **49**(2); p. 1271-81