A Realistic Phantom for Brain Segmentation Comparative Evaluation

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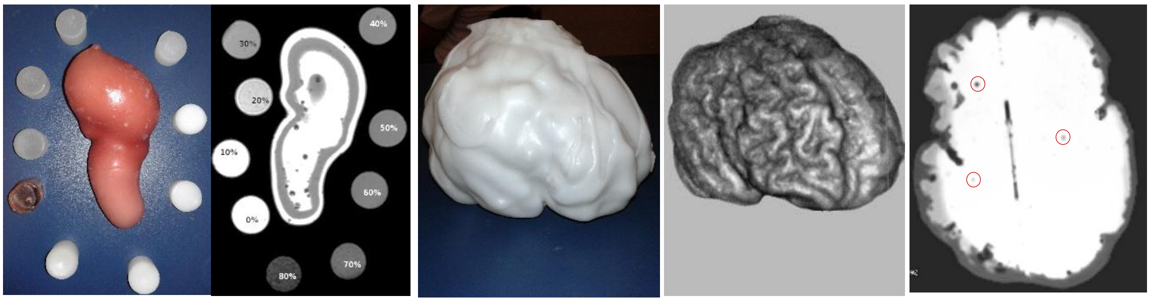
Introduction – All Imaging techniques need to be evaluated for quantifying inherent confidence. Image Segmentation is one the most used imaging techniques to volumetric analyze of Magnetic Resonance Image (MRI) of brain. Comparison of Brain segmentation methods is a big challenge. Usually two different ways are used to evaluate them; expert manual segmentation and phantom imaging. In addition, phantoms are divided to two main groups digital [1] and physical phantoms [2]. Since all automatic or semi-automatic segmentation are compared with manual ones, there may always be uncertainty with human errors and real measured volumes which are not measurable. Here by using three materials, a physical brain phantom was constructed. By measuring density and mass of materials, volume of compartments were calculated accurately. In addition, bubbles inside three materials were measured. Then automatic and semi-automatic segmentation methods can be compared with the measured volumes. Absolute error for segmentation methods even manual method can be calculated.

Method: We prepared nine different gel samples using the copolymer styrene-ethylene/butylene-styrene (SEBS) (Kraton Polymers) in mineral oil in a concentration of 10% w/w. Solid paraffin was added in a mass fraction of 0-80% of solvent (oil mass). The gels preparation involved continuous stirring the SEBS copolymer, mineral oil and paraffin. This mixture remained at 120ºC, to ensure the complete homogenization, for approximately five hours in a laboratory oven. The T1 and T2 measurements of the samples are around 50-70 ms. Based on rational intensity of MRIs for three compartments White and Gray Matter and Cerebrospinal Fluid (WM, GM and CSF respectively), three most similar to real tissues were chosen. Then a hypothalamus was constructed to be tested by 3.0 Tesla MRI scanner. Next, a brain phantom, by chosen materials and a 3D model of infant brain with atrophy in one lobe, was constructed. After, the bubbles inside phantom was measured. Finally, measured volumes of GM, WM, CSF and bubbles (may as lesions) can be used to calculate error of manual, semi or automatic segmentation methods.



(a) (b) (c) (d) (e)

Figure 1. (a) Hypothalamus phantom with 9 different combination of materials. (b) Acquired image of (a) shows different intensity. (c) Brain phantom of infant made by three materials. (d) Acquired volume image from (c). (e) One slice of MRI of brain phantom.

Results: As it can be seen in figure 1, (b), 0% of paraffin (or 100% gelatin) was chosen as WM, 30% and 80% were chosen as GM and CSF respectively. We can see some bubbles in Figure 1 (e). After constructing phantom, the total volume was measured again which was more than sum of volume of GM, WM and CSF. This difference was considered as bubbles. Thus, WM, GM, CSF and bubbles were measured accurately.

Conclusion: In this study, a brain phantom was constructed by three materials as three compartments of brain which are WM, GM and CSF in order to evaluate segmentation methods include manual one. Next steps are trying to remove bubbles to have more homogeneity and have a comparison between recent segmentation methods.

References:

[1] Aubert-Broche, Berengere, Alan C. Evans, and Louis Collins. "A new improved version of the realistic digital brain phantom." NeuroImage 32.1 (2006): 138-145.

[2] Perilli, E., et al. "A physical phantom for the calibration of three-dimensional X-ray microtomography examination." Journal of microscopy 222.2 (2006): 124-134.