3D MRI Head Segmentation in Newborn Infants

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I. INTRODUCTION

Nowadays, magnetic resonance imaging (MRI) has become one of the most important medical imaging techniques for studying the human brain. Very often, tissue segmentation is a prerequisite for a further clinical analysis.

MRI segmentation of different head structures in newborn infants plays a crucial role in three-dimensional (3D) volume visualization and allows us to measure the growth, to explore developmental changes and to detect early disorders of different anatomical structures for both scientific and clinical investigations. For example, to combine electroencephalography (EEG) and MRI for the epileptic source localization, an anatomic head model is required with segments of scalp, skull, cerebrospinal fluid (CSF) and brain tissue, which have significantly different electrical conductivities. However, accurate tissue segmentation is a difficult task and presents a range of challenges (i.e. presence of noise, partial volume effects, bias field and motion artifacts). This is even more complex for developing neonates, mainly due to the fast growth process and different biological tissue properties. To date, many MRI segmentation techniques have been reported for adult brain, but very few for the neonatal brain [1].

II. METHOD

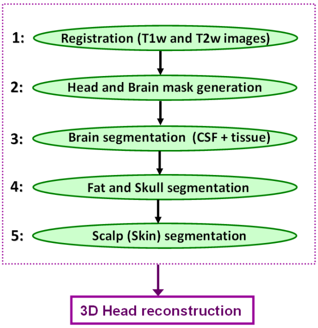

Figure 1. Outline of the proposed MRI segmentation algorithm.

In this work we present a hybrid segmentation algorithm that combines fuzzy-c means (FCM) clustering, thresholding, mathematical morphology and active contours. Our proposed algorithm performs 3D head segmentation based on information from T1-weighted (T1w) and T2-weighted (T2w) MRI and is tested on neonates with the gestational ages from 38 to 42 weeks. Due to the low inter-slice resolution, each slice is processed separately and the head is segmented into five classes: scalp, fat, skull, CSF and brain tissue.

The proposed algorithm is implemented in the five following steps (see Fig. 1):

Step 1: Affine registration of T1w and T2w images using mutual information [2].

Step 2: Automatic generation of the head mask and brain mask using histogram thresholding, morphology and active contours [3].

Step 3: Brain segmentation into two clusters, CSF and brain tissue, using a FCM segmentation algorithm with adaptive enhancement [4], [5]. In order to increase the performance of the algorithm and to generate a fast and reliable estimator of the FCM's parameters, an intensity-

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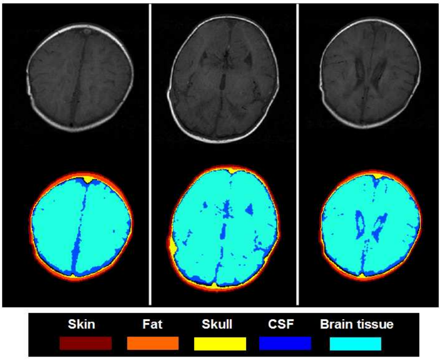

Figure 2. 2D segmentation of the head of a 39 weeks old infant. Upper row shows original T1w MRI images and the lower row presents the segmented images. At the bottom is given explanation of the labels.

based thresholding is used for the initialization.

Step 4: Segmentation of the fat and skull using the same FCM algorithm applied to the images without brain tissue.

Step 5: Scalp (skin) reconstruction by selecting all pixels between the edge of the head mask and fat using a morphological dilation with a circular structuring element of a radius one.

Afterwards, when different compartments of the brain are obtained, the 3D reconstruction of the head is made. Due to the low inter-slice resolution, the head has a step-shaped layout. To improve the results and 3D visualization we apply curve interpolation on segmented slices.

III. RESULTS

T1 MRI images were acquired on a Siemens 1,5T MRI scanner ($256\times256\times20$ voxel matrix with a resolution of $0.7\text{mm}\times0.7\text{mm}\times4\text{mm}$). The recorded data sets are processed using our proposed method. Final 2D and 3D results are shown in Fig. 2 and Fig. 3. When presenting these results to the expert physician, he scored them as highly plausible and acceptable.

One of the applications of this work is development of a realistic head model for EEG source localization.

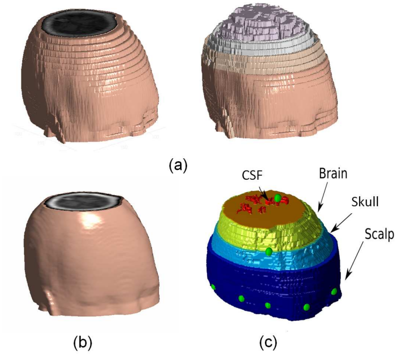

Figure 3. 3D segmentation: (a) segmented head with a low inter-slice resolution; (b) segmented head after final refinement; (c) realistic head model with labels.

IV. CONCLUSION

In summary, we have introduced a head segmentation method for neonates without using prior knowledge, like atlases and probabilistic algorithms. This method yields a good segmentation performance even in noisy images, and it has been validated on real MRI brain images. The validation results demonstrate an encouraging future of practical applications of the proposed method.

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