Comparison of UTE based Attenuation Correction Methods for simultaneous PET/MR Imaging of the Children's Brain

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Synopsis
In current PET/MR systems, PET attenuation correction is based on MRI, unlike PET/CT systems, which using CT measurements. Various approaches have been developed based on templates, atlas information, direct segmentation of T1-weighted MR images. In the present study, we introduced two approaches of UTE based attenuation correction for simultaneous PET/MR imaging focusing on children's brain, including segmentation-based method and support vector machine (SVM) regression method, to compare with Gaussian mixture regression (GMR) model method.

Purpose
The derivation of attenuation map as required for quantitative PET is one of the most challenging problems in PET/MRI; especially when compared to PET/CT, where attenuation information could be acquired by CT. A particular challenge for brain attenuation correction is the correct characterization of bone due to its low water density and fast signal decay. UTE sequences were specifically designed for reliable MR bone depiction[1]. However, bone of children has an even shorter relaxation time than that of adults. Therefore, it is of great significance to investigate the feasibility of visualizing bone of children with these sequences. In this study, we presented two children's brain attenuation correction methods and compared with Gaussian mixture regression (GMR) model method[2].

Methods
Image acquisition: Three children patients and six adult patients were scanned on a 3T whole-body simultaneous PET/MR scanner (Biograph mMR, Siemens Medical Systems, Erlangen, Germany). Each data set includes 1 T2-TSE MR (TE: 87ms, TR: 4540ms, FA: 10degrees, matrix size: 640×616×23), 2 UTE MR (TE_1/TE_2: 0.07/2.46ms, TR:11.94MS, matrix size: 192×192×192), and 1 corresponding PET raw data. Besides, each adult data set includes 1 CT volumes (120kVp, 100mAs, matrix size: 512×512×45) to be compared with generated pseudo-CT. UTE_1 with very short echo time contains all information including bones, while UTE_2, the longer echo, has no bone information. Hence bone information can be acquired by combining 2 UTE images.

Data analysis:
Segmentation method: The segmentation-based method put forward by Keereman[3] used UTE images to discriminate air and bone. After MR and PET images had been registered, an R2 map was calculated from two UTE images and a mask was calculated

to correct voxels containing air. Then, the MR images were segmented with an optimal threshold value 0.3 rather than 0.5 in the paper. The imaging processing procedure is summarized in Fig. 1.

SVM method: We developed another atlas-based method combined with machine learning, called support vector machine (SVM) regression method, to generate pseudo-CT from MR information. First, the preprocessing processes including registration, masking, and normalization were conducted. Then, SVM method was used to find the weights that can transform MRI to pseudo-CT. LIBSVM[4] software in Matlab was used for SVM regression. ε-SVR (epsilon support vector regression) was selected as the SVM formulation. The regression input and output demonstration is shown in Fig. 2.

GMR method: GMR method is performed by aligning the voxel intensity, mean value, and standard deviation of each neighborhood as input and training the model of 20 multivariate Gaussians.

PET reconstruction: To compare the results of above methods on the PET images, we reconstructed the PET images using Ordered Subset-expectation Maximization (OSEM) with 9 subsets and 16 iterations, with attenuation maps derived from the three methods discussed above.

Results

Fig. 3 shows the attenuation maps of the segmentation-based, SVM, and GMR methods. Fig. 4 shows the PET reconstruction results with the segmentation-based, SVM, and GMR methods.

Discussion and Conclusions

This work presents three PET/MRI attenuation correction methods and compares the feasibility of these methods for children's brain imaging. Although true CT images have not been acquired due to potential radiation to children, and SVM and GMR method were accomplished based on data of adults' brain, the SVM method appears to produce better attenuation map and to improve PET image accuracy.

References

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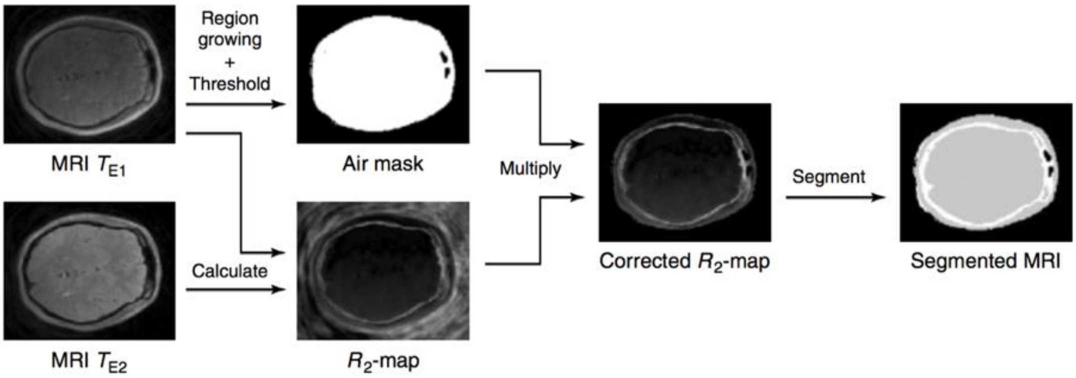

Figure 1: Image-processing workflow. Uncorrected R2 map is calculated from two UTE images obtained from TE1 and TE2. R2 map is multiplied with air mask derived from first-echo image to yield corrected R2 map. Corrected R2 map can be segmented into bone, soft tissue, and air.

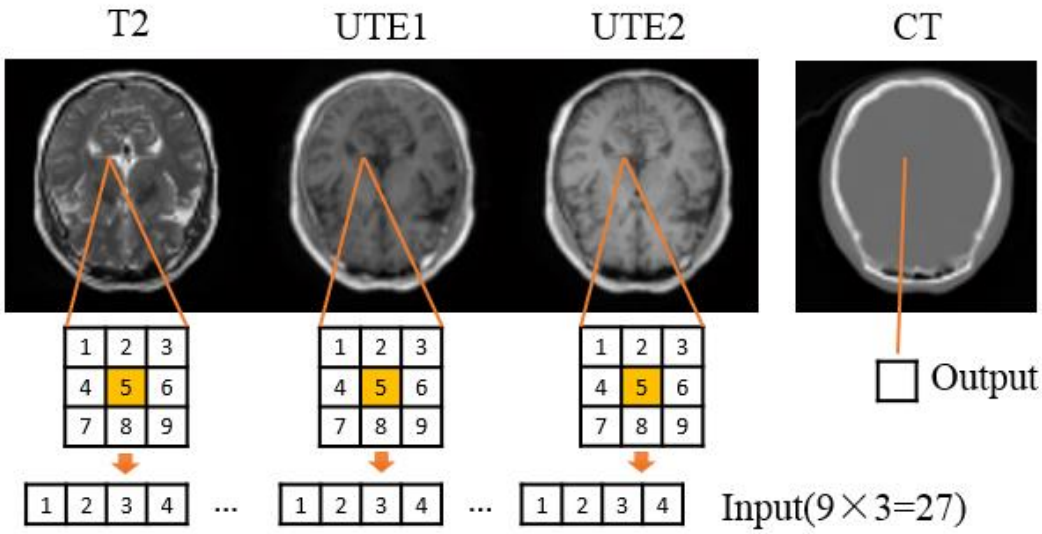

Figure 2: Regression input and output demonstration. Intensity of each voxel and its eight neighborhood voxels of the three MR images were used as input, with CT values of the voxels as output.

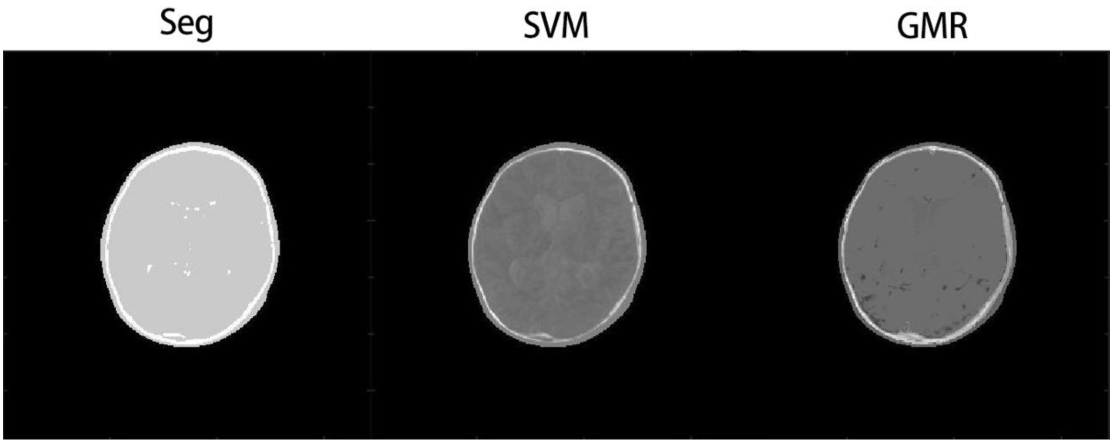

Figure 3: Comparison of the segmentation, SVM based, and GMR attenuation map for one of the test patients.

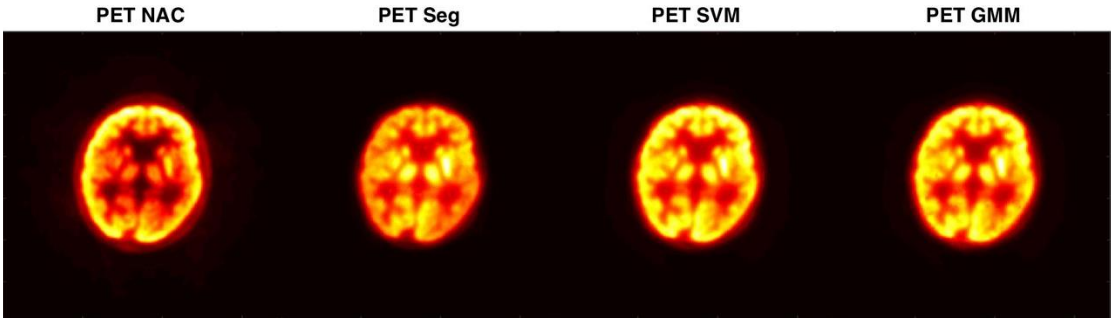

Figure 4: Comparison of PET reconstruction results with non-attenuation correction, segmentation correction, SVM correction, and GMR correction, respectively.