Attenuation correction for TOF-PET with a limited number of stationary coincidence line-sources

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INTRODUCTION Accurate attenuation correction remains a major issue in combined PET/MRI. We have previously presented a method to derive the attenuation map by performing a transmission scan using an annulus-shaped source placed close to the edge of the FOV of the scanner. With this method, simultaneous transmission and emission data acquisition is possible as transmission data can be extracted using Time-of-Flight (TOF) information. As this method is strongly influenced by photon scatter and dead time effects, its performance depends on the accuracy of the correction techniques for these effects. In this work we present a new approach in which the annulus source is replaced with a limited number of line-sources positioned at 35 cm from the center of the FOV. By including the location of the line sources into the algorithm, the extraction of true transmission data can be improved. The setup was validated with simulations studies and evaluated with a phantom study acquired on the $LaBr_3$-based TOF-PET scanner installed at UPENN.

MATERIALS AND METHODS First we performed GATE simulations using the digital NCAT phantom. The phantom was segmented into bone, lung and soft-tissue and injected with 6.5 Mbq/kg ^{18}F-FDG. Simultaneous transmission/emission scans of 3 minutes were simulated using 6, 12 and 24 ^{18}F-FDG line sources with a total activity of 0.5 mCi. To obtain the attenuation map, the transmission data is first extracted using TOF information. To reduce misclassification of prompt emission data as transmission data, only events on LORs, which pass within a radial distance of 1 cm from at least one line source, are accepted. The attenuation map is then reconstructed using an iterative gradient descent approach. As a proof of concept, the method was evaluated on the $LaBr_3$-based TOF PET scanner using an anthropomorphic torso phantom injected with 2mCi of ^{18}F-FDG. 24 line-sources of 20µCi each were fixed to a wooden template at the back of the scanner. Simultaneous transmission/emission scans were acquired using 24 line sources.

RESULTS Simulation results demonstrate that the fraction of scattered emission events classified as transmission data was reduced from 4.32% with the annulus source to 2.29%, 1.25% and 0.63% for the 24, 12 and 6 line sources respectively. The fraction of misclassified true emission events was reduced from 1.10% to 0.42%, 0.24% and 0.13% respectively. Only in case of 6 line sources, the attenuation maps showed severe artifacts. Compared to the classification solely based on TOF-information, preliminary experimental results indicate an improvement in the accuracy of the attenuation coefficients of 10.44%, 0.12% and 5.09% for soft-tissue, lung and bone tissue respectively.

CONCLUSION The proposed method can be used for attenuation correction in sequential or simultaneous TOF-PET/MRI systems. The PET transmission and emission data are acquired simultaneously so no acquisition time for attenuation correction is lost in PET or MRI. Attenuation maps with higher accuracy can be obtained by including information about the location of the line-sources. However, at least 12 line sources are needed to avoid severe artifacts.