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Attenuation estimation using non-TOF PET scattered photon energy information and an anatomical MRI prior

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Emission-based attenuation correction methods aim to derive the attenuation information directly from the emission data. Although promising results have been obtained with this approach, joint-reconstruction of activity and attenuation suffers from several limitations. Nearly all studies report cross-talk between the estimated activity and attenuation distributions if time-of-flight information is not available.

It has recently been proposed to use scattered photon data as an additional source of information that could be integrated into the reconstruction algorithm, by relying on multiple energy window measurements. In previous preliminary work, we demonstrated that stand-alone scattered data do contain useful information and can be used to estimate the attenuation-map in realistic energy resolution scenarios using maximum likelihood (ML) optimisation, if the emission is known. However, we observed that the image quality is degraded by noise over iterations.

Therefore, we propose here to take advantage of the MR information available from the PET/MR scanner. We incorporated an MRI-derived prior into the reconstruction algorithm, which enforces common edges between the estimated attenuation-map and the MR image. The chosen anatomical prior relies on the concept of Parallel Level Sets (PLS). It makes use of directional information derived from the anatomical image and encourages images with aligned spatial gradients. In the case when no structural information is available, the prior reduces to the total variation prior.
Simulations have been conducted on a cylindrical phantom and realistic 3D XCAT images, using the geometry and characteristics of the Siemens mMR scanner. We compared results from different initialisations of the algorithm, and with different structures in the MR-based prior.

Results show that the incorporation of the anatomical prior helps in controlling the noise level in the reconstructed image, enhancing the edges and improving quantification. However, over-smoothing can occur where no anatomical information is present.
In conclusion, the PLS anatomical prior shows promising results but more investigation on parameter tuning is warranted.

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