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List-mode TOF MLEM reconstruction for the total-body J-PET with a realistic system response matrix

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We modify the time-of-flight maximum likelihood expectation maximisation (TOF MLEM) image reconstruction algorithm by an updated model for the system response matrix (SRM) of the total-body Jagiellonian PET (J-PET) scanners, which modular multi-layer geometry complicates SRM estimation and requires more computational power to calculate correction factors [1].
The elongated plastic scintillators of the J-PET, which use Compton scattering for the detection of positron-electron annihilation photons, imply the smooth dependence of SRM on the obliqueness angle θ. We thus represent it as a set of functions unique for each bin and acquired by a log-polynomial fit of the Monte Carlo simulated emissions of γ-photons on 2D transverse planes with different θ.
By utilising the GATE software [2], a NEMA IEC phantom [3] was simulated in a 140-cm long 24-module J-PET, comprised of 2 detector layers (inner radius 393 mm) and a layer of wavelength shifters [4]. The data collected from a 500-s long scan was post-smeared according to the assessed temporal (191 ps) and axial (5 mm) resolution. Only true coincidences were considered.
The updated SRM was employed for the list-mode TOF MLEM reconstruction. For the predefined NEMA IEC attenuation map, two versions of attenuation correction were applied: a conventional (integration over bins) and a simplified on-the-fly recalculation for each measurement, which improves performance and is less sensitive to boundary effects.
Compared to the reference list-mode TOF MLEM from the CASToR framework [5], a substantial improvement in the image quality and mean squared error with respect to ground truth were observed. The simplified attenuation correction proved to be a reliable alternative, producing outcomes similar or better than the conventional approach.
To summarise, the proposed analytical SRM model for the total-body J-PET proved to be superior to the reference method employed for crystal-based scanners. The modified TOF MLEM and attenuation correction do not require high computational power and can be extended to account for the non-collinearity, positron range and other factors.

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