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An Algorithm for Maximum-Likelihood Estimation of the Timing Resolution in TOF-PET

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As is well known, utilization of time-of-flight (TOF) information can reduce noise and improve convergence rate in PET image reconstruction since it allows to incorporate the (Gaussian) probability density function (the "TOF-kernel") of the annihilation event position along the respective LOR into the image reconstruction process. In doing so, it is crucial to use the best possible estimate of the actually given timing resolution in order to achieve a realistic contrast recovery and minimize noise. In this context, it is relevant to recognize that the timing resolution of a time-of-flight PET system is count rate dependent. However, count rate dependent TOF-resolution calibration is usually not provided by the vendors. We, therefore, developed a procedure which is compatible with clinical routine and is also applicable retrospectively to existing data.
We propose a novel Maximum-Likelihood Timing Resolution Estimation (MLTRE) algorithm that maximizes likelihood by updating activity image and TOF-kernel width alternately. The algorithm was evaluated using phantom and patient studies covering a large range of count rates that were acquired with a Philips Ingenuity TF PET/MR scanner.
Our preliminary results indicate that the proposed algorithm is capable of realistic timing resolution estimation, while being convenient and easy to use in clinics. To the best of our knowledge, the dependency of timing resolution on singles rate of the Philips Ingenuity TF PET/MR scanner was never published before. According to our findings, the timing resolution of this scanner degrades rapidly with increasing count rate.

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