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Determining the equivalent Gaussian TOF-resolution of PET systems with multiple and non-Gaussian TOF-kernels

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The effective sensitivity of a PET system can be increased by improving its time-of-flight (TOF) resolution. For that purpose, new detectors are being developed, including detectors that use not only scintillation but also Cerenkov photons, and detectors consisting of two different scintillators. Such systems have events with different coincidence time resolution (CTR), i.e. different TOF-kernels, and the shape of these TOF-kernels can be non-Gaussian. In some systems, it may be possible to assign to each event an estimate of its CTR. This CTR can then be used during image reconstruction. If this is not possible, all events must be considered as samples from an overall TOF-kernel, which may have a non-Gaussian shape with a narrow peak (events with good CTR) and wide tails (poor CTR events). These developments raise two questions: (1) how can we compare systems that have TOF-kernels of different shapes and (2) how much information is added by labelling each event with its CTR.
Tomitani [1] computed, for a uniform cylinder, how the variance in the centre of the reconstructed image depends on the CTR, assuming a Gaussian TOF-kernel. We extended his approach to non-Gaussian TOF-kernels, and found that the same result can be obtained by computing the SNR for a hot spot detection task. This enables us to assign an SNR to each TOF-kernel. For CTR-labelled events, the system SNR is obtained by averaging the squared SNRs of the TOF-kernels. If the events cannot be labelled, the system SNR is computed from the averaged TOF-kernel. Thus, one can compute an effective Gaussian TOF-resolution: a conventional system with this Gaussian TOF-kernel has the same effective sensitivity as the system with multiple and/or non-Gaussian TOF-kernels. The results were verified with 2D TOF-PET simulations, reconstructed with MLEM.

[1] T. Tomitani. "Image reconstruction and noise evaluation in photon time-of-flight assisted positron emission tomography". IEEE Trans Nucl Science NS-28.6 (1981).

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