Implementation and evaluation of scatter estimation algorithms in positron emission tomography

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In positron emission tomography (PET) the current trend is to use the fully 3D capabilities of scanners to increase sensitivity and hence improve the quality of data or reduce the scanning time. To make this feasible, some problems have to be addressed. The largest contributor to image degradation in 3D PET is Compton scatter since these photons comprise more than 50% of the total coincidences in many whole body studies. Much progress has been achieved the last few years by the use of scatter correction algorithms, such as the single scatter simulation (SSS). In this work, a model-based scatter simulation (MBSS) algorithm has been implemented in a software library called STIR (Software for Tomographic Image Reconstruction) initially based on the SSS. The aim of the current work is to validate the MBSS implementation; investigate the influence of several parameters, for example, the detector sampling and voxel size of the transmission image; and, if feasible, to improve on the existing algorithm. The results of the implementation are compared with both the SimSET Monte Carlo simulation package and measured data. The comparison shows that SSS is in excellent agreement with the single scatter distribution produced by SimSET and in several cases can approximate the total scatter well. However, SSS is just an attempt to approximate the total Compton scatter effect. It is physically possible that both photons are being scattered, and potentially more than once. As it is shown, the single scatter distribution and the total scatter distribution have a different shape. How close this approximation could be depends on how much multiple scattered photons have been detected, which depends on the energy

resolution of the detectors and consequently to the used energy window of detection. Multiple scatter is much more likely to happen if the attenuation medium has large volume, and hence it is more severe in 3D PET studies of the torso than of the head. In this work, the methodology used in the single scatter simulation algorithm is extended to handle double scattered events and we propose an efficient recursive algorithm to estimate even the rest multiple scatter distribution. A detailed discussion on how to implement the double scatter simulation (DSS) and a preliminary evaluation is included. The results are quite promising even if the required time for DSS is much longer than for SSS; however it can be still fast.