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The Effect of Position Resolution on LoR Discrimination for a Dual Head Compton-Camera

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The SmartPET is a novel Positron Emission Tomography (PET) system that uses High Purity Germanium (HPGe) detectors in a dual-head camera design. Alone, the superior 3D position resolution o_ered by semi-conductor detectors removes the depth-of-interaction problem inherent in many PET camera designs. However, there is another opportunity o_ered by the system. Coincident measurement, in a single detector, of an interaction sequence arising from the path of a single photon allows each of the detectors to act independently as a Compton Scatter Camera (CSC).

The CSC relies on the measurement of the position and energy from individual inelastic scattering and photo-absorption interactions of a single incident photon. Measurement of two or more of these interactions (and knowledge of the incident energy) allow the CSC to define a Cone-Surface of Response (CSR), along which lies the incident trajectory of the photon. The resolution of this CSR is defined entirely by the uncertainty in position and energy in the measurements of the individual interactions.

The angular resolution of this CSR is defined by the scattering angle, the spatial and spectral resolutions of the detector, along with the distance between the first two interactions in the sequence [1].

The current study proposes the use of these CSR events in the discrimination of Lines of Response (LoR) in a PET system. Current PET studies show that up to 36 % of detected events may scatter inside the object [2], furthermore, in fully 3D PET up to 50 % of the coincident detections might arise from random coincidence [3]. LoR validation through CSR aquisition o_ers the ability to discriminate Compton scattered and randomly coincident detections, without the need to apply scatter correction algorithims nor implement delay coincidence channels respectivly.

As each of the detectors acts as a standalone CSC, each will acquire a number of different interaction sequence types, depending on the number of interactions that an incident photon undergoes. In a dualhead PET system coincident interaction sequences may be acquired leading to LoRs. Generally, in order to correctly define a CSC a knowledge of the incident energy is required. However, for discrimination purposes, 511keV may be assumed due to the CSC/LoR relationship requiring that an LoR lie along any associated CSC. If the assumption is false then a correct match is highly unlikely. Further, if time resolution is introduced at the interaction sequence level, then the coincidence of two interaction sequences in opposing detectors may not be defined uniquely, particularly in a high activity environment. In this scenario, each interaction sequence in a timing bin may be interrogated for LoR matching purposes.

The above validation was performed on co-linear 511 keV photon events simulated using Geant4. The simulation modeled HPGe detectors separated by 6-10 cm and a dual source at the center of the detector geometry. While energy resolution is still required in the definition of CSRs, the importance of position resolution in this PET detector design was the main focus of this study. Hence, energy resolution was initially assumed to be perfect, and the e_ect of position resolution on the ability of the CSRs to discriminate LoRs was investigated. CSR discrimination proved successful in removing both Compton scattered and random coincidences from the data. Moreover, the importance of positional resolution in CSC detection in the PET process is highlighted by this study.

These techniques may be used to reduce the number of false LoRs in a PET image obtained from such a system. It also indicates that the importance placed on full energy deposit and timing information, the focus of PET measurement over the past few years, may be reduced.

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