ComptonRec: Mastering Conic Sections for a Direct 3D Compton Image Reconstruction

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Abstract: Given the complexity of the image reconstruction procedures for Compton Camera events, especially when a 3D image is required for distributed sources in space, a simple, direct algorithmic approach is presented in this work. The developed ComptonRec package carefully handles the geometry of the conic sections to accumulate ray density distribution in a user defined voxelized volume inside the specified field of interest. Prior to planar reconstruction, the event selection part of the program filters out misidentified coincidence events and other physical background events with unbalanced total energy or inverse interaction.

1. Principle of Operation

Compton Camera

A Compton Camera consists of two detectors, the scatterer and the absorber. Its functionality relies on the Compton scattering effect. An initial photon of the source interacts with the first thin detector and then is absorbed by the second thicker one. The interaction point at each detector and the energy deposited in the absorber are detected for every single event. A conical surface (Figure 1) is formed with its vertex defined by the first interaction point and its axis determined by the two interaction locations at the detectors.

2. Reconstruction

Method of Image Reconstruction

The Compton Camera Image Reconstruction techniques are similar to those used in SPECT and PET. These most commonly used reconstruction algorithms show, not only for the Compton Camera modality, known and significant disadvantages.

• Analytical algorithms: Require large number of data and need to solve complex mathematical problems. They prove to be unstable and also can not handle complicated factors, present in the Compton Camera, mainly induced by the spatial intensity variation.

• Iterative algorithms: Need the use of spherical harmonics and due to the above mentioned variation are less efficient.

Any reconstruction procedure for this modality is seeking to optimally determine the intersection points for all conical surfaces corresponding to measured events. In order to minimize computational time and to achieve optimum image quality an event based reconstruction technique is preferable.

3. The Reconstruction Program: ComptonRec

The Philosophy behind the Reconstruction Method

A novel, simple, direct algorithmic approach, that masters conic sections in a user defined voxelized volume is proposed here.

The main action in the event loop is the conical surface calculation for a selected event and its conic section with the corresponding Z-plane inside the camera’s Field of View. Accumulated information is stored pixelwise in each of the predefined Z-planes. The final 3D image is assembled by taking into account volume effects. In order to reduce background events various cuts must be implemented.

4. Event Filtering

Event Selection Criteria

For each accepted event a series of planar reconstructions is performed, where the density distribution is the accumulation product of the conic intersection with all the geometrical characteristics.

5. Simulating the Compton Camera

Model Design and Performance Study

The performance of a Compton Camera is studied through GEANT4/GATE simulations for various geometrical characteristics. The reconstructed planar image needs density normalization due to the strong dependence on the source distance (volume effects).

6. Phantom Simulation

Evaluation of ComptonRec

A simple but not symmetric phantom was simulated in the GEANT4/GATE environment in order to test the algorithms efficiency, always taking into account the volume effects. The phantom consists of three spherical sources that form a triangle on the Compton Cameras XY plane.