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Modeling the Collimator-Detector Scattering Using Stochastic Differential Equations and COMSOL

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Single photon emission computed tomography (SPECT) is a nuclear medicine imaging technique that uses gamma rays. It has been especially useful for bone scans, cardiac perfusion imaging, tumor scans and brain imaging. The main advantage of SPECT imaging is that it can target particular tissue receptors allowing one to focus on the imaging of the diseased tissue. However the computational time need for reconstruction of SPECT images is quite large. This is mainly due to the fact that SPECT images are susceptible to higher level of statistical noise in the images caused by photon attenuation, scatter and collimator-detector response.

The modeling of photon attenuation and scattering has been subject of considerable research interest. However, due to its complexity the instrumentation effects i.e., collimator-detector response has mostly been accounted through simplified empirical-based algorithms. While in some cases it may be sufficient in certain SPECT procedures, especially for particular dosage levels and/or isotopes the scattering effects in collimator: photoabsorption, Compton and coherent scattering may severely degrade image quality and thus restoration accuracy.

In most cases Monte Carlo simulations are employed in order to calculate probability density functions of scattered photons. In this paper we utilize transport equations modeling photon flow based on the definition of Markov processes and present the equivalent set of stochastic differential equation. Then, we solve the corresponding differential equations for an arbitrarily shaper collimator whose geometry is constructed using COMSOL GUI. Next, using general PDE mode we solve for the corresponding probability density function of the single photon. We finally compared our results to those of commercially available simulators for SPECT imaging.