Purpose: To develop a GPU-based kV Monte Carlo (MC) simulation tool for computing CBCT x-ray projection images including both primary and scattered photon signals.
Methods: We have developed a MC simulation code on GPU architecture using NVIDIA's CUDA API. Photon cross section data of various interaction types in the kV energy range are obtained from the PENELOPE database. The Woodcock transport technique is used for simulating photon transport without the need for voxel boundary crossing. Photon energy fluence at a detector location is recorded as the projection image. Multiple tallies are employed to record primary photon energy fluence (no scattering) and the fluences from photons undergoing first, second, and higher order scatters. To test our MC code, we simulated the geometry of a realistic Varian OBI system. We imaged a patient's head and an XCAT chest phantom with 10 billion source photons having a flat source fluence map collimated to a 40.0 cm by 30.0 cm detector. A mono-energetic x-ray source of 100.0 keV is used.
Results: The computation time to simulate 10 billion photons for imaging both patient's head and the XCAT chest phantom was around 16 minutes on an NVidia C2050 GPU card. We found the total scattering signal to be approximately 10 percent of the primary signal in both cases. We also found that the total signal from higher order scattering is not negligible when imaging the XCAT chest phantom due to its large size and higher probability of scattering the photons.
Conclusion: We successfully developed a Monte Carlo based kV imaging tool for simulating x-ray projections. X-ray projections obtained by this work will facilitate many research projects, where accurate x-ray projection images are needed, such as scatter removal in the CBCT reconstruction problem.