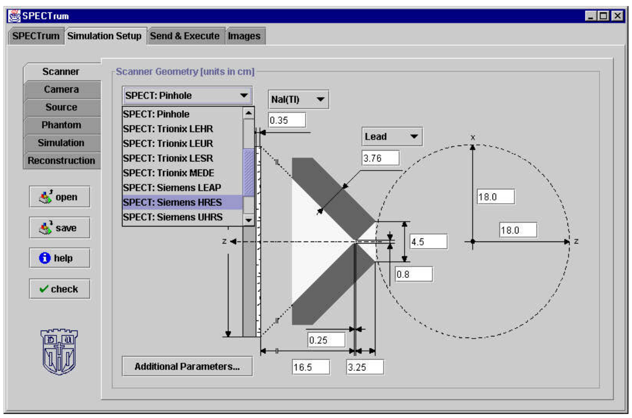
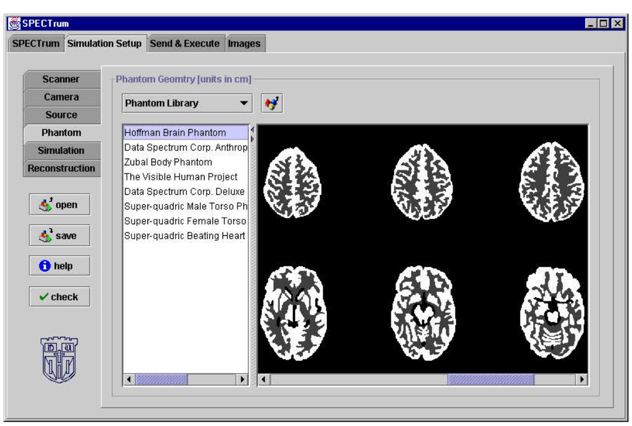
Distributed Monte Carlo Simulation for SPECT and PET Imaging Systems

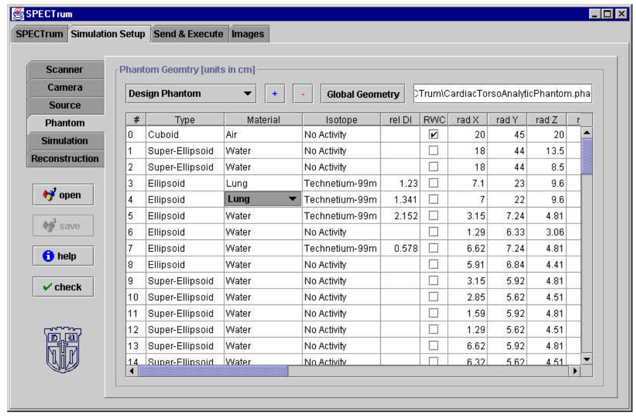
Objective: To develop a state-of-the-art framework for MC simulation of geometrically complex source distributions and arbitrary detector geometries to be used in PET and SPECT, the main imaging modalities in nuclear medicine.

The long term objectives of this work include the following: a) to develop and employ one of the most versatile and fastest MC codes available that simulates both SPECT and PET systems and is also capable of ray-tracing analytical as well as voxelized tomographic phantom representations; b) to provide a graphical user interface that guides the scientist/physician through the

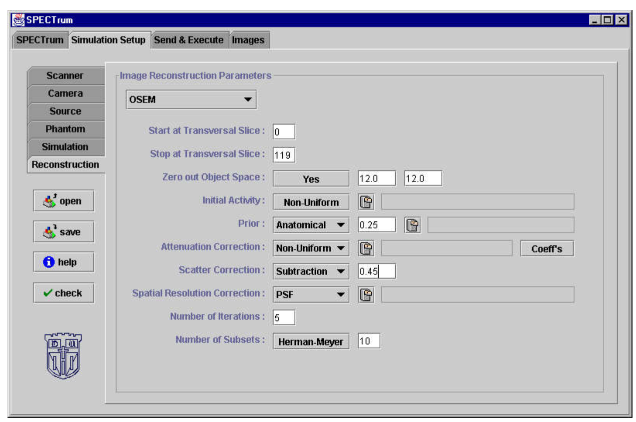


process of setting up the system to be simulated; c) to implement a server architecture which enables users from other research facilities to employ this tool to support their own research projects; and d) to distribute the computational very expensive process of simulating (and reconstructing) data automatically over a set of available computers. Whereas the MC and reconstruction codes are written in C and implemented on Unix workstations, the state-of-the-art GUI is developed entirely in Java as are the server and front end programs. The MC code, in particular, simulates the following SPECT acquisition





configurations: parallel/fan/cone beam, astigmatic, and pinhole collimators with arbitrary and multiple focal line/point locations. In PET mode, cylindrical and dual head PET detectors can be modeled. The code can simulate tomographic data of any dimension, three and four-dimensional analytically defined superquadric-based phantoms, and combinations of voxelized and analytical phantoms.Medium-energy photons can be tracked independently for several scatter orders and can be detected within arbitrarily defined energy windows. Several variance reduction techniques are implemented in



order to improve computational efficiency. In addition, Monte Carlo simulation as well as (two-dimensional) reconstruction of tomographic data can be distributed easily which divides the computational burden by the number of available computers. Simulations are distributed and performed independently by splitting the acquisition span angle, and subsequent (two-dimensional) reconstruction of the projection data can be distributed by sub-setting transversal slices. The implemented simulation code has been used in several research projects and has helped to explain technological as well as clinically relevant imaging aspects.

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