An MCNP-Based Tool for Polychromatic X-Ray CT With Applications to Advanced Algorithm Development and Verification

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Abstract

The aim of this work is to aid the current progress in image formation algorithms for X-Ray CT used in luggage screening applications. We provide a user-friendly access to MCNP, a useful but complex Monte-Carlo particle transport code available from the Department of Energy. Previous research has shown that this program can be used to accurately simulate the behavior of photons more realistically than deterministic methods. This research tool allow users to define their own sample geometries using primitive shapes and materials using atomic or mass compositions. It will enable selection of critical runtime parameters including energy spectra, number of particles, and tally considerations. A user may choose to bin tallies based on the number of collisions a photon has undergone during transport, a useful value when scatter is considered. Tests with simple geometries and well-defined materials show that this tool can be used to validate state-of-the-art reconstruction techniques.

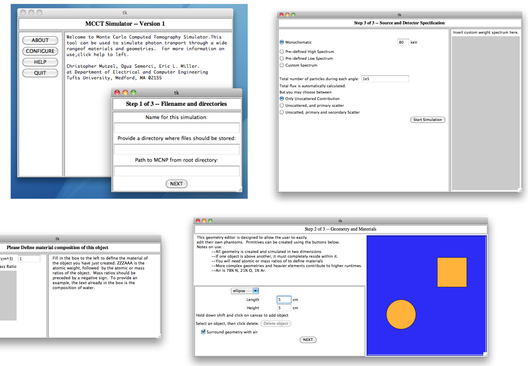
Relevance

- Validation of image formation algorithms requires either complex simulation tools or access to proprietary specifications and calibration methods for industrial scanners
- Deterministic methods fail to accurately simulate inconsistences such as beam-hardening, partial volume effect, and scatter.
- Challenges:
  - Scanner information is very difficult to obtain for academic research.
  - Existing simulation codes exist but are very complex requiring months to learn.
- Our goal is to provide a user-friendly, visual interface to the MCNP code designed specifically for generation of data sets for validation of luggage-screening image formation methods.
- Advances F3 Thrust area through development of methods to optimize the entire detection system.
- Comparison of results with known values shows accurate physics treatment and noise simulation.

Technical Approach

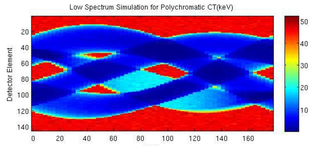
User friendly Research Tool:

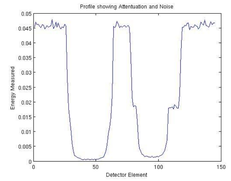
- Geometry, materials, and settings are easily defined without knowledge of MCNP code or its complexities.
- User may run their simulation using a GUI interface, rather than the command line.
- Standards values such as characteristic X-Ray spectrums are provided.

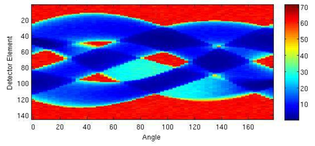


Quantitative Results:

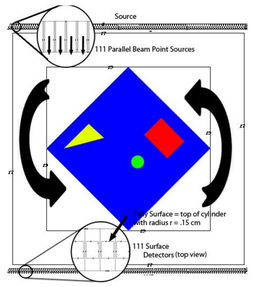
- Physics of photon interaction are mimicked by MCNP.
- 2D profiles compare with those measured experimentally as provided by other research.







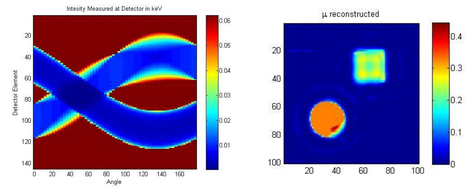
Geometry:



- Generic 2D geometry to test machine-independent inversion techniques.
- Surface detectors measure equivalent of integration across all energies and particles.
- 145 parallel beam sources and detectors.

Verification:

Reconstruction using iterative methods provides correct attenuation values.
60 angles of projection, each with 10^8 particles sent.
Two materials: H_2O and TNT.



Runtime Environment: 4 Quad-Core 2.3 gHz processors(AMD Opteron 8356) share between users. Running 64-bit Red hat Linux Enterprise Linux 5
Uptime = About 50 hours (50 minutes for each angle) for Relative Error = .0010

About Monte-Carlo N-Particle

- Export controlled transport code from Las Alamos National Laboratory
- Program input and outputs are ASCII based text files and are run from command line
- Individual particles undergo a "random walk". Average behavior and statistical analysis provided as part of results.
- Requirements: Requires 2.3Gb of hard disk space and 128 Mb RAM

Work flow of Discussed Research Tool:

Geometry and simulation parameters modified via GUI. → User input is converted to MCNP text input format. → Python program batch creates and runs MCNP input files, one for each rotation. → ASCII out from each simulation is parsed for relevant data. CSVs provided as output.

Accomplishments Through Current Year

- Framework including source and detector elements, and rotational geometry developed.
- Validation of output through comparison with known results verified ability of MCNP to achieve desired results.
- Shift from command line to graphical user interface in early December 2010.

Future Work

- Comparison of output results with industrial machines would allow significant progress to be made in further verifying generated data.
- More work must be done to ensure that scatter accurately models real-life interactions.
- GUI will be expanded to include more options for better usability.

Opportunities for Transition to Customer

This research creates an opportunity for researchers to access a more accurate simulation method than previously available. Its use will contribute to better threat detection methods in the luggage screening process.

Open Source

Once finished, the tool described in this research will be open source. Its use and documentation will be available for free download. Users will need to obtain a copy of MCNP1.5, which is export controlled by the US Department of Energy.

Publications Acknowledging DHS Support

Christopher Mutzel, Oguz Semerci, Eric L. Miller, "A Simulation Tool for Parallel-Beam Computed-Tomography Based on MCNP", student poster presentation at Research2Reality RICC 2010, DHS ALERT Center of Excellence and Gordon Center for Subsurface Sensing and Imaging, Northeastern University, Boston, MA, Oct 17 2010.

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