A Volume Clearing Algorithm for Muon Tomography

D. Mitra¹ (IEEE Senior Member), K. Day¹-², M. Hohmann² (IEEE Member)
¹ Department of Computer Science, Florida Institute of Technology
² Department of Physics and Space Sciences, Florida Institute of Technology

Introduction

• Millions of packages enter the US every day, but only a small percentage can be scanned without slowing down the process.
• Nuclear material can be easily smuggled by using lead shielding to hide the emitting radiation.
• There is a need to see through lead shielding without being intrusive or time consuming.

Muon Tomography

• 3D scanning method uses naturally occurring muon showers.
• Muons passing through a dense material scatter in its trajectory.
• A muon tomography station (MTS) records incoming and outgoing paths of muons.
• Point and angle of scattering is recorded where the projected incoming and outgoing rays come closest (POCA).
• POCA Algorithm: Analyzing high-angle scattered points shows image of the densest materials.
• A prototype cubic foot detector has been built at Florida Tech using Gas Electron Multiplier detectors positioned above, below, and on two sides of probed volume.

Method & Result

Scattered and Non-scattered Tracks

Data acquired at Muon Tomography Station

With five objects placed on central plane

Lead, Tungsten, DU, Tin, and Iron

Green Voxels: No scattering material

Red Voxels: Threat

Blue Voxels: Not-sufficient data yet

Problem & Goals

• We have no control on the slow and sparse incoming muon flux.
• Visualizing sufficient scattered POCA points in target volume satisfactorily takes long time.
• Muons with unscattered straight tracks are typically ignored by reconstruction algorithms.

Question 1: Can the straight tracks be used to clear some regions of the observed volume?

Question 2: Can we qualify if the scan time is sufficient to clear a volume, and if not, which area(s) to focus looking into with further incoming muons?

Algorithm Volume-clearing:

// Input: Set E of coincidence events; each event is (A_p, D_p, A_o, D_o) where A_p, D_p are angle and point on a detector of the incoming muon, and A_o, D_o are those of outgoing ray of the same muon at another detector;

// Probed volume V with voxels v_m: m ≤ M;

// Threshold parameters: POCA angle α, POCA counts in a voxel c, tracks count in a voxel t;

// Output: Classified voxels in V for threat / cleared / insufficient-information types

// Ray tracing part of the algorithm

1. For each event in E do
2. Draw lines l_i using A_p, D_p and l_o using A_o, D_o;
3. Find POCA point and angle of scattering between l_i and l_o respectively as [p, Φ];
4. If Φ > threshold angle α
5. Increment POCA count C_m of voxel v_m;
6. Else
7. Ray-trace R between detector points D_p to D_o;
8. For each voxel v_m on the ray path of R Increment straight-track count T_m of voxel v_m;
9. End For loop; // over voxel-wise countings
10. End For loop; // on events

// Decision making part of the algorithm

8. For each voxel v_m in V
9. If C_m > t then v_m is “threat-type”;
10. Else if T_m > t then v_m is “cleared”;
11. Else v_m is “insufficient-data”;
12. End For loop; // over voxels
13. Return the voxels’ status in V

Conclusions & Future Work

• We can clear more voxels in a given period of time than we can find sufficient scattering (POCA) points within threat voxels.
• Algorithm volume-clearing provides the evolving scenario as muons come in, and also is highly parallelizable.
• Suspicious threat voxels get indicated early enough for further waiting on information near those regions.
• Quality and locations of insufficient-data type voxels may determine when to terminate a scan.
• We will develop automated decision making process regarding when to stop the scanning based on statistics and machine learning.

References