
AMD
Fusion 11
DEVELOPER SUMMIT

EXPLOITING ACCELERATOR-BASED HPC FOR ARMY APPLICATIONS

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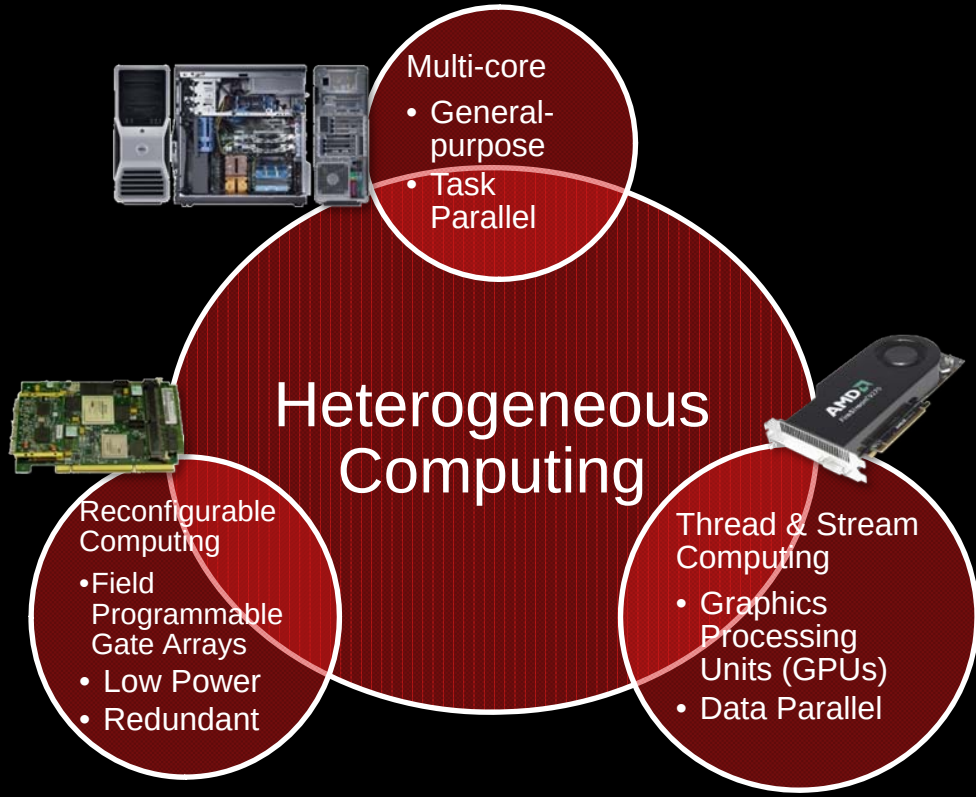
OUTLINE

- Motivation
- Ongoing Investigation
  - Investigation of Algorithms
  - Octree Algorithm
- Ballistic Threat Simulation
  - Early Prototype
  - Quadtree Search Algorithm
  - Application-Specific Ray Tracer
- Combined Simulation + Visualization
- Results

MOTIVATION

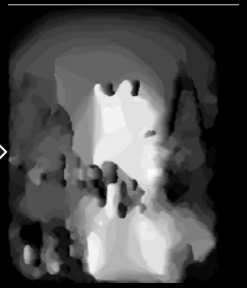
The power of supercomputing in the hands of the Army warfighter

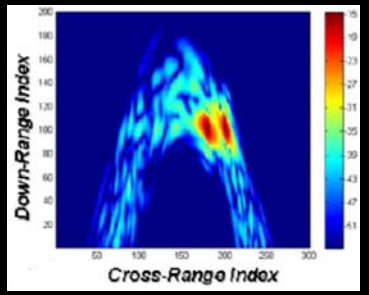
ONGOING INVESTIGATION

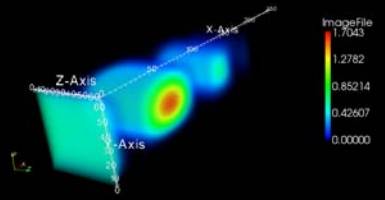


- Ongoing 2+ year investigation of GPGPU technology
  - Collaboration/support from BDT and HPTi
- Spanned 3 generations of processor architectures
- Investigation includes:
  - Hardware (Nvidia and AMD/ATI)
  - Programming environments (CUDA, Brook+, OpenCL)
  - Software/algorithm analysis, design, optimization
- Objectives:
  - Investigate hardware performance for Army relevant HPC applications
  - Develop approaches to software design and optimization
  - Develop in-house expertise with GPGPU technology
  - Leverage expertise of government, industry and academic partners

- **Computational kernels investigated by ARL across range of Army HPC applications:**
  - **Encryption**
  - **Image registration**
  - **Monte Carlo**
  - **N-Body dynamics**
  - **Seismic**
  - **Radar image processing**
  - **Ballistics**
  - **Ray tracing**
  - **Electromagnetics**

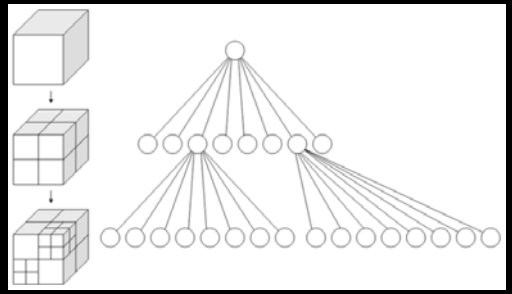




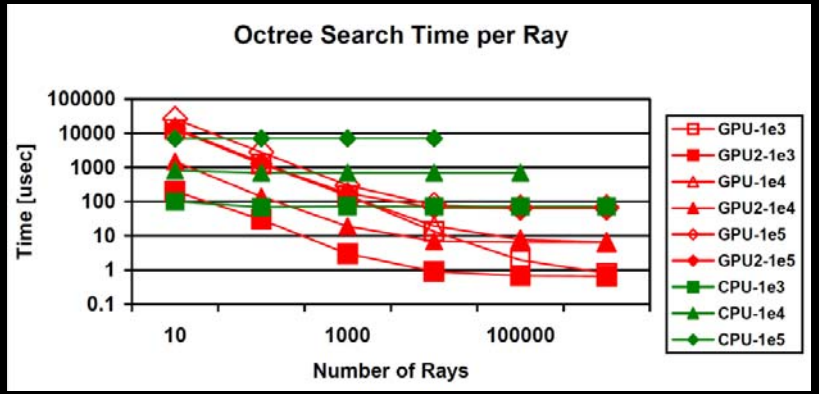


OCTREE ALGORITHM

- Octree used to represent the recursive bisection of space in 3 dimensions
- Algorithms using octree require tree traversal techniques
- Accelerating data structure for 3D spatial search
  - Application to ray tracing
- Octree partitions 3D space

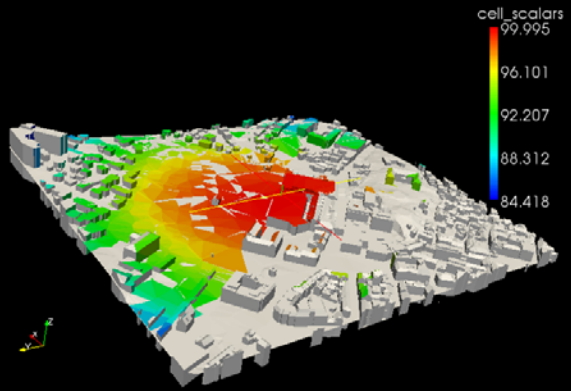


3D space partitioned into octree



BALLISTIC THREAT SIMULATIONS

- **Problem:for a given set of known threats within an urban environment, determine the threat probability at every location**
- **Depends on:**
  - **3D polygon representation of the environment**
  - **Line-of-sight paths**
  - **Specific ballistic models**
  - **Dependent on specific ballistic models**
- **Applications to research and training**
  - **Requires user interaction with the calculation**



BALLISTIC THREAT SIMULATIONS

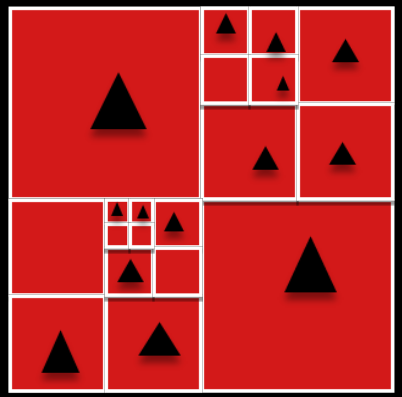
- Components of the calculation
  - First-hit ray tracing to compute line-of-sight / distance
  - Ballistic model(s) for hit probability
  - Accelerating data structures and tree search algorithms
    - Choose quadtree – maps well to 2D cityscapes
    - Adapt octree algorithms from earlier work for use with quadtree

INITIAL PROTOTYPE

- Constructed initial prototype using OpenCL to perform the threat probability calculation on a GPU
- Probability mapped/associated to each polygon in the 3D map
- Algorithm:
  - For each threat, identify polygons with line-of-sight path
  - For each such polygon, apply ballistic model to determine probability of a ballistic hit
- Key component is the quadtree search for ray-polygon hit calculation
- Results post-processed for visualization using Paraview/VTK

QUADTREE SEARCH ALGORITHM

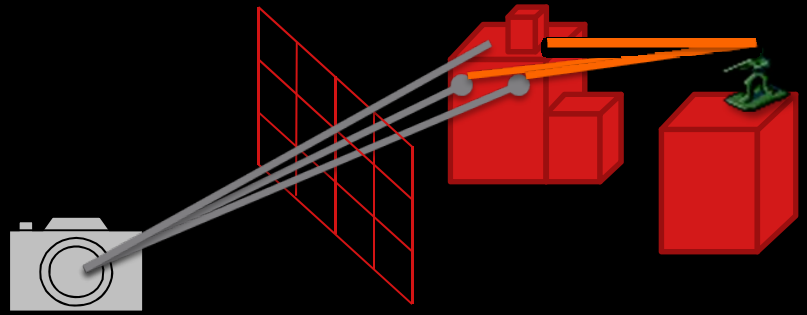
- Quadtree pre-processed on CPU and sent to GPU
- Each cell has an associated start and final index into triangle list
- Performance improvements can be obtained by moving tree data to local memory (not triangle list)



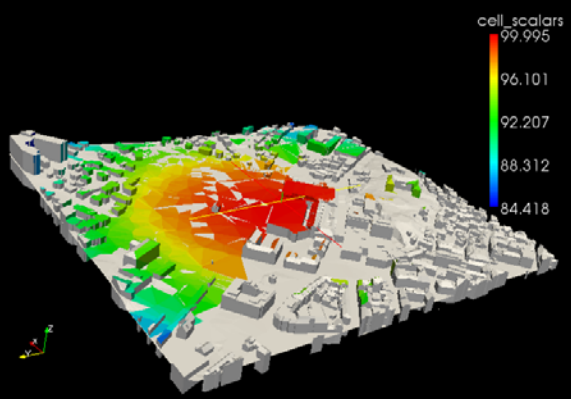
Processor / Method	Execution Time (sec)
CPU / linear	323
CPU / quadtree	34
GPU / quadtree	3.4

VISUALIZATION-DRIVEN CALCULAITONS

- Issues with the initial prototype:
  - Partial triangle occlusion leads to false/imprecise probability
  - Calculation performed for non-visible locations that may or may not be of interest.
- Idea: let the visualization drive the calculation
  - For each pixel in rendered image, cast a ray from the camera into the scene geometry
  - The cast a ray to each threat accessible via a line-of-sight path
  - Apply the ballistic model to determine the hit probability to be displayed

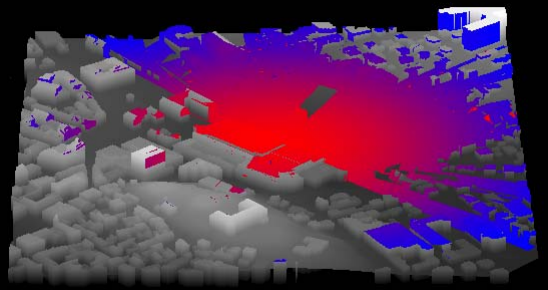


VISUALIZATION-DRIVEN CALCULATION



- How the image was formed:
  - Map copied to GPU
  - Threat probability calculated on GPU
  - Result copied to host
  - Visualization using VTK/Paraview
- Proof-of-concept for simulation

- **How the image was formed:**
  - **Map copied to GPU**
  - **Elevation map generated on GPU**
  - **Threat probability calculated on GPU**
  - **Combined bitmap generated on GPU**
  - **Bitmap copied to host**



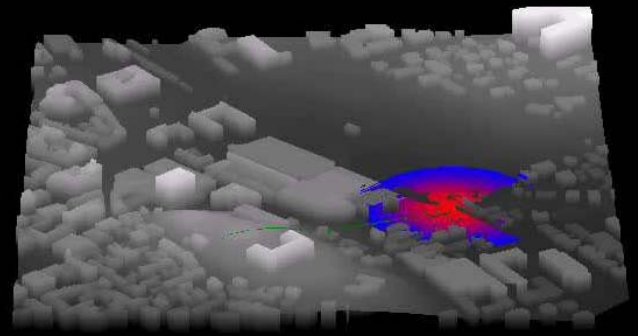
- **Proof-of-concept for <u>combined simulation and visualization</u>**

COMBINED SIMULATION + VISUALIZATION

- Traditional HPC built upon data generation through computational simulation, with visualization as a post-processing step
- GPU-compute capability allows the possibility to tightly couple simulation with visulation
  - Mirrors the OpenCL/OpenGL buffer sharing mechanisms
- Visualization of simulation results can be performed entirely on the GPU
- Combine simulation + visualization opens up interesting applications of GPU-based HPC

DYNAMIC SCENARIO DEMO

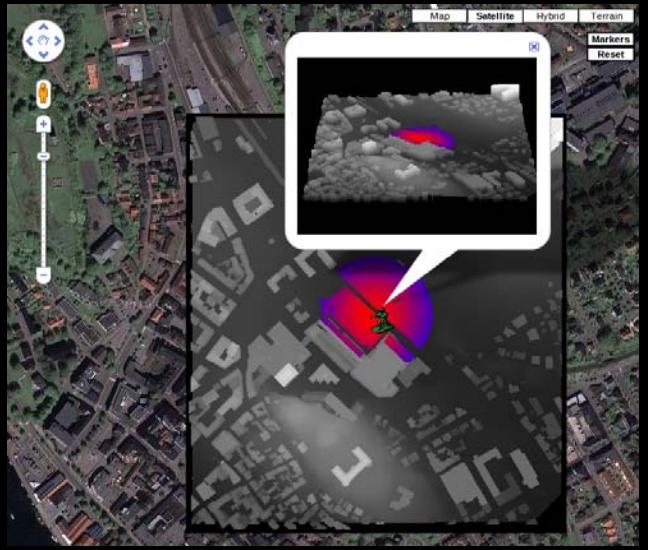
- Dynamic scenario demonstration:
  - Shooter moves along a fixed path
  - Hit probability calculated each frame
  - 4 seconds per frame - ray-traced
  - Bitmaps copied back to host
  - Sequenced into simple MPEG



- These initial proof-of-concept demonstrations lead to current work investigating OpenCL/OpenGL buffer sharing for entire simulation + visualization on GPU

INTEGRATION WITH USER INTERFACE

- **Demonstrations integrating the ballistic threat simulations with external user interfaces**
  - **Interactive performance using Google Maps**
  - **Cross-platform, browser-based API for portability (Android, iOS, PC)**
  - **Scenario and model selection using simple controls**



ONGOING WORK

- Focus on small, powerful workstation-class systems to be placed in critical locations requiring performance
- Exploiting CL/GL buffer sharing
- Tightly coupled simulation and visualization
- Remote access from low-power smart phones and other devices
- Scenario and model selection request

SUMMARY

- ARL investigating use of heterogeneous CPU/GPU platforms
- Application-specific first-hit ray tracer for training in urban environments
- Accelerator data structures to obtain high performance on GPU systems
- Prototype demonstrated combined computation and visualization
  - Cuts out post-processing of simulation data
  - Visualization-driven calculation
- Cross-platform capabilities on diverse, heterogeneous CPU/GPU architectures
- Remote access, scenario generation, and graphical display on mobile platforms

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