An efficient algorithm to compute the viewshed on DEM terrains stored in the external memory

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What is viewshed?

- Points that are visible from an observer of the terrain
- Limited by interest ray
- Calculated with points height
Applications

- **Viewshed Applications**
  - Help on sitting multiple observers problem
    - Cell phone or internet towers
    - Fire watch-tower
    - Military applications
    - Sensors network
    - Surveillance positioning

- **Technological advances in data collection (LiDAR)**
  - Huge terrain models
Objective

- To develop a method to calculate the viewshed on DEM terrains that exceed internal memory size
- DEM
  - Simplicity
  - Large use
Original Viewshed Calculation

- First, all points on terrain are considered not visible
- Terrain sweep is based on “sweep rays” by the xy plane
- “Sweep ray” is a vertical cut on terrain
Original Viewshed Calculation

- In each cut we determine the visible points
- If the line of sight (LOS) $OP$ ($O$ – observer and $P$ – current point) doesn’t intercept any other point, $P$ is visible
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Internal memory algorithm problem

- Random access – inefficient on terrains bigger than the internal memory
- Sequential access is faster than random access
- Random access on disk is about $10^6$ times slower than the same access in internal memory
I/O Efficient Algorithms

- The bottleneck are the I/O operations (not the CPU processing)
- The complexity is determined by the number of I/O operations
I/O efficient algorithms complexity

- Aggarwal and Vitter model
- Complexity orders
  - $O(\text{scan}(N))$ – read $N$ contiguous items on disk
  - $O(\text{sort}(N))$ – sort $N$ contiguous items on disk
- $O(\text{scan}(N)) < O(\text{sort}(N)) << O(N)$
- I/O efficient algorithms try to achieve $O(\text{scan}(N))$ or $O(\text{sort}(N))$ complexity
Proposed algorithm

- Uses external memory lists
- Sort algorithm (mergesort)
- STXXL library – Standard Template Library for Extra Large Terrains
Proposed Algorithm

- Read the terrain sequentially
  - Determine the process order of each cell
  - Insert each cell in an external memory list $L$ with the respective order of processing (index)
  - Sort $L$ by the index
  - Calculate the visibility of each point using an algorithm similar to original
Index determination

- Ray 0’s points:
  - Order = 0,1,2,...,10

- Ray 1’s points:
  - Order = 11,12,..,21

- \( \text{Index} = N \times \text{RAY} + D \)
Index Determination

- The index of each point is easily determined.
- One cell can be intercepted by more than one ray.
  - It is inserted more than one time with different indices.

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Visibility Computation

- Algorithm similar to the original using LOS
- All visible points are stored in another external memory list $L'$ that is sorted by coordinates $(x,y)$
- The final result is a matrix with all points on the terrain. Visible points are indicated by 1 and not visible by 0.
Results

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Results

- EM_VS is 3.5 faster than WRF_VS
- EM_VS is 3.5 faster than Haverkort et al. method
  - Simpler and easier to implement
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Results

2 GB Terrain

Running Time [sec]

ROI (radii of interest)

WRF_VS  EM_VS

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References


