Multiple Observer Siting on Terrain with Intervisibility or Lo-Res Data

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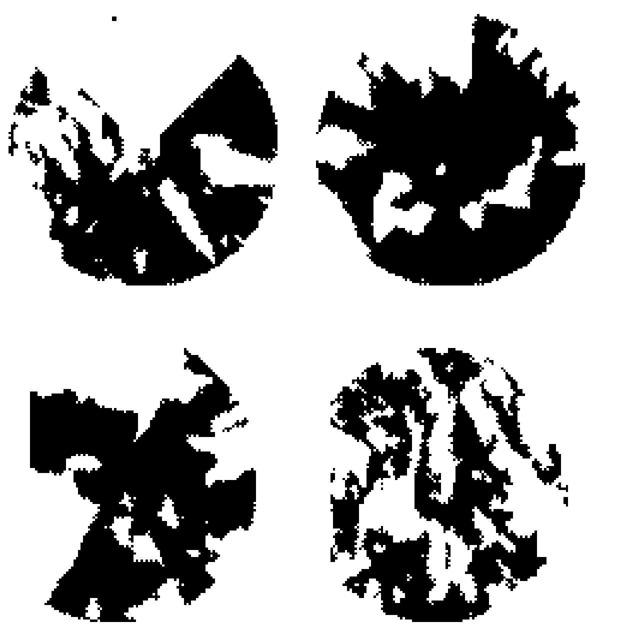
http://wrfranklin.org/siting/

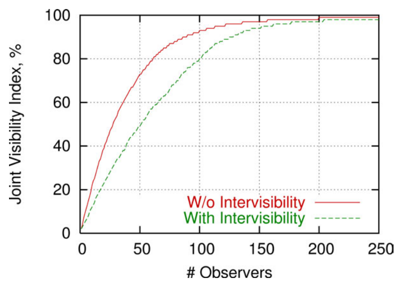
Preliminaries

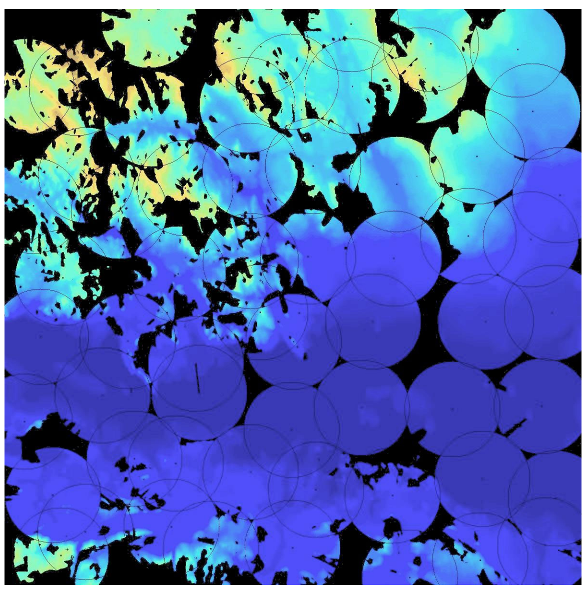


- viewshed,
- visibility index (vix),
- $\mathcal{R}$: radius of interest,
- $\mathcal{H}$: observer and target height.
- No vegetation.
- No curvature correction, since that's easy. (For each target at a distance D from the observer, subtract $\frac{D^2}{2E}$ from its elevation, where E is the earth's radius. Relative error: $\left(\frac{D}{2E}\right)^2$.)
- Data format: matrix of elevation posts.

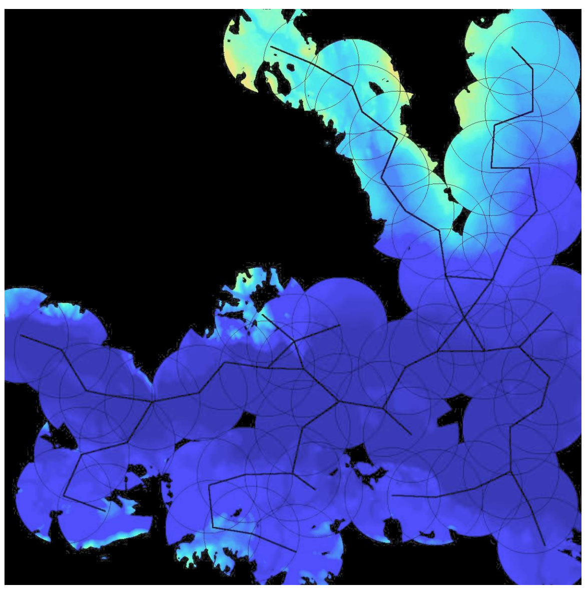
Intervisibility

- Assume an edge between any pair of mutually visible observers.
- Require this graph to be connected.
- *Intervisibility requires more observers.*





W/o intervisibility



With intervisibility

Procedure

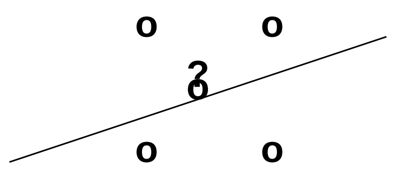
1. VIX calculates approximate visibility indices of every point in a cell. VIX considers each point in the cell in turn as an observer, picks $\mathcal{T}$ random targets uniformly and independently distributed within $\mathcal{R}$ of the point, and computes what fraction are visible. That is this point's estimated visibility index.
2. FINDMAX selects a manageable subset of the most visible tentative observers from VIX's output, to be called the *top observers*. This is somewhat subtle since there may be a small region containing all points of very high visibility, such as the center of a lake surrounded by mountains. Since multiple close observers are redundant, we force the tentative observers to be spread out as follows.
   (a) Choose an appropriate value for $\mathcal{L}$, the desired number of top observers. Experimentally, $\mathcal{L} \approx 800$ suffices to cover 80% of the terrain, while a 95% coverage requires $\mathcal{L} \approx 3000$.
   (b) Partition the map cell into about $\mathcal{L}/\mathcal{K}$ equal-sized smaller blocks. Experimentally, $\mathcal{K} \approx 2$ is good.
   (c) In each block, find the $\mathcal{K}$ points of highest approximate visibility index (as determined by VIX). If there are more than $\mathcal{K}$ points with equally high visibility index, then select $\mathcal{K}$ at random (using a multiplicative hash function of the point's coordinates as a secondary sort key), to prevent a bias towards selecting points all on one side of the block. If a block has fewer than $\mathcal{K}$ points, then return all its points.
3. VIEWSHED finds the viewshed of a given observer at height $\mathcal{H}$ out to radius, $\mathcal{R}$, as follows.
   (a) Define a square of side $2\mathcal{R}$ centered on the observer.
   (b) Consider each point around the perimeter of the square to be a target in turn.
   (c) Run a sight line out from the observer to each target calculating which points adjacent to the line, along its length, are visible, while remembering that both the observer and target are probably above ground level.
   (d) If the target is outside the cell, because $\mathcal{R}$ is large or the observer is close to the edge, then stop processing the sight line at the edge of the cell.

   One obvious "improvement", when the target is outside the cell, would be to move the target in to the edge of the cell before running the sight line. However, this would cause the computed viewshed to depend slightly on $\mathcal{R}$, which looks bad.

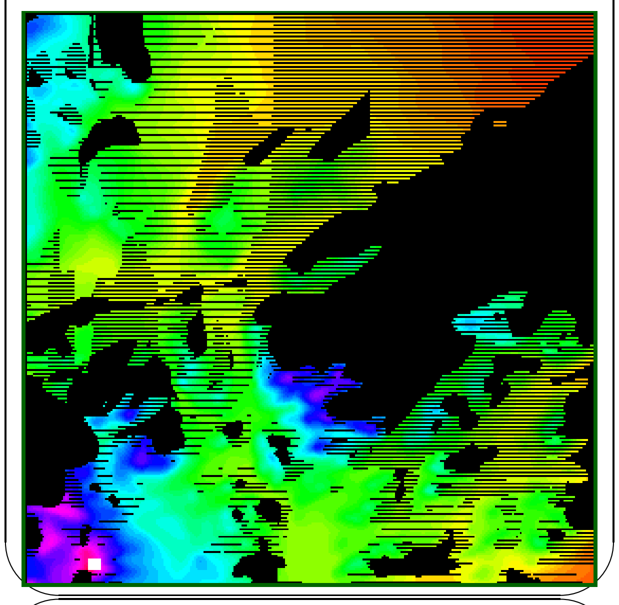
   Various nastily subtle implementation details are omitted. The above procedure is an approximation, but so is representing the data as an elevation grid. (Triangles are no better.)
4. SITE takes a list of viewsheds and finds a quasi-minimal set that covers the terrain cell as thoroughly as possible. The method is a simple greedy algorithm. *(It works for us!)* At each step, the new tentative observer whose viewshed will increase the joint (or cumulative) viewshed by the largest area is included, as follows.
   (a) Let $\mathcal{C}$ be the joint viewshed, or set of points visible by at least one selected observer. Initially, $\mathcal{C}$ is empty.
   (b) Calculate the viewshed, $\mathcal{V}_i$, of each tentative observer $\mathcal{O}_i$.
   (c) Repeat the following until it's not possible to increase $area(\mathcal{C})$, either because all the tentative observers have been included, or (more likely) because none of the unused tentative observers would increase $area(\mathcal{C})$.
      i. For each $\mathcal{O}_i$, calculate $area(\mathcal{C} \cup \mathcal{V}_i)$.
      ii. Select the tentative observer that increases the joint area the most, and update $\mathcal{C}$. Not all the tentative observers need be tested every time, since a tentative observer cannot add more area this time than it would have added last time, had it been selected. Indeed, suppose that the best new observer found so far in this step would add new area $\mathcal{A}$. However we haven't checked all the tentative new observers yet in this loop, so we continue. For each further tentative observer in this execution of the loop, if it would have added less than $\mathcal{A}$ last time, then do not even try it this time.

Uncertainty

- Must interpolate sight line elevations between adjacent posts.



- The particular rule may greatly change the computed viewshed.
- Black/dark grey/light/grey shadow: certainly/probably/possibly hidden



Applications

- Radio transmitters
- Observation
- Visual nuisance mitigation

Advantages of Our Method

- Very fast
- Handles 2000×2000 cells.

Environment

Linux, Matlab, Povray, LaTeX, g++, icc, xv

Acknowledgements

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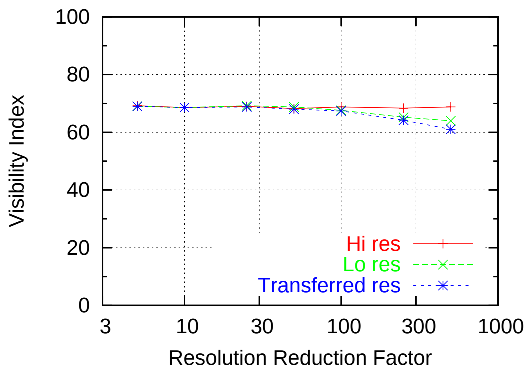
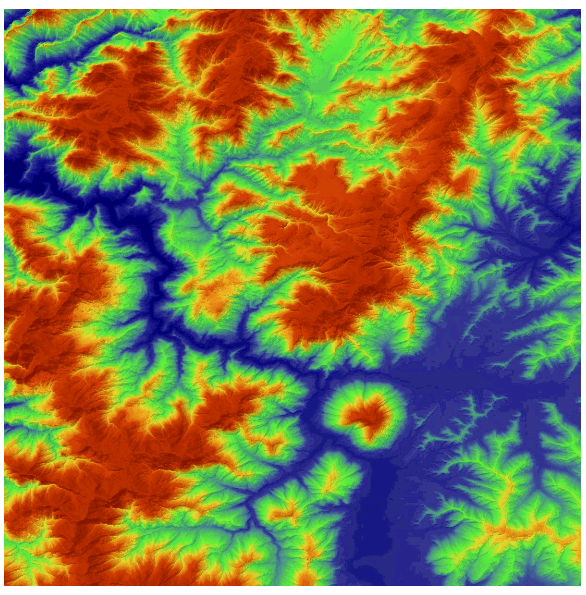
Reducing Vertical Resolution

- Do we need hi vertical resolution?
- Vertical resolutions: 0.1m. .5, 1.0, 2.5, 5., 10., 25., and 50.m.
- $(\mathcal{R}, \mathcal{H})$: (80,10), (100,5), (100,10), (100,30), (100,50), (300,10), (500,50).
- *Conclusion:* little effect.



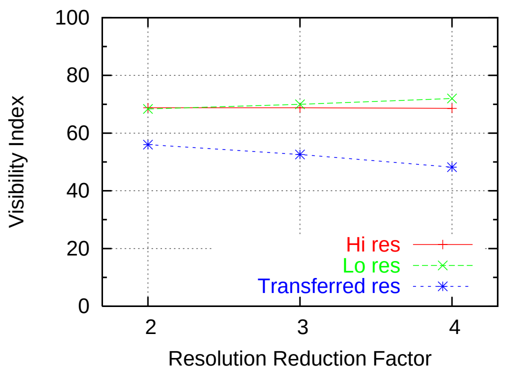
Reduced Resolution Test Case



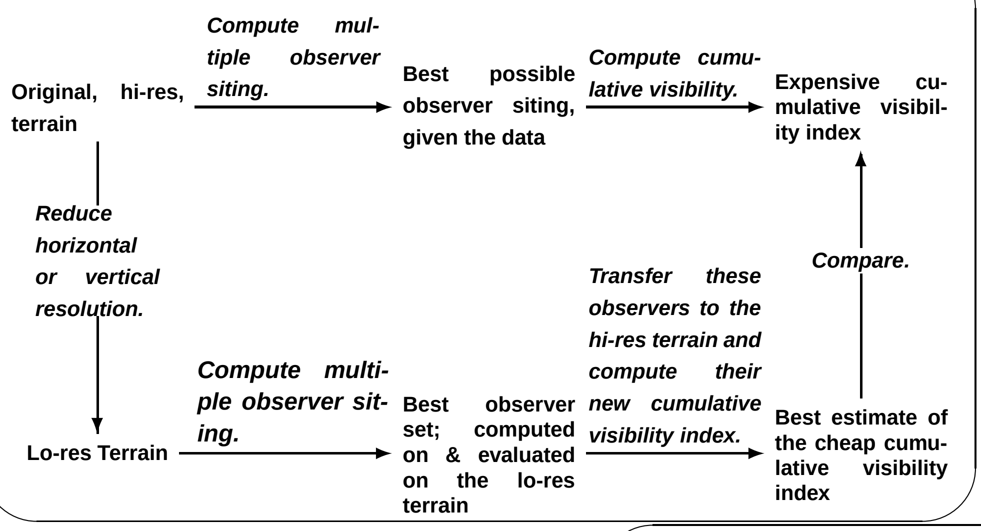
$(41.2822, 42.4899)$, $(-123.8700, -122.6882)$, on the California-Oregon border.

Reducing Horizontal Resolution

1. Reduce from 1201×1201 to 600, 400, 300.
2. Test $(\mathcal{R}, \mathcal{H})$: (80,10), (100,5), (100,10), (100,30), (100,50), (300,10), (500,50).
3. *Conclusion:* Even a factor of 2 reduction impacts the siting.



Reduced Resolution Evaluation Procedure

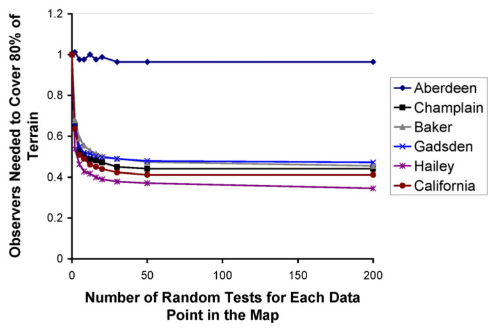


Optimizing FINDMAX

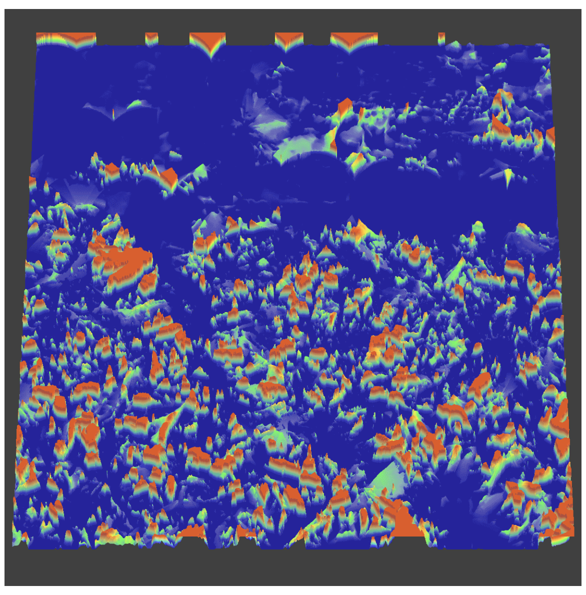
- Force the top observers to be spread out.
- Partition the cell into blocks and select a few top observers per block.
- Many small blocks with 1–3 top observers per block is good.
- Potential for more system-wide optimization.

Optimizing VIX

- Approximating visibility index with 20–30 random targets per observer is adequate.
- Effect of varying the number of tests per observer on the number of observers needed to cover 80% of various cells, for $R = 300$, $H = 10$:



Effect of Higher Observers



Height of each point represents the observer ht at which that point becomes visible (up to some max ht).