Efficient Multiple Observer Siting on Large Terrain Cells

W. Randolph Franklin & Christian Vogt
ECSE Dept, Rensselaer Polytechnic Institute
JEC 6003, 110 8th St, Troy, NY 12180–3590
gis@wrfranklin.org & vogtc@rpi.edu

Introduction

This paper refines our multiple observer siting toolkit for fast *Viewshed* and fast approximate *visibility index* determination, (Franklin, 2002; Ray, 1994). We process DEMs up to 2402×2402, while executing so quickly that multiple experiments are easily possible. Both the observer and target may be at a given fixed height above the terrain. Applications of multiple observer siting include radio towers, terrain observation, and mitigation of environmental visual nuisances. Speed of execution on large datasets is important, since that leads to a qualitative improvement in what's possible; also some other siting techniques may work on only small examples.

Our Siting Toolkit

Consider a terrain elevation database, and an observer, $\mathcal{O}$. Define the *viewshed* as the terrain visible from $\mathcal{O}$ within some radius of interest, R, of $\mathcal{O}$. The observer might be situated at a certain height, $\mathcal{H}$, above ground level, and might also be looking for targets also at height $\mathcal{H}$ above the local ground. Also, define the *visibility index* of $\mathcal{O}$ as the fraction of the points within R of $\mathcal{O}$ that are visible from $\mathcal{O}$.

Our suite of research programs to experiment with visibility and intervisibility algorithms is detailed in Franklin (2002), and summarized here. Its purpose is to select a set of observers to cover a terrain cell. It consists of four core C++ programs, supplemented with zsh shell scripts, Makefiles, and assorted auxiliary programs, all running in linux. VIX calculates approximate visibility indices of every point in a cell. FINDMAX selects a manageable subset of the most visible tentative observers from VIX's output, called the top observers. It forces the top observers to be spread out by partitioning the cell into blocks and selecting the best observers in each block. VIEWSHED finds the viewshed of a given observer at height $\mathcal{H}$ out to radius $\mathcal{R}$. SITE takes a list of viewsheds and finds a quasi-minimal set that covers the terrain cell as thoroughly as possible, using a greedy algorithm, which works quite well.

Vix and Findmax Experiments

Our goal here was to optimize VIX and FINDMAX, and to achieve a good balance between speed and quality. We used six test maps. Five of those maps were level-1 DEM maps, with 1201×1201 postings and a vertical resolution of 1 meter. The maps, chosen to represent different types of terrain, from flat planes to rough mountainous areas, were Aberdeen E, Gadsden

E, Lake Champlain W, Baker E, and Hailey E. The sixth map is a National Elevation Data Set (NED) downloaded from the USGS "Seamless Data Distribution System". From the original 7.5-minute map with bounds $(41.2822, 42.4899), (-123.8700, -122.6882)$, the first 2402 rows and columns were extracted. This map is from a rough mountainous region, and was chosen to test our programs on a larger higher resolution map, since some siting programs have difficulties here.

The VIX experiments tested the effect of varying *T*, the number of random targets used by VIX to estimate the visibility index of each observer. A higher *T* produces more accurate estimates but takes longer. Note that precise estimates of visibility indexes are unnecessary since these are used only to produce an initial set of potential observers. Actual observers are selected from this set according by how much they increase the cumulative viewshed.

Figure 1 shows results for $R = 300$ and $H = 10$. The results were normalized to make the output from the experiments with 0 random tests to be one, which can be considered as the result that can be achieved by randomly choosing top observers for SITE. Every value higher than one is worse than random; every value lower then one is better. Figure 2 shows the Baker test case in more detail.

The purpose of testing FINDMAX was to evaluate the influence of FINDMAX on the final result of the siting observers problem. The two parameters evaluated were the number of top observers and the block size. The number of top observers specifies how many observers should be returned by FINDMAX. A larger number slows SITE because there are more observers to choose from, but may lead to SITE finally needing fewer observers. Therefore we want to keep this number as low as possible. It is computationally cheaper to increase the sample set in VIX than to increase the number of top observers. The block size specifies how much the top observers returned by FINDMAX are forced to spread out. A smaller number increases the amount of blocks on a map and therefore reduces the amount of top observers from a given block. This parameter has no influence on the computational speed.

More details about all these experiments and evaluations are in Franklin (2004); Franklin and Vogt (2004); following are the highlights.

Conclusions

VIX Experiment

- A sample size of 20 to 30 random tests for VIX is a good balance between the quality of the result and the computational speed. Surprisingly this value is good for a wide range of parameters and terrain types.
- VIX improved the result on the level-1 DEM maps in the best case by reducing the amount of observers needed to 39% compared to randomly selecting top observers. The largest improvements were achieved for large or rough terrain for large R or low H. The smallest improvement was achieved on flat terrain.

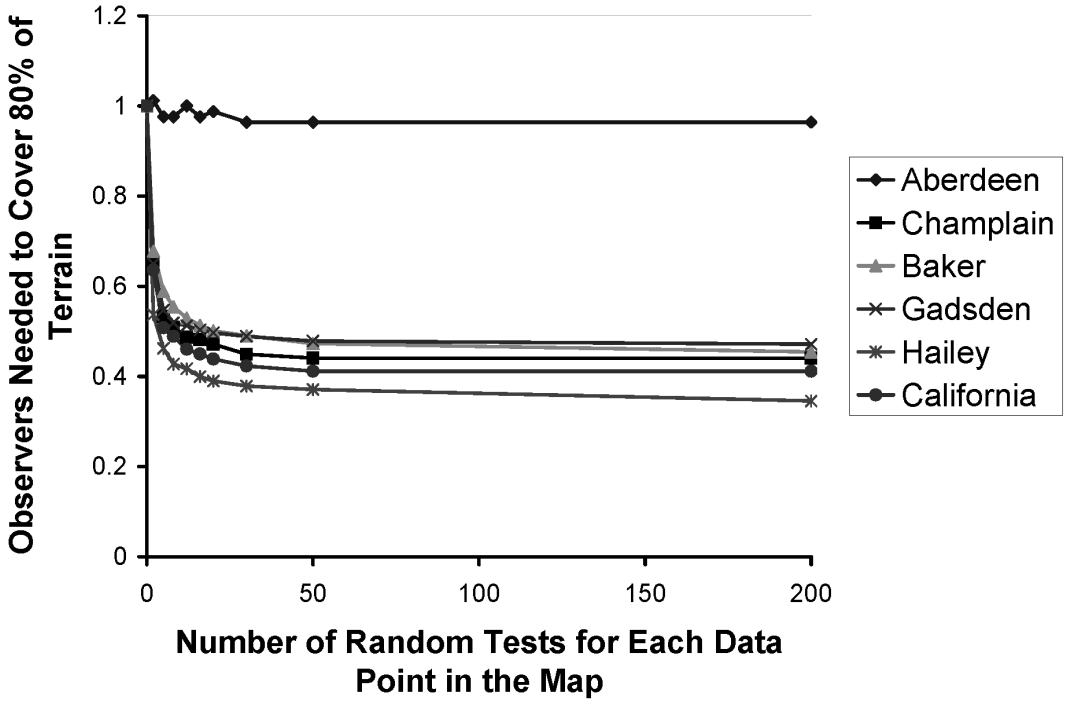

Fig. 1. Effect of Varying the Number of Tests per Observer on the Number of Observers Needed to Cover 80% of *Various* Cells, for $R = 300$, $= 10$

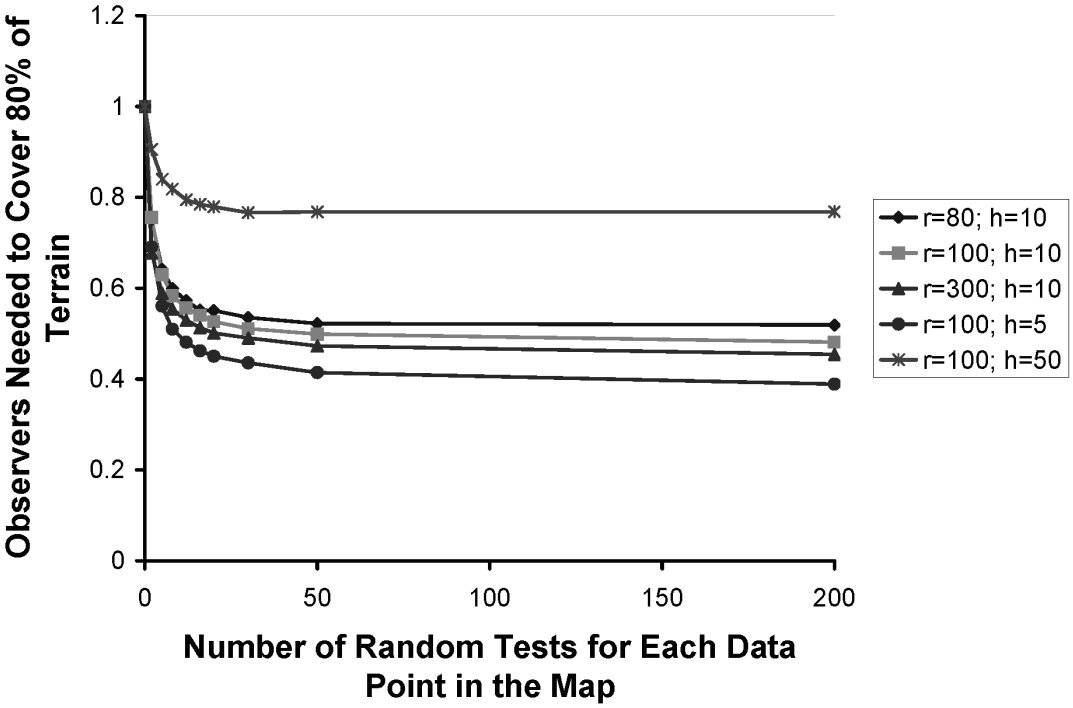

Fig. 2. Effect of Varying the Number of Tests per Observer on the Number of Observers Needed to Cover 80% of the *Baker East* Cell, for Various R and H

- On the larger map the improvement of VIX was even bigger. Possible explanations are that this terrain is the roughest, and that there were fewer top observers per data point than in the smaller maps.

FINDMAX Experiment

- The block size should be chosen to be small, i.e., 2 to 5 observers per block. When covering a larger fraction of the terrain, a smaller number of observers per block is important.
- Increasing the number of top observers in FINDMAX increases the quality of the result, but requires much more time. It is cheaper to increase the number of random tests in VIX, but there is a limitation for what can be achieved by increasing the number of random tests. The best results in the entire experiment were achieved with 10000 top observers. This might not be obvious when comparing the graph of the results from the VIX experiments with the results from the FINDMAX experiments. However, during the FINDMAX experiments a relatively large number of random tests was chosen. Therefore the visibility index for FINDMAX was of a high resolution.

Acknowledgements

This work was supported by the National Science Foundation grant CCR 03-06502.

References

Franklin WR (2002) Siting observers on terrain. *in* D Richardson and P van Oosterom, eds, Advances in Spatial Data Handling: 10th International Symposium on Spatial Data Handling. Springer-Verlag pp. 109–120

Franklin WR (2004) Terrain observer siting research web site. `http://wrfranklin.org/research/siting/`

Franklin WR and Vogt C (2004) Multiple observer siting on terrain with intervisibility or lores data. *in* XXth Congress, International Society for Photogrammetry and Remote Sensing. Istanbul

Ray CK (1994) Representing Visibility for Siting Problems. PhD thesis, Rensselaer Polytechnic Institute