Extended Abstract

Approximating Visibility

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1 Introduction

Consider a raster terrain elevation database, and an observer, $\mathcal{O}$. The *viewshed* is the terrain visible from $\mathcal{O}$ within some distance R of $\mathcal{O}$. The observer might be situated at a certain height above ground level, and might also be looking for targets at a certain height.

The *visibility index* of $\mathcal{O}$ is the fraction of the disk of radius R centered on $\mathcal{O}$ that is visible from $\mathcal{O}$. We estimate this by choosing T random targets within R of $\mathcal{O}$, and counting the number visible. The *visibility map* is an image representing the visibility index of each original point by a color.

Siting radio transmitters is one application of terrain visibility. Here, the identities of the observers of highest visibility index are of more interest than their exact visibility indices, or than the visibility indices of all observers. Locating points at which to hide is a corollary application. For example, we may wish site a forest clearcut to be invisible to tourists driving along a highway that is itself sited to give a good view. Notable earlier work on visibility includes De Floriani and Magillo (1994); Defloriani et al. (1993); Fisher (1993); Lee (1992); Shannon and Ignizio (1971).

The compute-intensive nature of the problem may be seen by assuming that we wish to process a 1201×1201 DEM with $R = 100$. Ignoring edge effects, there are $1201^2\ 100^2\pi = 4.5\ 10^{10}$ observer-target pairs.

The question is, how R, H, and T affect the visibility map. The theoretical solution would start with a formal model of terrain, but that doesn't yet exist. Until then, we must run experiments on sample terrains, hoping that the results are representative. Currently, we visually examine the visibility map and calculate histograms. More sophisticated tests will be used in the future.

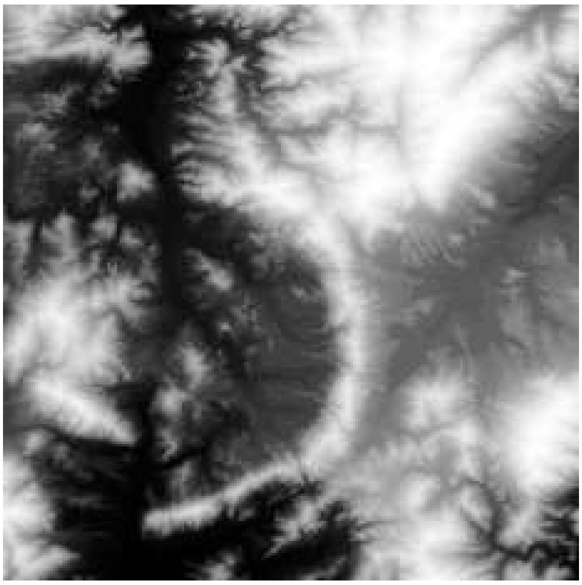

Figure 1: Korea Test

2 The Test Cases

2.1 Korea

The first test case is a 232×232 section of a level-1 DEM, about the same as originally used in Franklin and Ray (1994), and shown in Figure 1. We computed all 36 combinations of $R = 20, 50, 100$, $H = 20, 50, 100$, and $T = 10, 30, 100, 300$. Figure 2 on the following page shows the 9 combinations of R and H for $T = 300$. We observe the following.

1. H, the observer and target heights have almost no effect.

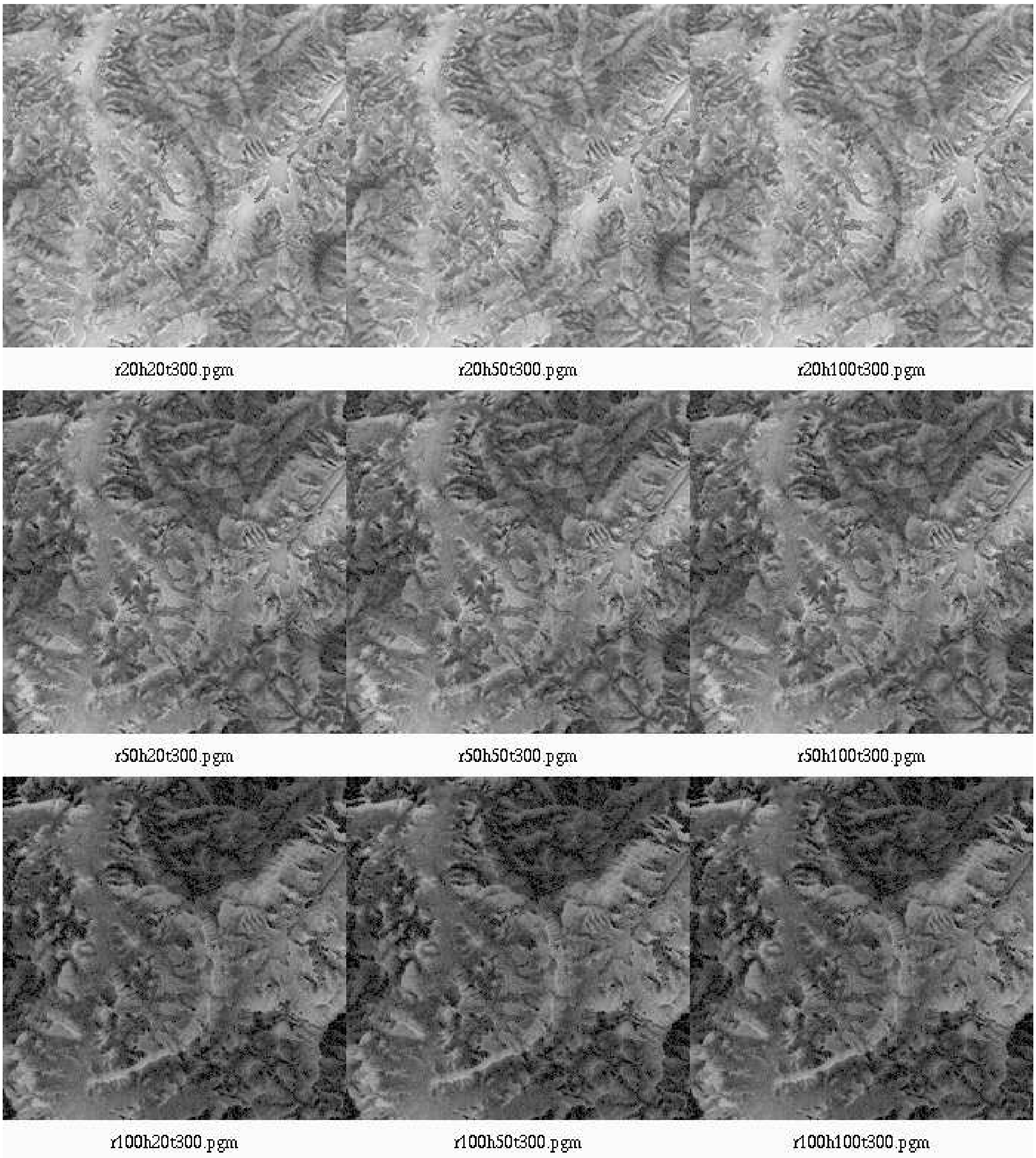

Figure 2: Varying ROI and Observer Height for Korea Test

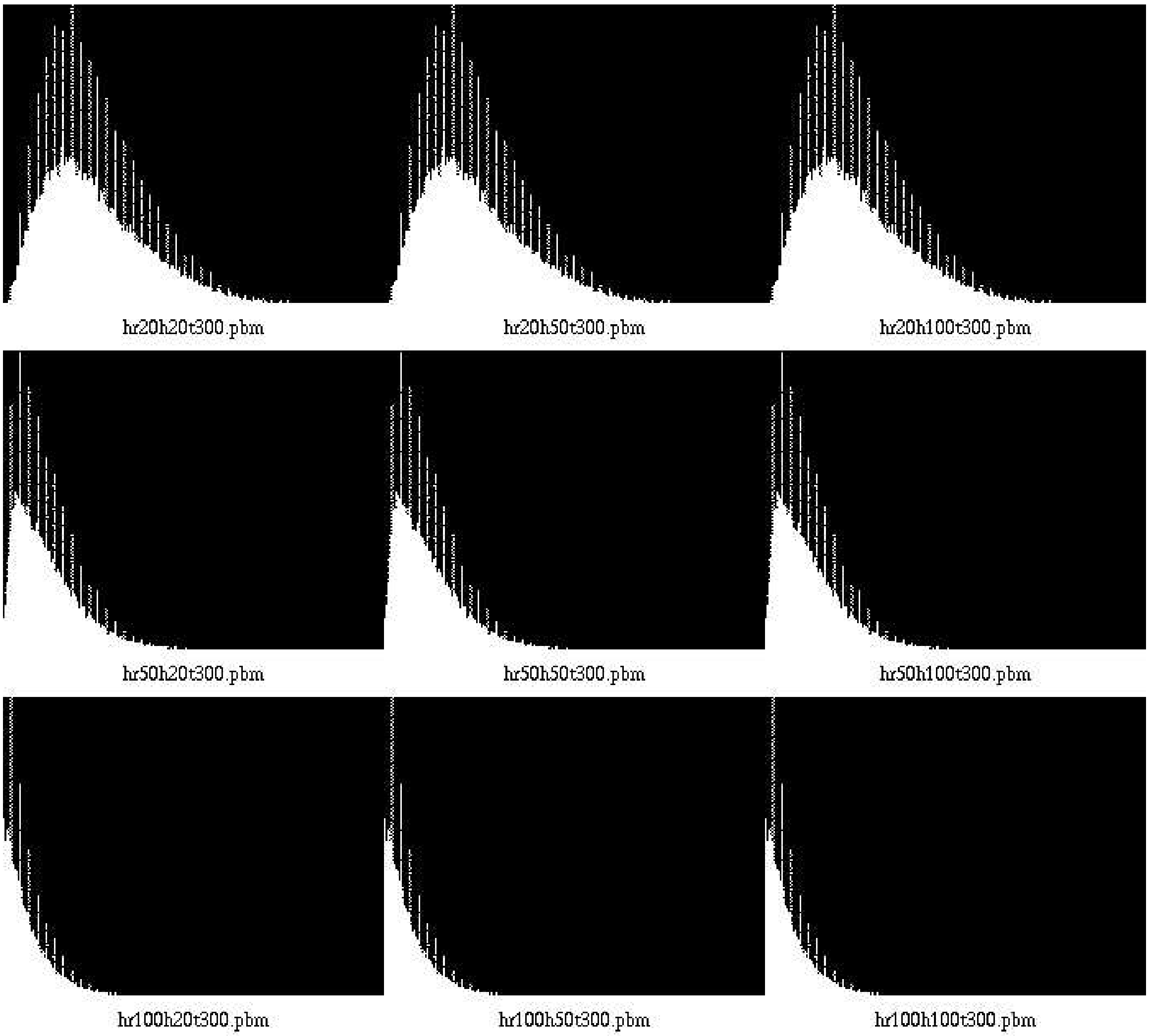

Figure 3: Histograms for Figure 2 on the preceding page

2. R has a large effect.

Figure 3 on the page before shows histograms. (Ignore the spikes.) Again varying H has no effect. Increasing R lowers the average visibility.

Figure 4 shows the effect of varying T, for $R = 100$ and $H = 100$. $T = 10$ is too small. $T = 30$ is perhaps acceptable. There is still an improvement as T increases from 100 to 300. Figure 5 shows histograms. Even only 10 tests per observer has the same visibility distribution as 300 tests. We plan to compare the actual visibilities, but this preliminary result is encouraging.

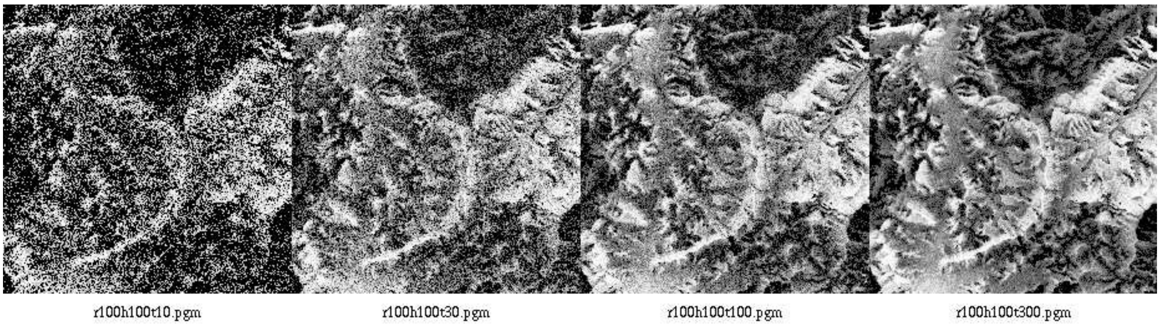

Figure 4: Varying the Number of Targets per Observer

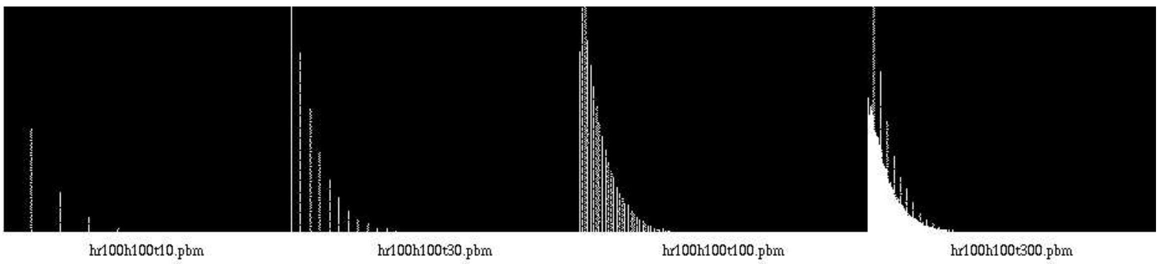

Figure 5: Histograms for Figure 4

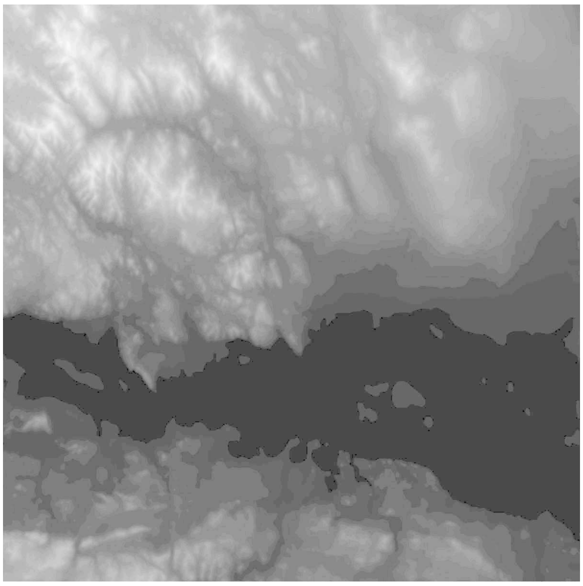

Figure 6: Lake Champlain W Cell

2.2 Lake Champlain West

The second test case was the 1201×1201 Lake Champlain West level-1 DEM from the USGS, shown in Figure 6. Briefly, the results are that increasing R completely changes the visibility map, such as causing finer details to appear. H has no effect. Scaling down the elevations to 1-byte precision causes artificial steps in the visibility map.

2.3 24 USGS DEMs

The final test was on 24 level-1 USGS DEMs, shown in Figure 7 on the following page. Figure 8 on page 9 shows the visibility maps of the 24 cells, using $R = 200$, $H = 50$, and $T = 30$, and Figure 9 on page 10 shows the histograms. All the histograms except for one have the usual exponential distribution. That one cell is half water, which probably affects

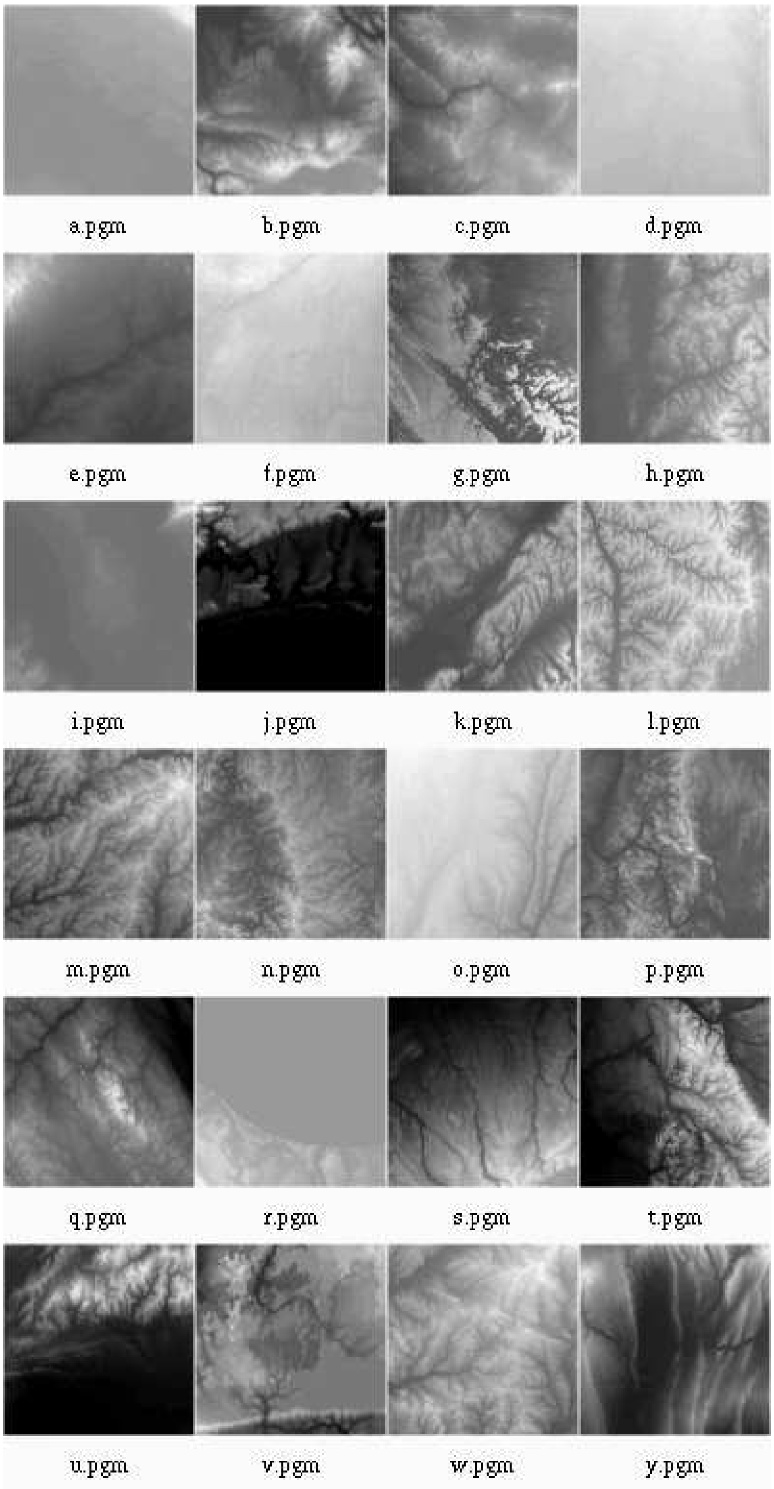

Figure 7: Twentyfour USGS Level-1 DEMs

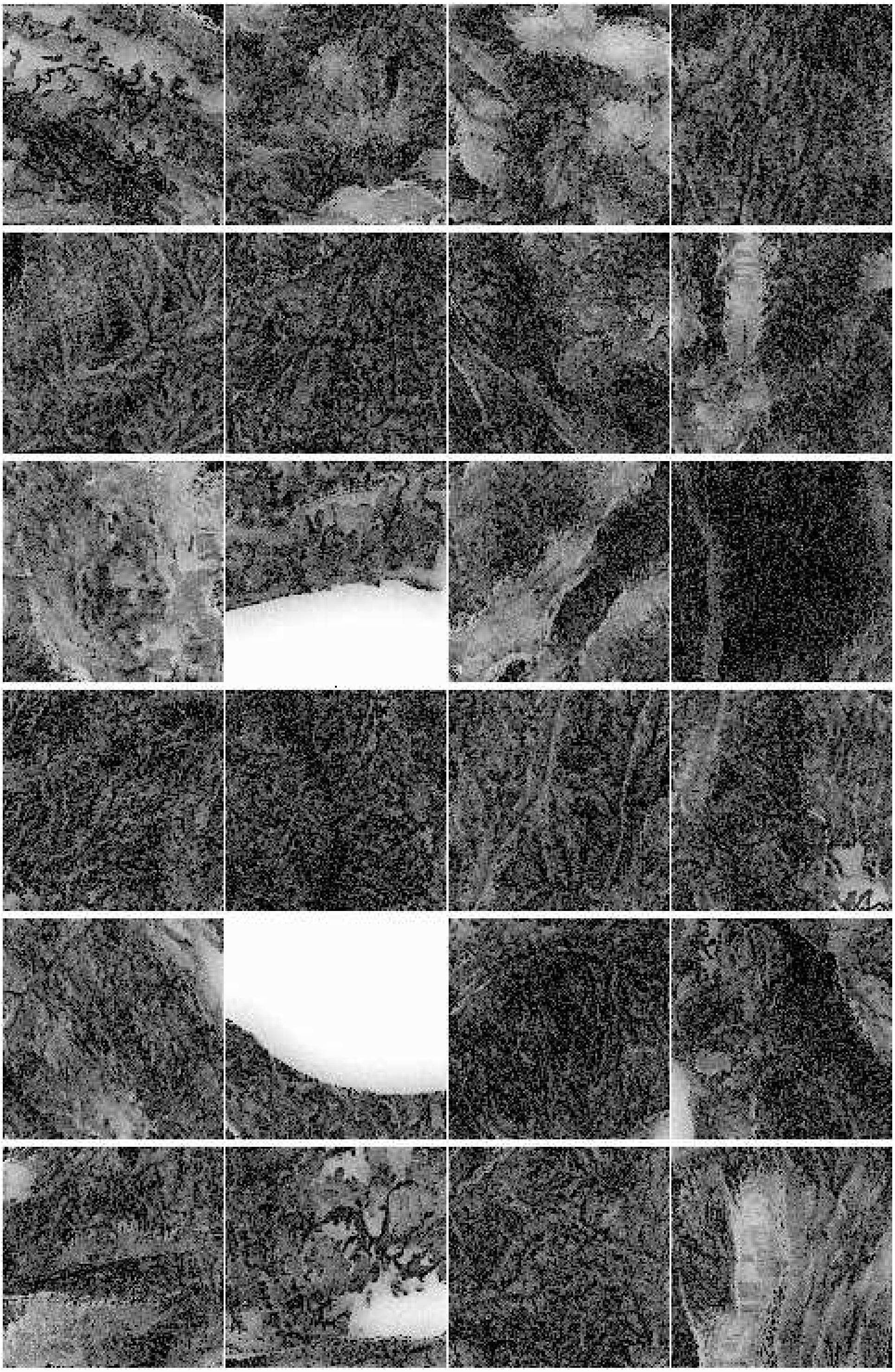

Figure 8: Visibility Maps for Figure 7 on the preceding page

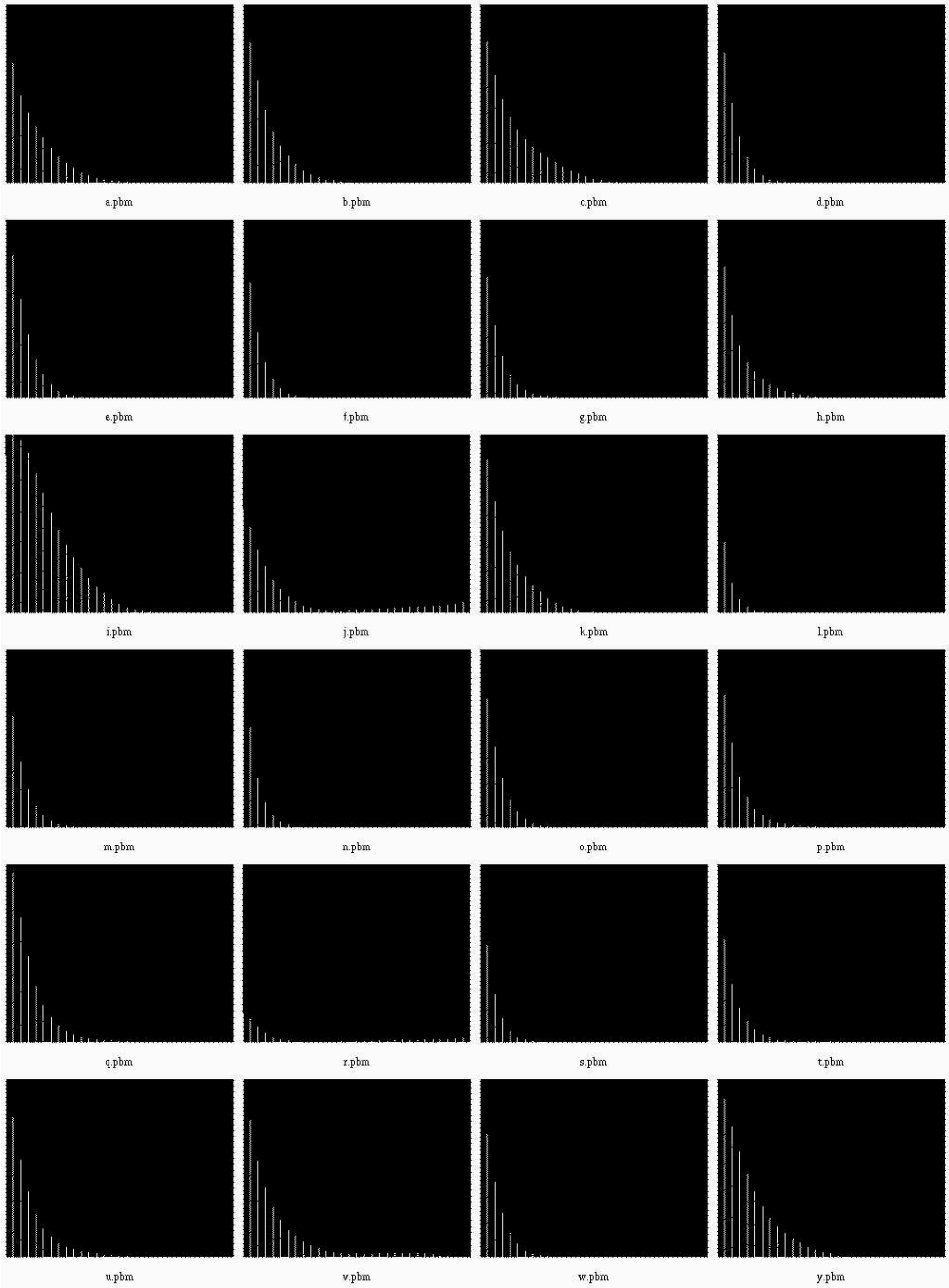

Figure 9: Histograms of Visibility Maps in Figure 8 on the page before

the result.

3 Industrial Engineering & Terrain visibility

We expect to use statistical sampling techniques from production quality control in industrial engineering to choose the minimum number of observer-target tests needed to identify the most visible observers, and then to select a group of observers that covers the whole terrain. Franklin (2000) gives more details.

4 Summary

We have studied the relative importance of various factors in visibility computation, with a view to making the process more efficient. Preliminary results include the following. Scaling down elevations to 8-bits precision doesn't change the general visibility indices, but can cause artifacts. The height of the observers and targets above the terrain has little effect on the result. Changing the radius of interest completely changes the result. A larger ROI leads to finer details in the visibility index map. It also leads to a smaller average visibility index. The visibility indices generally appear Poisson distributed. When we approximate the visibility index by running various numbers of lines of sight from each possible observer to many random targets, 10 targets per observer is insufficient. 30 targets per point appears to lead to a visibility map that resembles the limit case. Nevertheless, there is still a visible improvement on increasing from 100 to 300.

Using these results, we hope to design more efficient visibility index programs.

References

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