Drainage Network and Watershed Reconstruction on Simplified Terrain

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Abstract

We present a new form of terrain compression to preserve the hydrological information that is lost using standard terrain simplification techniques. First, we compute the drainage by using a system of linear equations to determine the amount of water flowing into each cell. The flow is then computed on the inverted terrain which provides an approximation of the ridge network. The drainage and ridge networks are simplified using the Douglas-Peucker algorithm, selecting the most significant points. These points represent our compressed version of the hydrology. To uncompress, we use Over-determined Laplacian Partial Differential Equations (ODETLAP) to "fill in" the missing data points. Our results show that the flow and watersheds on the reconstructed terrain are typically better than original ODETLAP point selection and lossy JPEG2000 compression.

1 Introduction

Terrain data is being sampled at ever increasing resolutions over larger geographic areas requiring special compression techniques to manipulate the data. Typically the effectiveness of a terrain compression technique is how well it minimizes the root mean square or the maximum error between the original terrain and the reconstructed geometry [2]. This metric is not always the best choice for preserving hydrological information, since channels and ridges, essential for the calculation of drainage networks [4], might be lost. For example, selecting two points on opposite sides of a river can flatten the terrain and block water flow. Even without applying a lossy compression technique, drainage information is almost always lost in the data collection process. This causes a problem when trying to compute water flow, in particular when there are numerous small depression in the terrain that are inaccurately modeled as capturing water. The key to our implementation is to compute the drainage network on the inverted terrain, which captures the significant ridges. Omitting insignificant ridges can prevent small upward variations in the DEM (digital elevation model) from impeding water passage.

2 Prior Art

For calculating the drainage network for both the original terrain and the inverted terrain, a D8 model is used, where water at each cell in the terrain can flow in one of a possible eight directions. A flow accumulation grid is computed, where each cell contains an integer corresponding to how many other cells contribute flow to that point. Different from other methods that use flooding [1], our method computes flow using a system of linear equations $Ax = b$ where x is a unknown $N \times N$ length vector equal to the amount of water accumulation at each cell. Matrix A contains which cells receive water from adjacent neighbors and b is the initial flow or "rain" at each cell, usually equal to 1. Watersheds are computed using a very fast connected components program developed by Franklin [3]. We deal with plateaus by determining the spill points and performing a breadth-first search.

Cells above a predefined threshold are considered significant and are added to the drainage and ridge network, which we call the ridge-river network. It is not necessary to store all these cells since they are clustered together and therefore add little value to a point selection compression technique. The Douglas-Peucker algorithm is used to reduce the number of points needed to represent each river segment to within a certain predefined error. The refined points can be stored and further compressed. To reconstruct the terrain we use an implementation of Over-determined Laplacian Partial Differential Equations (ODETLAP) [2]. Each point is considered to be the average of its four neighbors, with the ridge-river points being known.

3 Results

Our reconstructed terrain captures the important aspects of the drainage network while still achieving a high compression rate. The reconstruction also has a more natural and realistic representation of the original hydrology because small insignificant ridges have been removed in the point selection process. This results in larger, fewer

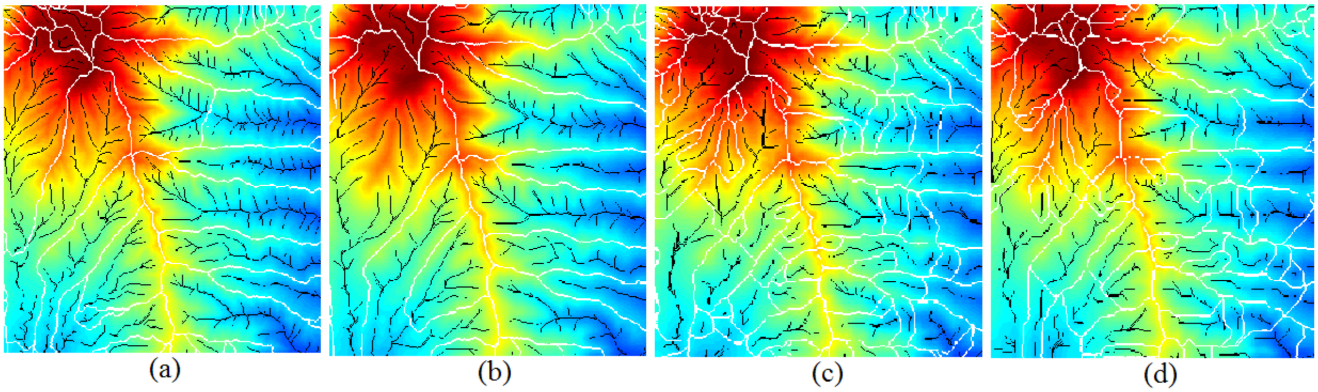

Figure 1: The watersheds(white) and drainage networks(black) on the original and recovered terrains.

watersheds. The recomputed drainage network is also captured accurately, besides the small tributaries which aren't considered of high importance. We can also store the compressed version using far fewer points then the original DEM. The user can define the level of detail and hence the number of points by adjusting the tolerance level for the Douglas-Peucker algorithm.

Figure 1 shows the drainage network computed on four instances of a 400x400 elevation matrix representing a segment of the Hawaiian island of Oahu. In (a) the hydrology was computed on the original elevation matrix. (b) and (c) correspond to hydrology computed on the reconstructed terrain using ODETLAP, where in (b) the points were selected using our ridge-river technique described above, and in (c) using the original ODETLAP method (in each iteration the k "farthest points" were included). In (d) the hydrology is computed on a terrain is recovered from a lossy JPEG2000 compression. All the reconstructions have a similar RMS error of about 8.5.

4 Conclusions and Future Work

The first results showed that the hydrology consistency is better preserved on terrain recovered based on the ridge-river point selection method than using original ODETLAP point selection and JPEG2000. To confirm this observation, we intend to define a metric function to evaluate the hydrology preservation, that is, to verify how the river network and watershed are different on the original and recovered terrains. Another interesting investigation would be to use the drainage network as a model of natural terrain formation. This could be used to extract structure from the terrain for segmentation and division, allowing for better compression.

References

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