A Viewshed Based Classification of Landscapes Using Geomorphometrics

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1. Introduction

Viewshed analyses are a potentially useful way of classifying landscapes for the purposes of geomorphometry as well more common applications in landscape evaluation, scenic quality assessment and associated comparative analyses (Fisher et al., 2004; Germino et al., 2001; Wilson et al., 2008;). It is theoretically possible to quantify a landscape based on openness and the cumulative visibility of a range of geomorphometric indices such as slope, aspect, curvature, roughness, ruggedness, altitudinal range, peakiness, etc (Wood, 2002, Fisher et al., 2004). This can provide the user with an indication of both how open the terrain is and what the precise characteristics of a landscape are that are visible from any point on a terrain surface. This could be implemented using standard, off-the-shelf viewshed analysis tools available in most proprietary GIS software, but the processing overheads, particularly in regard to the extremely long run times involved, where t = years rather than hours or days, make this an impractical proposition even with the most powerful processors. Of course, parallelisation of viewshed algorithms has been shown to be effective in reducing the time required for such analyses (Ware et al., 1996; Kidner et al., 1997; Ware et al., 1998) and distributed GRID computing offers still further reductions in overall run times (Rana and Sharma, 2006), but these methods do not lend themselves easily to most users of desktop GIS. Much effort has been put into developing faster and more efficient viewshed tools in GIS (Huanping et al., 2007; Izraelevitz, 2003) using a variety of algorithms such as tracking in, tracking out, approximation of line of sight, reference plane and block partitioning. This paper describes an alternative approach that utilises a novel voxel-based viewshed algorithm that can significantly reduce overall run times to acceptable levels and allow interactive, real-time evaluation of viewsheds on a standard desktop PC with large terrain models consisting of several million cells.

2. Methods

The algorithm developed uses efficient ray-casting and voxel modelling techniques popularised by realistic 3D computer games developed during the 1990s. In the voxel surface model, each of the raster cells in a digital terrain model are projected as a series of vertical columnar elements whose vertical and horizontal surfaces can be independently checked for partial visibility. At moderate cell resolutions this model produces results which are effectively indistinguishable from more sophisticated (though not inherently more accurate) interpolated surface models. Ray-casting is an efficient method of ensuring that only the parts of a terrain surface potentially visible from any viewpoint are considered in calculating the viewshed, and that calculations are not unnecessarily reproduced. The judicious combination of these techniques reduces viewshed runtimes to a fraction of those offered by algorithms available in common GIS packages such as ArcGIS and MapInfo. Individual viewsheds are accelerated to the point where observer or feature locations can be interactively auditioned in real time. This also makes "viewshed transforms" a practical possibility on a modest desk top PC, whereby the cross-visibility of every terrain cell from an observer position on every other terrain cell can be mapped. This opens up a host of sophisticated visibility-based landscape assessments that would hitherto be so time-consuming as to be impractical.

The resulting efficiencies realised means that the voxel viewshed transform is able to out-perform the equivalent calculations required by ESRI's ArcGIS software by a factor of approximately 1300. One of the immediate implications of this increase in viewshed algorithm efficiency is the ability to perform real time viewshed analyses across relatively high resolution terrain surfaces, where the total number of cells is in the region of $n \times 10^6$. This is shown in Figure 1 and can be used to interrogate terrain data and animate viewsheds in real time. The advantages of the voxel-based model are also realised in the model's ability to incorporate calculations of both plan and profile area of features visible in the landscape, and modify these according to distance decay functions. This allows the user to load feature data representing any surface feature or index and calculate:

1. the number of distinct classes visible;
2. a discrete count (e.g. the number of individual features); and
3. a continuum (e.g. the proportion of a surface).

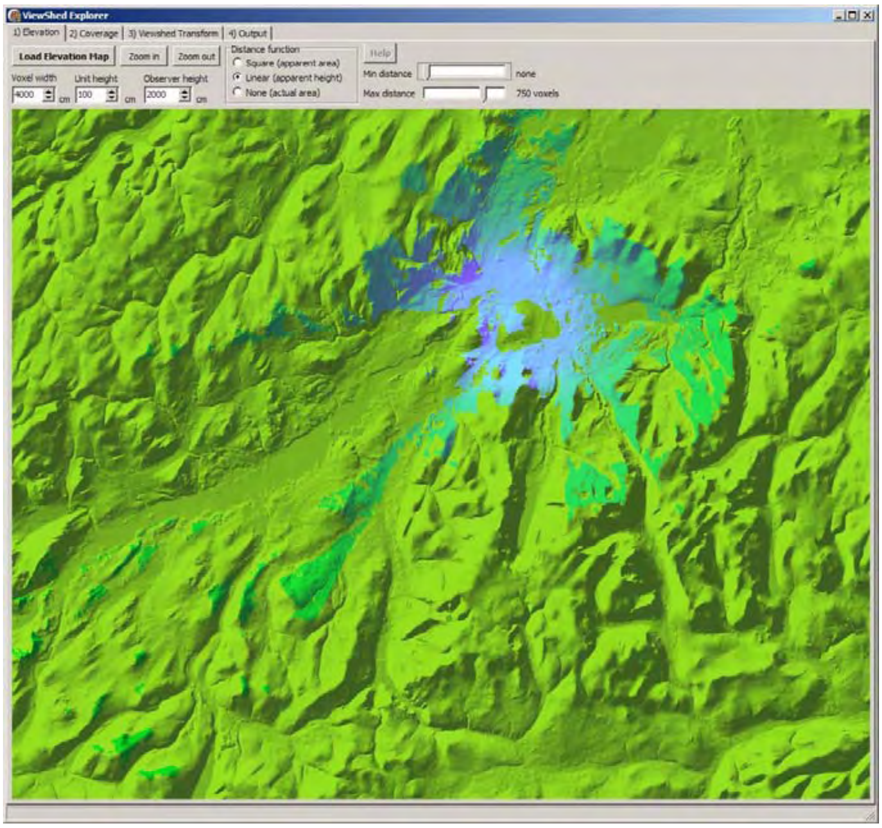

Figure 1. Voxel viewshed tool used to interrogate terrain data and produce real time viewsheds for a 6,000 x 10,000 cell DEM

3. Study Area

Example applications are given for the Cairngorm National Park in northeast Scotland. The Cairngorm is a high mountain plateau composed mainly of granitic rocks which is deeply incised by glacial troughs and bowls. The high plateau is the largest area of the UK above the 4000 foot contour and is nationally important for its unique arctic flora and fauna. The area is designated as a National Nature Reserve, a Site of Special Scientific Interest and was recently designated as a national park. A 5 metre resolution digital surface model and 5 metre resolution digital terrain model created from Synthetic Aperture Radar data are used to describe the land surface and surface significant features including forest and artificial structures, such as buildings and other structures, that project above the underlying terrain surface. An example is shown in Figure 2 together with a general view of the terrain. A sample dataset measuring 15 x 15 km (3,000 x 3,000 cells) is used here.

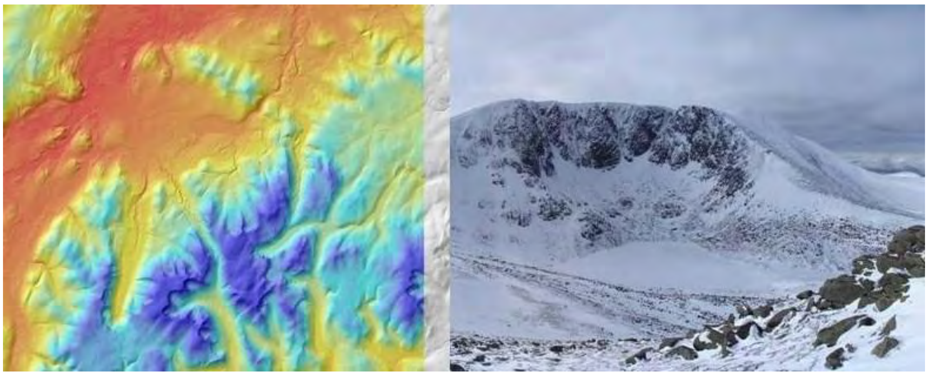

Figure 2. Cairngorm National Park and sample data

4. Results and Discussion

Results from the Cairngorm show that it is possible to classify landscapes by visible geomorphometric features. While the example runs at 5 metre resolution are possible using a ‘scavenger’ network of separate machines running in parallel on sub-samples of terrain data to speed up run times, the 1300 fold speed increase over conventional viewshed tools means that analyses can be run in a matter of days rather than years, making this level of analysis a practical proposition. The sample data for the Cairngorm National Park shown in Figure 2 are used to derive and extract a suite of terrain indices including overall openness, altitude, slope, aspect, curvature and surface significant features. Cumulative visibility totals for each of these terrain indices are shown in Figure 3 and results for surface significant features are shown in Figure 4.

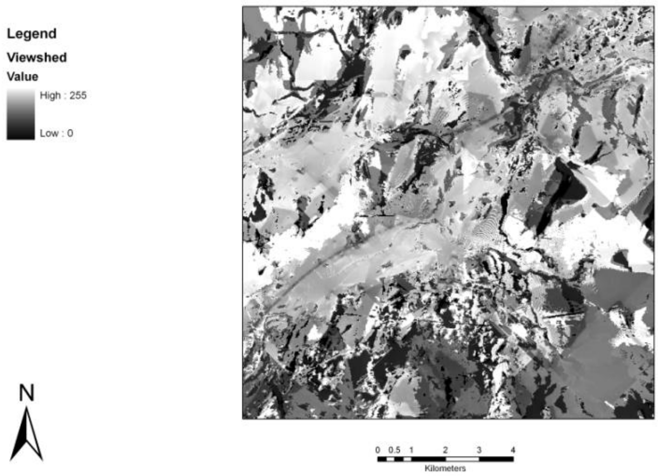

Figure 3. Openness

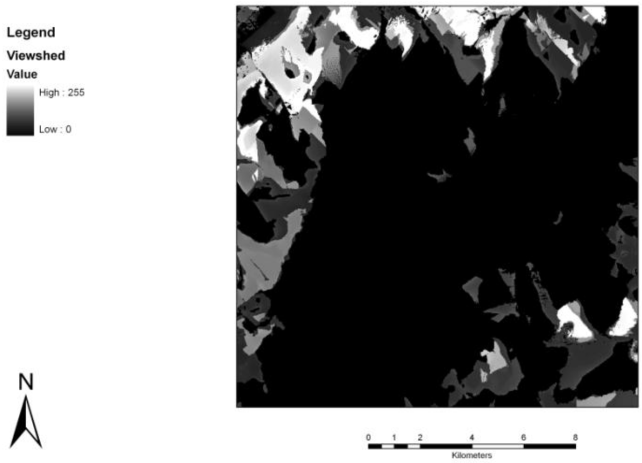

Figure 4. Surface significant features

This new algorithm can be used to generate detailed geomorphometric analyses across large, high resolution terrain models based on openness and what surface features are visible within the cumulative viewshed. This has a range of potential applications beyond geomorphometric studies including the calculation of openness for exposure modelling, radar and cellular communications, siting of viewshed critical facilities such as cell masts, observation towers and radar installations, evaluation of zones of visual influence (ZVIs) for obtrusive developments such as wind farms, landscape assessments based on a knowledge of what is visible from where, landscape planning and decision support, and comparative analysis of contrasting geomorphological regions.

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