# New Horizons for the Standford Bunny : A Novel Method for View Analysis

Neil Sang[1]

[1]James Hutton Institute, Aberdeen, AB15 8QH
Tel. (+44 (0) 844 928 5428)  Fax (+44 (0) 844 928 5429)
neil.sang@hutton.ac.uk, http://www.hutton.ac.uk

## Summary:

Visualisation and Visual Analysis are placing new demands on spatial data, requiring new analytical methods and with this a need to identify potential sources of uncertainty. This work applies techniques developed in the field of computer graphics to analytical problems at the landscape scale. A series of occluding horizons seen in perspective may be considered as a 2D graph in the view plane. Edges of this graph function to mediate ‘Visual Topology’, which is defined as the topological relationships between objects in the 2D view plane. Visual Topology may be stable under changes in viewpoint, scale and resolution. It therefore presents the possibility of developing landscape metrics that are view specific but which are also stable with respect to local viewpoint change and are thus amenable to mapping. A method is presented for the computation and mapping of Visual Topology that may be of wider relevance to visibility analysis.

**KEYWORDS:** Visibility Analysis, Landscape, Topology, Perception, MAUP

## 1. Introduction

Moran et al. (2003) describe the selection of an appropriate unit of analysis as the “greatest challenge to theory in human ecology”. It is a challenge which must be undertaken if an understanding of processes at the landscape scale is to be achieved since, by definition, landscapes are formed by the interaction of human and natural processes. Unfortunately information on the component parts of such processes is often not available in the same units (Sang, Birnie et al. 2005) leading to Modifiable Area Unit Problems (MAUP) or may not be appropriate to the intended use. One end use of increasing significance is landscape visualisation.

Perspective influences the scale at which different parts of the map data is seen, and landform can mask parts of the data (Germino, Reiners et al. 2001).  It could be, for example, that a polygon on the map is classed as heather, but the segment of the polygon actually visible in the view is predominantly rough grassland. These sources of uncertainty may be given focus by any particular perspective view. If one wishes to automatically detect such issues or automate production of perspective statistics for analysis, a data structure is needed to give computational access to the view.

The question may be addressed by considering the view as a 2D plane, and thence may be split into a scalar and topological component. As with cartographic projections, geometry will vary continuously with view point change, but the topological relationships between objects may be stable until some event changes this, e.g. occlusion. In cartography, topological change is generally to be avoided. In visual perception it is, according to some seminal research (Kaplan and Kaplan 1982; Gibson 1986) an event of particular interest.

## 2. Graph Topology of Horizons

Visual Topology (VT) is used here to describe the spatial relations between objects (or parts of the same object) as they appear in the 2D viewing plane. In a landscape context this topology between a landcover in the foreground and that which it partially occludes. In such a case, a horizon may be visible (if sufficient contrast exists) and such horizons may also intersect each other, as in Figure 1 :

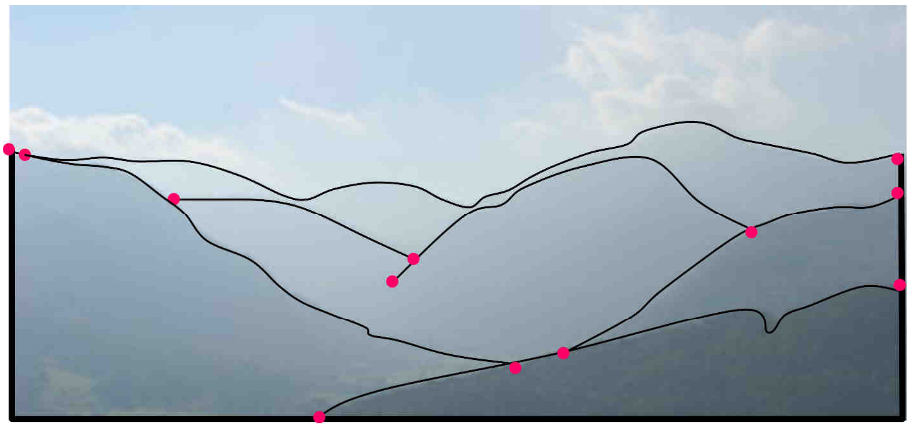

**Figure 1 – The Horizon Graph of a View**

Horizons mediate aspects of the view which have been considered relevant to perception (e.g. fractal index (Hägerhäll, Purcell et al. 2004) or depth of view (Bishop, Wherrett et al. 2000)) and for which one might wish to automatically compute statistics. They also form a graph as in Figure 1, which Sang, Miller and Gold (*subm*) point out is locally stable to view point change. Its topological characteristics may thus be validly mapped to zones. Indeed they represent discontinuities in the visible surface, which make variance, over space, in scalar visual metrics difficult to predict. Sang, Hagerhall and Ode (*subm*) show that the topological complexity of the Horizon Graph (specifically the number of loops) is itself psychologically salient.

## 3. Spatially modelling Horizons and Visual Topology.

When performing visibility analysis on a Delaunay Triangular Irregular Network (TIN) one may assume that, by scanning the mesh from the view point outwards, any object with the same x co-ordinate in *screen* space as a previously projected object, and lower screen space y co-ordinate, must be occluded (as expounded from object graphics to GIS visibility analysis by Madern et al. (2007). Intersect testing can be avoided except for edges which, after approximate testing via the end nodes, might still intersect the current horizon, e.g. line a-b Figure 2i (Madern, Fort et al. 2007).

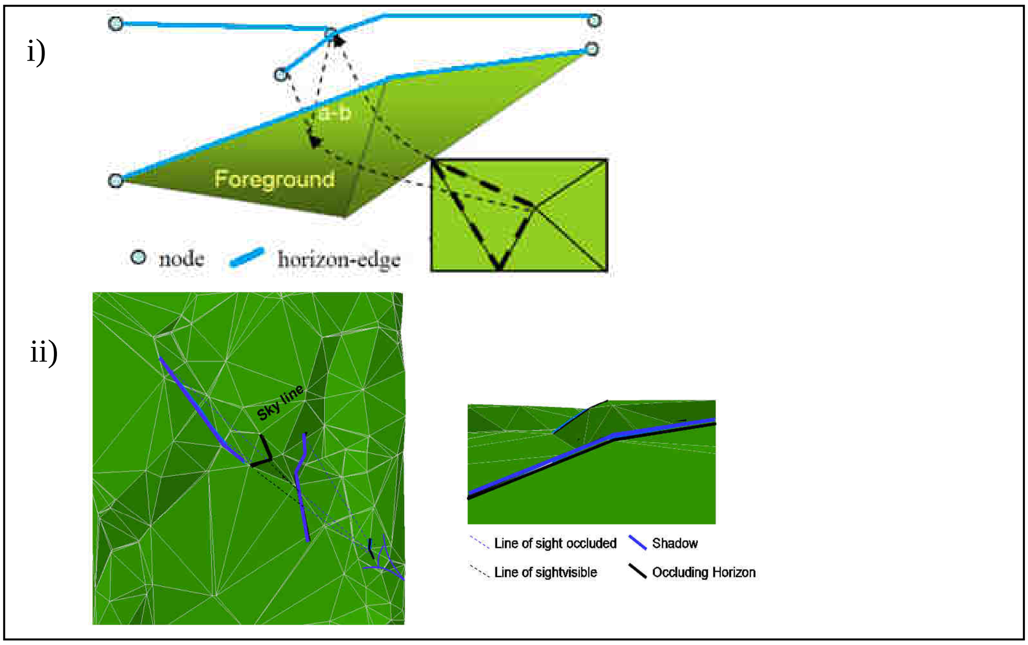

**Figure 2 : (i) Maintaining a current horizon for Hidden Surface Removal and (ii) the resulting information in orthographic and perspective views**

A map of the visible horizon edges, and the edges on which their shadows fall, completely describes the visibility of the land surface in between. So, rather than holding a viewshed as a separate surface, one could incorporate this horizon and shadow information as attributes of the DEM. To determine visibility at any given point, one simply establishes if the first line intersected between that point and the view point is an occluding horizon, if so, the point is occluded, else it is visible (Figure 2ii).

When an intersection is identified the occluded edge may have a pointer attribute set to the memory address of the occluding edge, thus VT is encoded in ‘Shadow-Horizon Links’ forming one or more trees from background to foreground. In Figure 3[1] this is shown by the green lines drawn between the mid-points of each edge, not the points at which the intersection occurs, and so does not always fall along a line of sight spatially. This is intended to emphasise that the links are topological not geometric.

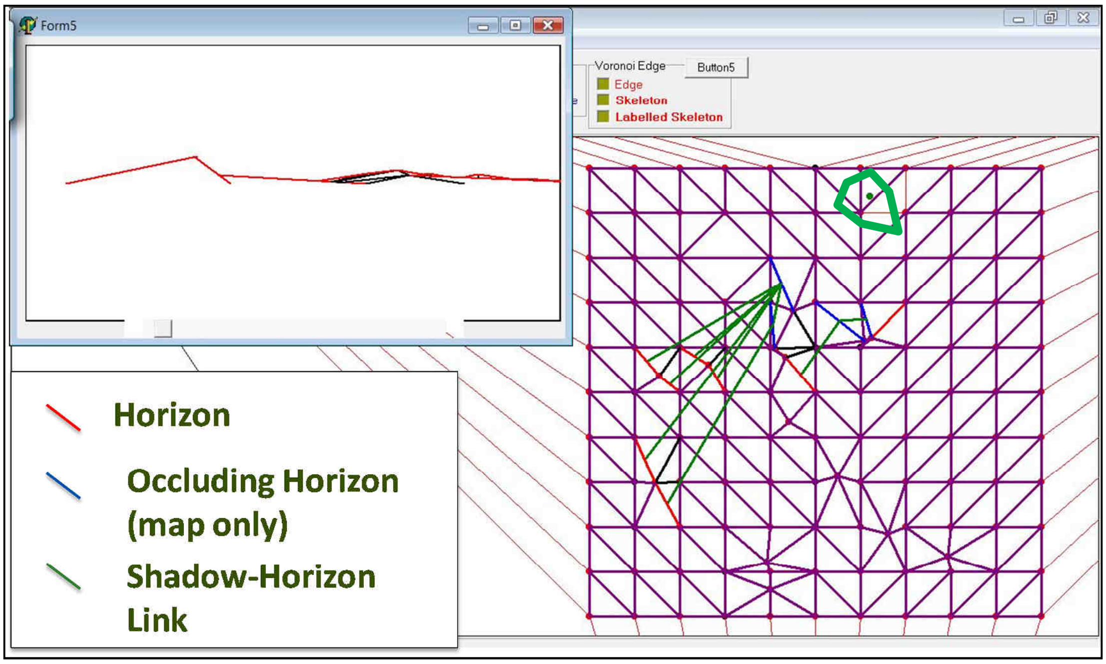

**Figure 1 : Perspective and map views of a horizon graph and Shadow-Horizon links**

## 4. Conclusions

The data structure developed has several notable advantages compared to a raster viewshed :

- The geometry of the view may be recovered.
- Unless there is a topological event, the map in Figure 3 will not change under viewpoint change. The view point (the green point to the top left Figure 3) could thus ascribe an area within which the topological horizon characteristics are stable (illustrated by the green polygon) creating a zonal map.
- The Shadow-Horizon Link can be used to query cross horizon adjacency and, depth of view change. This allows calculation of visual metrics such as those mentioned in section two, but also identification of when map polygons are intersected by horizons and thus when issues of

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[1] Figure 3 contains a screen shot from the author’s implementation of this methodology in VoronoiMagic, a Delphi based Quad-Edge Delaunay TIN modeling environment developed by Christopher Gold, Maciej Dakowisz and others.

MAUP may be present.

- The Shadows, Horizons and their link remain in their spatial context, so may be used as test geometry for potential changes to the visibility map.
- There is no reason why multiple such sets of links cannot be embedded to provide for multiple viewpoints.
- Since, in theory, topological relationships are a-scalar the memory requirement for recording the Shadow-Horizon links is independent of the resolution of the dataset, only the number of edges needed to model the horizons shadows would change.
- The Horizon-Graph is encoded.

Although important research questions remain, Visual Topology presents a potentially new approach to visual modelling in GIS. It allows scene analysis based on a richer representation of visual perception and provides a rationale for landscape reporting units with some measure of homogeneity and scale-independence in their scenic properties.

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## 7. Biography

Neil Sang has worked as researcher in GI Science at the James Hutton Institute (formerly the

Macaulay Land Use Research Institute) for 10 years. His main interest is developing theory and methodology in response to applied problems in spatial analysis, and creating software solutions to deliver these to scientists from other fields. Most recently this has addressed issues of landscape analysis and spatial sampling. This work represents a summary of his PhD undertaken part-time at the University of Glamorgan. He now holds a part-time position at the Swedish University of Agricultural Sciences (SLU), and runs a consultancy in GI Science (www.ansergis.se).