Art in Scientific Visualization of Terrain Data

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Cartographic Information Systems Research Group, University of Hull.

This is a record of an invited exhibition posted by Mahes Visvalingam at the Royal Institution (UK) to accompany the Friday Evening Discourses on :

- **Where Art Meets Science** by Lord Puttnam of Enigma Productions, NESTA on 5 November 1999
- **The Information Age : Public and Personal** by Dr J M Taylor, Director General of Research Councils, Office of Science and Technology **on** 17 March 2000


CISRG members at the Royal Institution in 1999 and 2000 respectively.

The exhibition was repeated by invitation on Friday October 20, 2000 at Trinity House (London) at IAP2000, the annual symposium of the UK Institution of Analysts & Programmers, which is being held in association with the British Computer Society. Mahes Visvalingam is extremely grateful for the support and assistance provided at all these events by John Whelan, who extended the exhibition to include his PhD output in his poster exhibition at the Annual Conference of the British Cartographic Society in September 2002.

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Abstract

The exhibition focuses on one thread of the CISRG's research on Algorithmic Sketching of Terrain Data; it outlines the background to this research and includes pointers to contemporary innovative visualizations of terrain within the UK. The exhibition consists of 24 x 4.5 feet of poster displays, four computer demonstrations, samples of published journal papers and CISRG Discussion Papers, and examples of innovative maps contributed by others. This web site includes posters and links to other sites. It also include two computer demonstrations of line generalisation and segmentation algorithms. (NOTE: This abridged version omits links and references to external sites which are no longer online).

The posters have been reduced both for speedy viewing on the internet and to discourage misuse of copyrighted material, especially those from other contributors. Even so, they provide a good impression of the theme and content of the exhibition.

Background

The images on posters for the Background only had copyright clearance for display at the Royal Institution and are now dated in any case. Their content is summarised here.

Until relatively recently, mainstream Computer Graphics has focused largely on fast interaction with photorealistic visualisations of terrain. Hardware and software platforms for photorealistic rendering of terrain have been available for over a decade. Many mapping agencies are also providing complete national coverage of very detailed map and terrain data. These advances have mad it possible to produce realistic images of terrain. (Illustrations from exhibition have been removed). The same digital technology is being used to visualise other types of data. For example, sonar surveys enable regular monitoring of hazardous objects on the sea bed. (the posters have been omitted)

In contrast, cartographic visualisation has focused on the removal of superfluous data for efficient and effective communication of pertinent information. The succinct depiction of terrain has been one of the major challenges. In the past, it was not feasible to draw all the available data. Instead, cartographic principles of selection, projection, typification and symbolisation were used in purpose oriented depictions of terrain. The skilled drawing of block diagrams and physiographic maps was regarded as a scientific art. Examples of maps which inspired the CISRG research on exhibition included sketches by W H Holmes to illustrate selection and use of multiple projections in route maps by A Wainwright. Symbols to facilitate speedy map reading vary from abstract geometric forms and colours with psychological and keyed meanings to readily recognisable patterns and textures.

A map is a graphic summary which is derived through analysis and interpretation of complex reality. Physiographic mapping involves the segmentation of geographic areas into different types of geomorphic units, such as dissected plateaus, rolling hills and immature valleys with interlocking spurs. Samples of pictorial patterns were often copied and adapted to fit the extent and character of the segmented regions. Example maps from Raisz (1938) and Lobeck (1924) were included in the exhibition. Also on display was a Walker's Map entitled Loch Alsh to Glen Shiel and surrounding area by Keith Gate of Contour Designs. The work of Heinrich C Berann has also inspired research into artistic terrain depiction. Readers may also be interested in Tom Patterson's website.

Many researchers are now seeking to develop distinctive styles for artistic visualisation of terrain on digital media. The exhibition focused on one strand of research within the CISRG which seeks to automate the art of landscape sketching.

4 Algorithms for Sketching Terrain

Painted landscapes seek to evoke an emotional experience of place. Landscape sketches can do the same through the art of caricature, which is also useful in scientific analysis.

The curiosity-led CISRG research was inspired mainly by the traditional block diagrams and black and white drawings of landscapes. Computer emulation of these techniques involves machine vision and an appreciation of how lines should be organised on the image to facilitate wholistic vision and recognition of detail.

It is relatively easy to sketch the skyline and the occluding contours. However, the skilled portrayal of other types of surface contours is still a challenge for automation.

Research to-date suggests that :

1. The major shape-defining convexities and concavities, which define the form of a surface, can be automatically located.

2. by drawing only the parts of terrain profiles which lie on these curvatures, it is possible to generate pleasing and effective sketches.

3. terrain may be animated smoothly in sketch form

4.1 Algorithms for Caricatural Generalisation of Lines

The sketch is a graphic precis of data. One cartographic style for sketching terrain, displays sections of the cross profiles in a profile plot. This ensures that the lines of the sketch lie on the surface of the terrain. The automation of this approach, involves two tasks, namely :

1. The **abstraction of the parts of the terrain profile** which should be displayed.

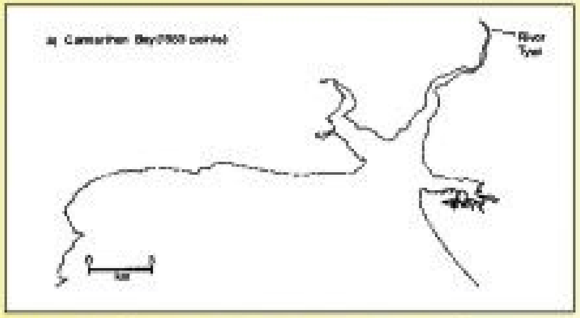
   This has been the main focus of the research to-date within the CISRG.

2. The design of **styles for depiction of these parts**

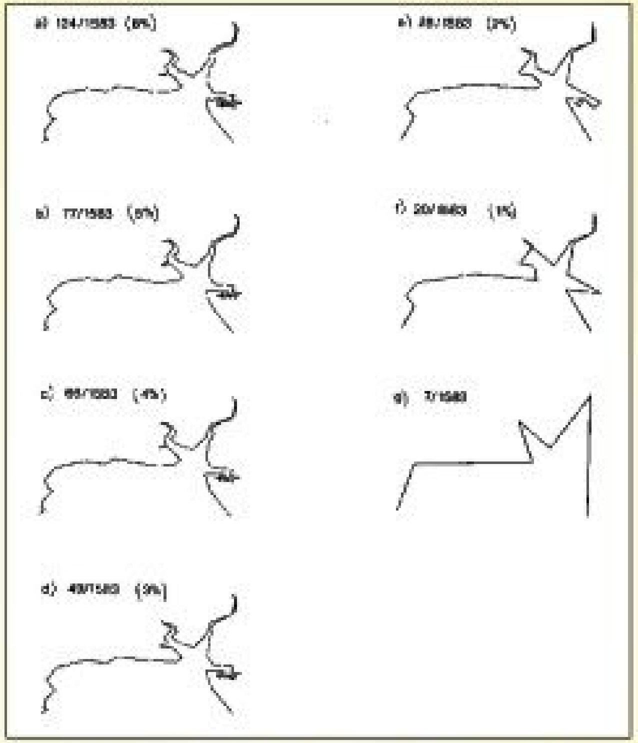
   To-date, the CISRG has only addressed this problem in a limited way since this phase has to be informed by the analytical stage, which is still incomplete.

It is well known that the lines of the sketch should be located where there are significant convexities and concavities. However, the location of globally important curvatures has been a challenge which has absorbed the attention of researchers in Pattern Recognition and in Digital Cartography. The next two panels use the coastline of Carmarthen Bay in Wales to illustrate the outcome of two different algorithms. The order in which they select points, a step at a time, can be seen in the interactive **computer programs on demonstration.**

4.1 Algorithms for Caricatural Generalisation of Lines



DATA: Ordnance Survey, Crown copyright reserved



Source: Visvalingam and Whyatt (1993)

Ramer's Algorithm

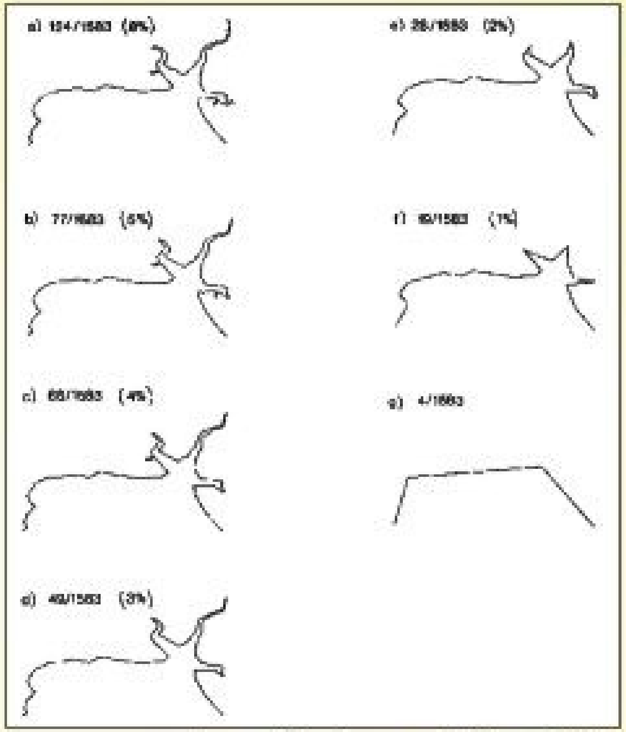
The most widely used algorithm was published in the early 1970s by both Ramer and by Douglas and Peucker. It is based on Attneave's empirical observation that shape-defining points are located at the extremes of line curvature. This extreme point algorithm has been very useful for curve approximation. However, it is not suitable for caricatural generalisation as illustrated here.

4.1 Algorithms for Caricatural Generalisation of Lines

Visvalingam's algorithm

Until very recently, it was widely believed that the art of caricature was beyond automation. However, Visvalingam's algorithm, with its iterative elimination of the least important vertices, has opened up new opportunities for caricatural generalisation of 2D and 3D maps. The algorithm may be used to weight the internal vertices of a line so that the line may be filtered to different levels at run time as shown here.

Unlike approximation, generalisation is concerned with forming representations based on creative interpretations of data. Algorithms, such as this, have only just taken a step in this direction. Current research is focusing on segmentation of the line into parts, describing features such as bays and rivers.



Source: Visvalingam and Whyatt (1993)

4.2 *The P-stroke Sketch*

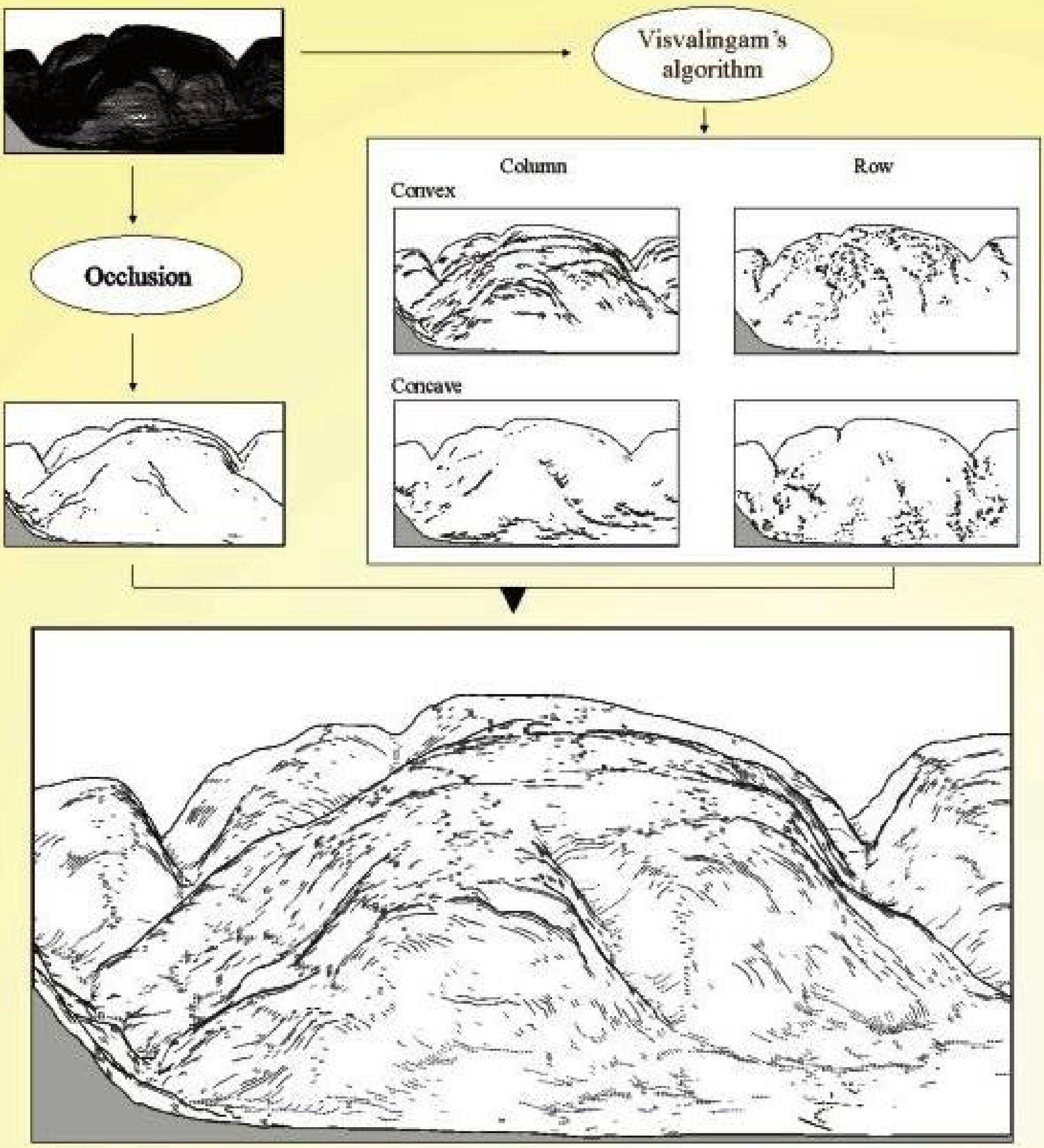
The CISRG's style of P-stroke sketching refers to the display of subsections of cross profiles, abstracted using Visvalingam's algorithm for line generalisation. The schematic diagram indicates the processes involved in P-stroke sketching.

The sketch consists of 5 layers of strokes. Four of these pick out significant convex and concave forms in row and column profiles respectively. A further layer includes view dependent perceptual enhancements; only occluding contours are included in these illustrations.

The input consists of a matrix of height values. The identification of view-dependent occluding contours is relatively easy. The detection of the significant curvatures in row and column profiles was more problematic. Here, their selection is informed by the weights, assigned by Visvalingam's algorithm to the cells of the Digital Elevation Model. Weight-based filtering of cells gives four sets of locations which are separated into their own layers..

Important breaks of slope are then depicted by placing a P-stroke at the filtered locations. The P-strokes and the occluding contours are then superimposed to form the final sketch.

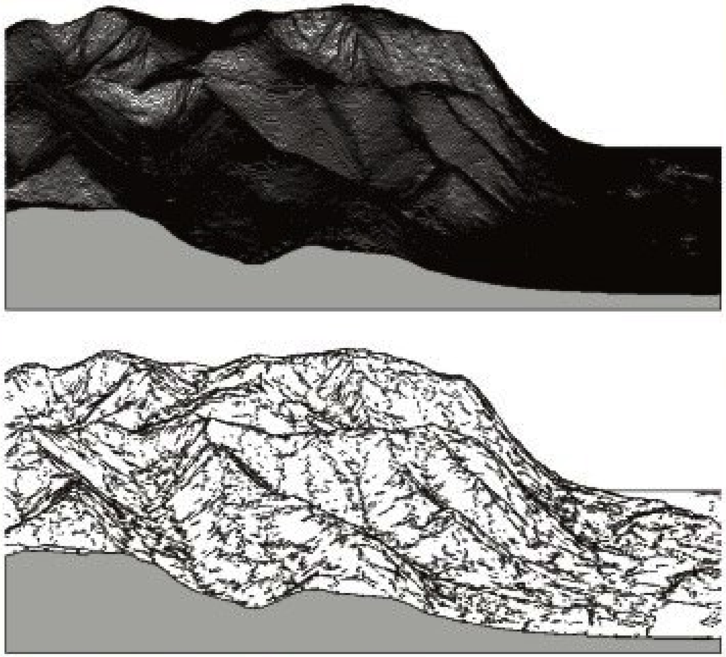
4.2 The P-stroke Sketch



Sketches: Visvalingam and Dowson (1998), Visvalingam and Whelan (1998)

The sketches indicate wave-cut platforms, alluvial fans, frontal breaks of slope and spurs. Features, such as boundaries between plateau tops and valley sides, have been inferred and sketched in to bring out the form of the terrain.

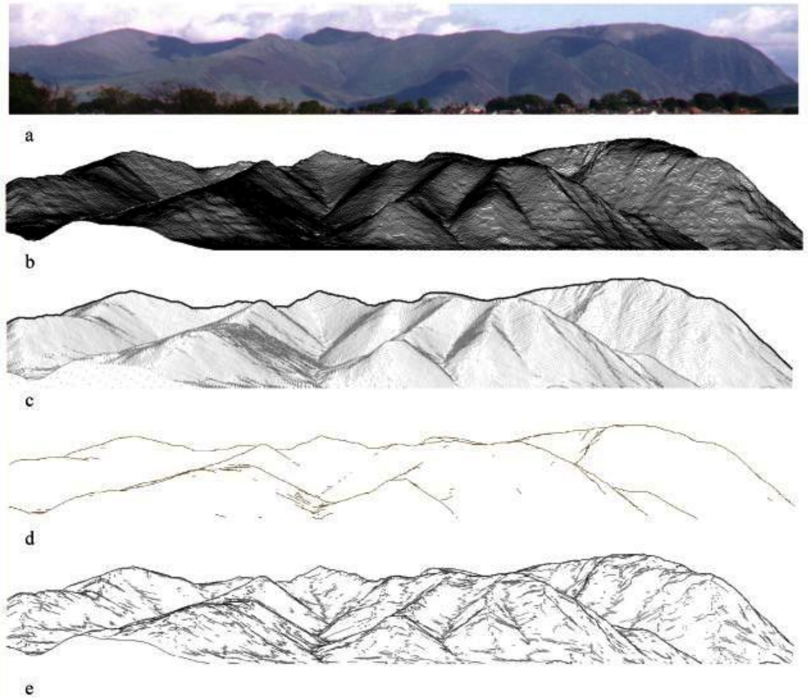
These figures show a part of the English Lake District. This view shows Grasmoor on the skyline as seen from the north through telephoto lens.



Data: *Ordnance Survey (GB), Crown copyright reserved*
P-stroke sketching: *Visvalingam and Dowson (1998)*
Images: *John Whelan, CISRG, University of Hull*

The source data shows artefacts arising from use of Delaunay triangulation for deriving the grid of heights from map contours. Despite these, the sketch shows the scope for abstracting the geomorphology for overlay of information by applications, such as geology, tourism and the military.

4.2 Visions of Terrain



Data: Ordnance Survey (GB), Crown copyright reserved
Images: (a-c) J C Whelan, 2000; (d-e) J C Whelan and M Visvalingam, 2000

The photograph (a) is of a part of the English Lake District. The profile plot (b) shows the entire data for the same area. Sketch (c) was derived from the z-buffer. Silhouettes (d) from the model are sufficient for distant views. Detailed forms are seen when P-strokes are added (e).

4.3 *Animating Sketches of Terrain*

Motion enables us to judge form and depth more clearly in real life. Kinematic displays have been used successfully since the early 1980s to perceive trends and structures in 3D scatterplots. They show that the mind is able to make temporal connections even in animations of sparse data. A Dalmation dog, cunningly camouflaged within a field of dots, is easily seen in an animated movie. This is engendered by the correspondence of marks on successive animation frames.

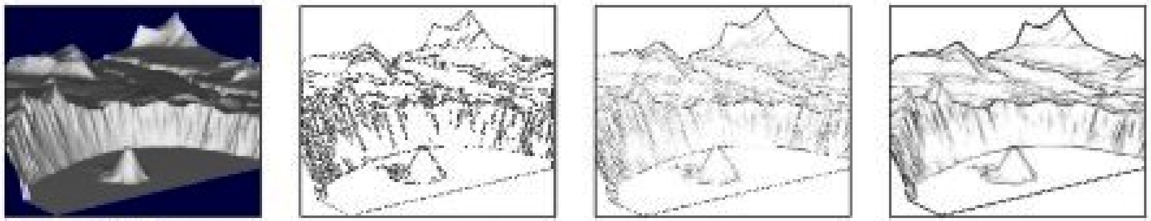
Given the irregularity and complexity of terrain, the abstraction of a series of 3D caricatures is a challenge. Not all sketches as seen by a moving camera connect into a smooth animation of terrain. For example, animation of just the occluding contours, which are easily determined, can be stilted and confusing.

The diagram shows the processes involved in deriving a sketch from a grey-scale luminance map of the terrain. The system traces the breaks in image luminance, which are normally caused by changes in surface orientation and depth. It was used for assessing the usability of sketches within interactive systems for exploring terrain.

4.3 Animating Sketches of Terrain

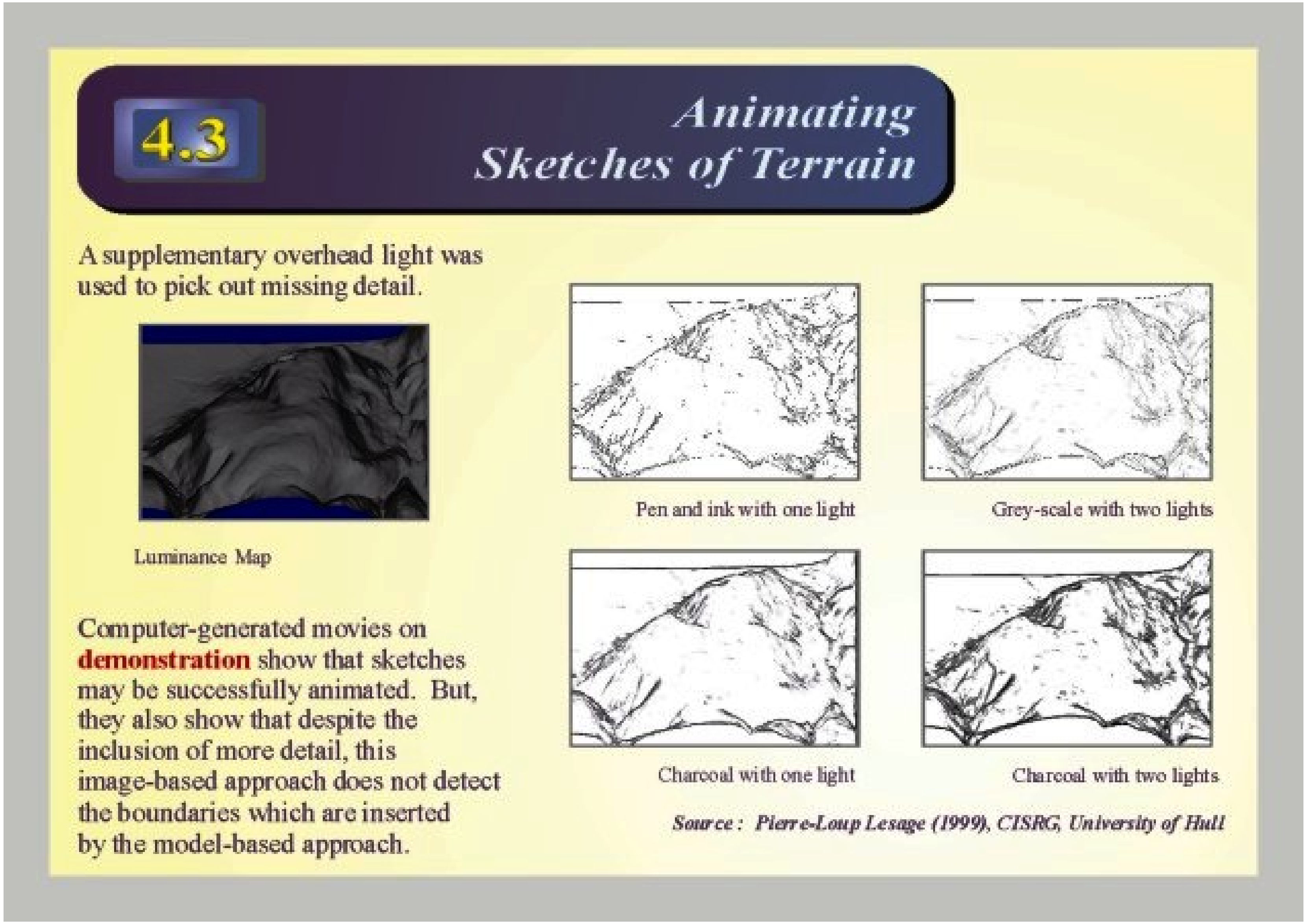
Lighting is critical in the luminance-based approach. When generating a set of frames, it is not feasible to fine-tune the lighting for each frame. So, the research focused on establishing the optimal lighting conditions for an entire movie, starting with just one light. A single light source, at infinity, from behind the camera was initially investigated to establish the extent of its sufficiency. This was prompted by the shading used in landscape drawings and the configuration of lines in profile plots.

Of the edge detectors investigated, the Canny operator gave the best sketches. Sketch quality, which depends on the resolution of the luminance map used,, degrades on enlargement and on conversion to the mpeg format used in the computer-generated animations.
(Please see the demonstration).



Original | Pen and ink | Pencil | Charcoal

Source : Pierre-Loup Lesage (1999), CISRG, University of Hull



Demonstration: Two mpeg videos have been archived as supplementary material to Lesage and Visvalingam (2002) and are also online at Hydra (see Lesage (1999) below).

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On the window of the electronic screen, artists use light, colour and movement to stir emotions and provoke physical and political responses to the virtual landscapes of their creation.

This window of the electronic screen is also a mirror. Reflections on this surface, have the power to coax intuition and insight. Sketches are tools for exploring mind sets pertaining to the terrain of data.

The dying art of cartographic sketching of terrain communicates largely through the symbolic vocabulary of drawing, which differs from realist and impressionist painting.

Like past masters of this art, research on algorithmic sketching of terrain seeks to discover patterns and to delineate forms that have fundamental universal meanings.

We are still at the start of this exciting research challenge.

Exhibition at the Royal Institution on 5 November 1999, © Mahes Visvalingam, CISRG 1999

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Other relevant resources are in the above references