UNIVERSITY OF Hull

Sketch-based Evaluation of Line Filtering Algorithms

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This is a record of the paper presented by Mahes Visvalingam at **GIScience 2000** (Oct 28-31, 2000 at Savannah, USA). Note that the images have been degraded to protect publishers' copyright.

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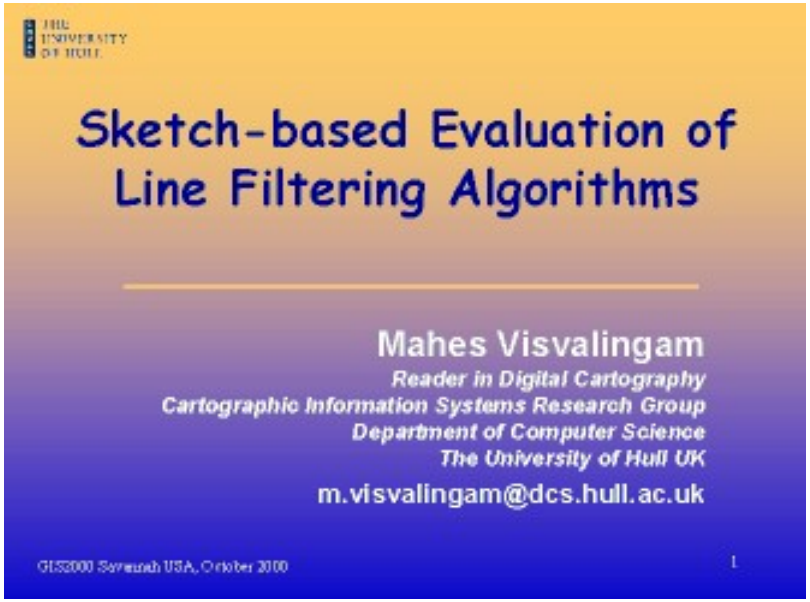
Abstract

CISRG research into algorithmic sketching seeks to revive interest in the lost art of landscape drawing as practised by Holmes, Lobeck, Raisz and others. Dowson (1994) and Visvalingam and Dowson (1998) developed the P-stroke style for sketching. Visvalingam's algorithm for line filtering (published in Visvalingam and Whyatt, 1993) served to rank the DEM cells. This ranking was independent of the view direction. Approximately 5% of grid cells, called core cells, lying on the major curvatures in the terrain data were filtered using four tolerances. These tolerances were varied to suit the view and convex and concave shape of forms. Fragments of row profiles, across the DEM, containing the core cells were filtered to provide P-stroke sketches. The sketches consist of about a third of the height values and are thus still in the realms of minimal simplification.

Visvalingam and Williamson (1995) found that the Douglas-Peucker algorithm (1973) was better than Visvalingam's algorithm for minimal simplification of 2D lines. Since the Douglas-Peucker algorithm is more readily available, Visvalingam and Dowson (1999) investigated its utility for P-stoke sketching. Comparisons of filtered terrain profiles were confusing and inconclusive. When these filtered points were plotted on contour maps, the Douglas-Peucker algorithm seemed to be better since it provided more connected runs of core cells. However, the sketches abstracted with the Douglas-Peucker algorithm lacked Gestalt qualities of coherence and pregnance. Whereas the P-strokes generated with Visvalingam's algorithm were perceived to be on a single terrain surface, those derived with the Douglas-Peucker algorithm did not. The visual system appears to have a tendency to project anomalous marks into the foreground where they may be ignored or scrutinised. In places, these projections seem to be dependent on interpretations of the pose of the graphic primitives, abstracted by the early visual system. The results suggest why extreme point methods for abstracting TINs from grid DEMs may not yield a set of optimal points for plateaus.

The results indicate that P-stroke sketching provides another approach to evaluating line-filtering algorithms. While the sketches output by the Douglas-Peucker algorithm may be instantly perceived as incoherent, the reasons for this had to be deduced. The need for reflection and deduction suggests that the visual system, having grouped marks in the early Gestalt stages of perception, may be performing some knowledge-based comparisons at a subconscious level. It also seems as if emotional judgements of the aesthetic quality of drawings may be based on qualitative spatial reasoning. Variations in conceptual and procedural knowledge make such qualitative evaluations subjective and unreliable. However, the notion that subconscious computation is triggered in a knowledgeable mind affords a methodology for computer evaluations based on cognitive criteria. The talk will therefore focus on sketches for cognitive evaluation of line filtering algorithms.

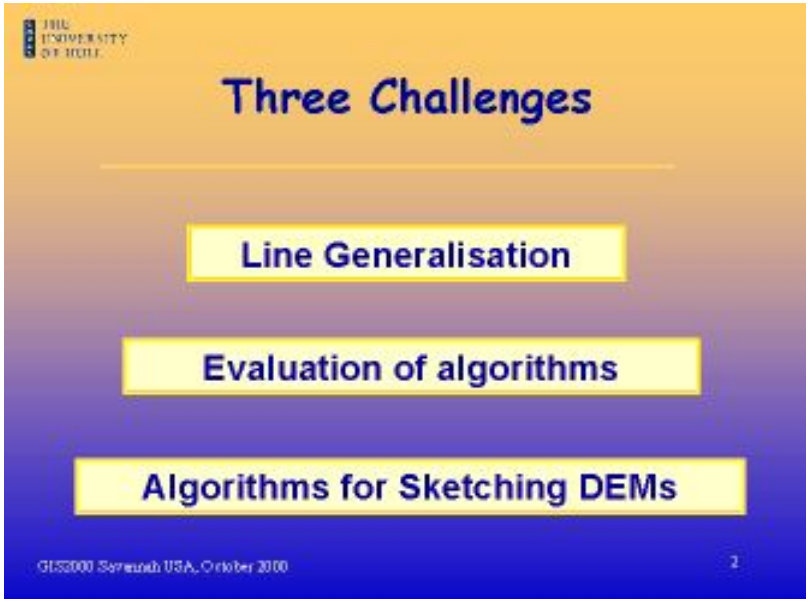


Introduction

This is a record of the paper presented by Mahes Visvalingam at GIScience 2000 on October 29, 2000 at Savannah, USA.

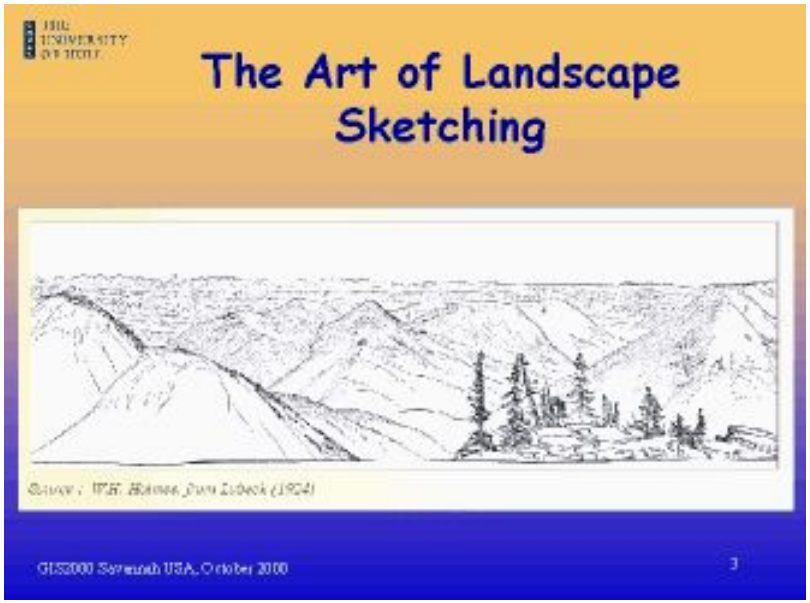
A detailed paper based on the theme of this talk was published in The Visual Computer.

The title of my talk identifies three challenges which my research students and I have been addressing.



Firstly, we regard line generalisation as an outstanding challenge. Some leaders in the field regard this as a solved problem. However, as far as we are concerned, we have not exhausted the research potential of even the line filtering algorithms.

Secondly, the evaluation of algorithms is another unsolved problem. Visual assessment is necessary but it is subjective. On the other hand, the current methods for mathematical evaluation become inappropriate as soon as we step beyond approximation. Since my line filtering algorithm was designed to address typification and caricature, the evaluation of algorithms is a continuing challenge for us.



My line filtering algorithm opened up a third challenge, namely the algorithmic sketching of DEMs and of surfaces in general.

This third challenge was inspired by the landscape drawings of Holmes, Lobeck, Raisz and others dating from the early 20th, 19th and even earlier centuries.

On the left is a sketch by Holmes W. H., 1876, in Lobeck A. K., 1924, Block Diagrams and Other Methods used in Geology and Geography pp. 178-179.

Lobeck, and others, regarded field sketching as a form of generalisation.

Sketching involves the delineation and depiction, in the universal language of graphics, of the pattern of landforms. This sketch by Holmes illustrates that sketching involves the :

- Abstraction of silhouettes to identify the main forms and their relationships in space;
- Abstraction of other form-defining lines, such as the edges of the plateaus in the distance;
- Completion of the sketch using a set of neat lines arranged almost in profile to bring out the shape of forms.

With the advent of photorealism and GIS, there has been little interest in landscape sketching.

I was keen to revive interest in the dying art of landscape drawing. Kurt Dowson experimented with some algorithms for sketching DEMs in his PhD project, completed in 1994.

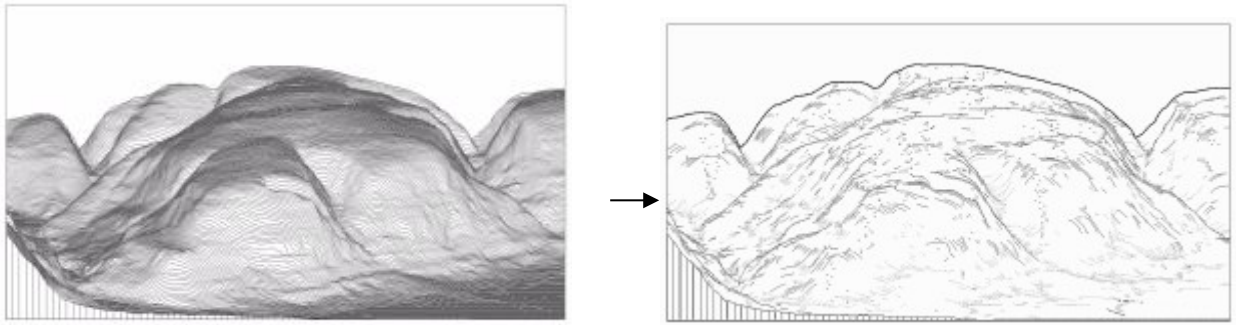
An overview of our research on sketching is provided in the web-record of an invited poster exhibition, entitled Art in Scientific Visualisation of Terrain Data, at the UK Royal Institution on 5th Nov 1999 and 17 March 2000.

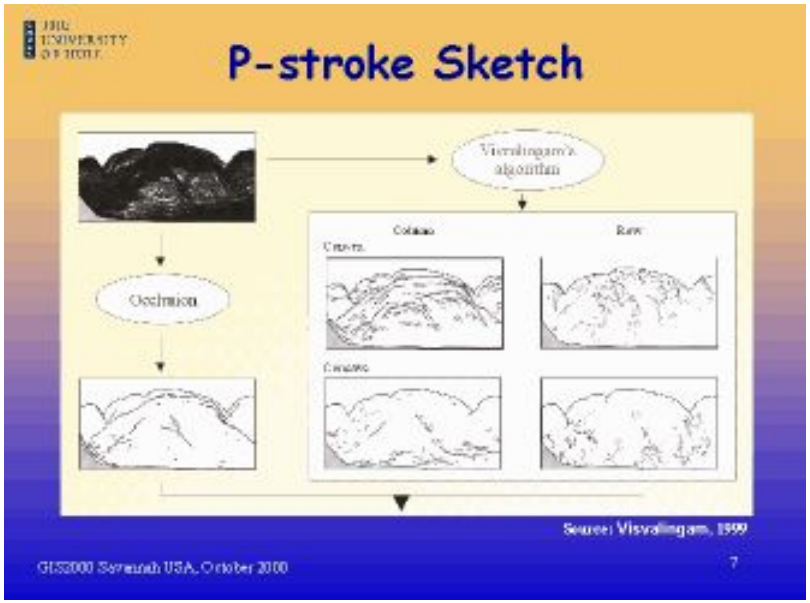
Now that the challenge of photorealism has been largely met, there is a surge of interest in non-photorealistic rendering (NPR) at several sites in America and Europe. Jim Foley (2000), the principal author of the most popular text on computer graphics, has listed abstraction and sketching among the top ten problems left for computer graphics in year 2000.

There have been periodic papers on sketching in computer graphics conferences but NPAR 2000 was entirely devoted to Non-photorealistic Animation and Rendering. This conference was co-sponsored by SIGGRAPH and the Eurographics Association

P-stroke Sketch

The sketch on the right (see Visvalingam and Dowson, 1988; Visvalingam and Whelan, 1988) shows the P-stroke style of sketching. P-stroke stands for profile-stroke since this type of sketch is no more than a filtered subset of the conventional profile plot. This style was inspired by Robinson and Thrower's and Dickinson's adaptation of Tanaka's inclined contours.





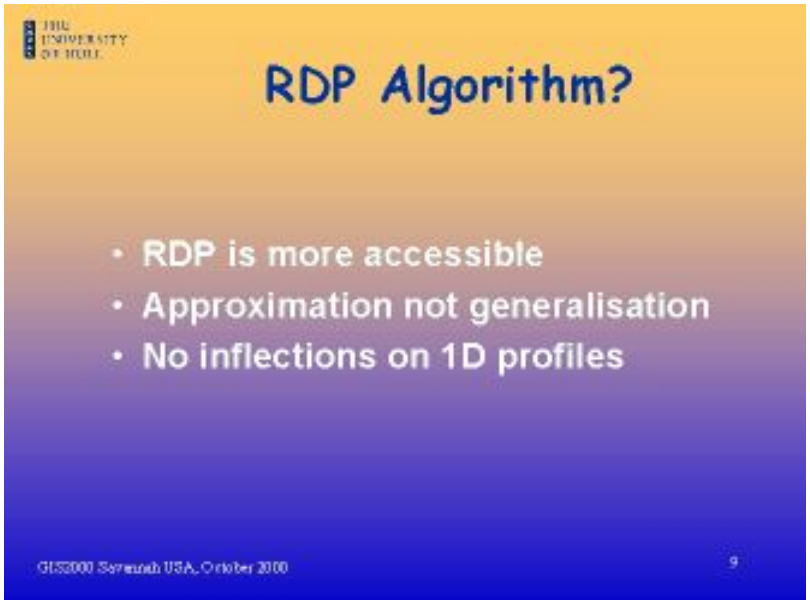
This Figure comes from the exhibition mounted at the Royal Institution. It shows the main elements in the sketch. The DEM cells (points) on row and column profiles are assigned measures of significance by my line filtering algorithm.

These values can be used to filter the more important form defining cells. The filtering is view dependent and only 5% of cells is filtered.

Portions of the row profiles, called P-strokes, containing the filtered cells are then selected. Different rules are used for selecting the P-strokes for the concave and convex forms on column and row profiles.

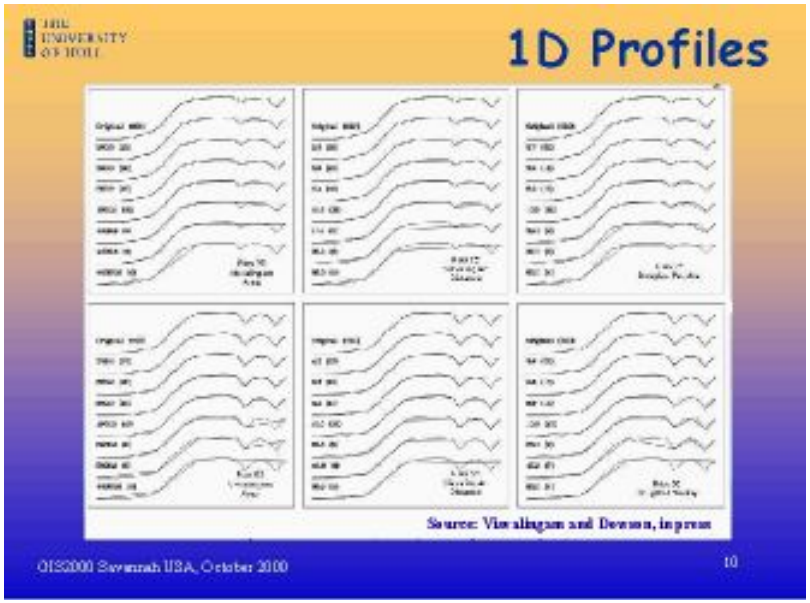
The four layers are superimposed to give the P-stroke sketch, which consists of about 28% of DEM cells. Occluding contours may then be added to enhance depth perception as shown in the sketch above.

As it stands, the sketch is still in the realms of approximation. Many of the drawings by past masters are also verging on approximation although there are excellent examples of typification (as shown in the Royal Institution exhibition).



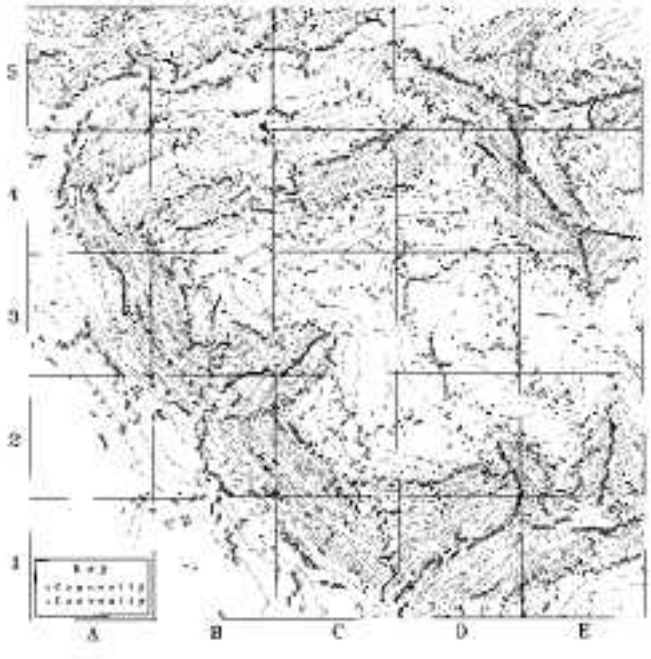
The Ramer/Douglas-Peucker algorithm: Comparisons

Since we are still in the realms of simplification, Kurt and I wondered whether we could use the more widely available RDP (Ramer/Douglas-Peucker) algorithm for sketching. 1D profiles across DEMs do not have the recumbent curves that coastlines tend to have, which make the RDP algorithm trip over itself.

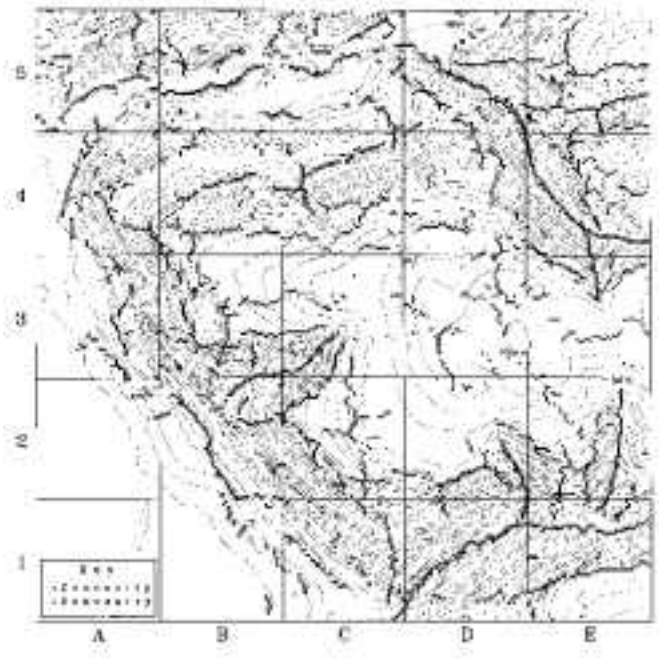


There have been numerous comparisons of the RDP algorithm with others based on isolated 1D lines. However, the comparisons of filtered versions of 1D terrain profiles tend to be rather inconclusive. Nevertheless, these plots were useful for finding the cut-off values which gave comparable results for both algorithms. The tolerances yielded a choice of about 5% of DEM cells.

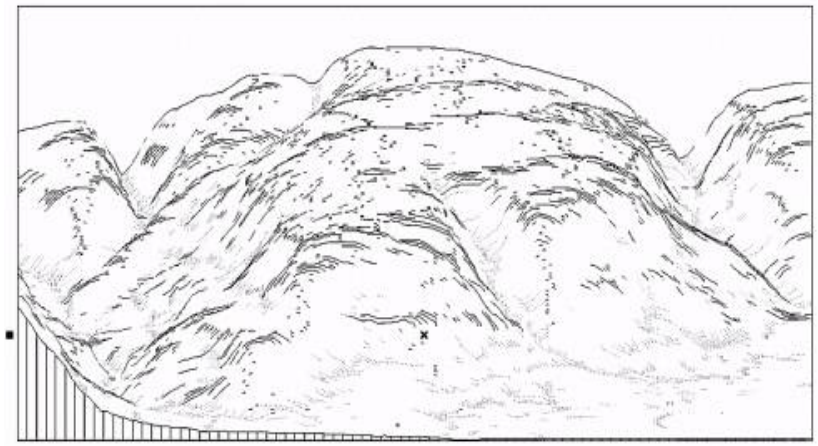
Filtered cells were also plotted against contour plots to pursue context-based evaluations. The cells filtered using Visvalingam's algorithm have a noisy dispersed pattern. In comparison, the RDP algorithm produced a cleaner, crisper distribution, which is less cluttered. It also produced more continuous lines across the terrain. This was the plot preferred by everyone, including Kurt and myself.



Visvalingam

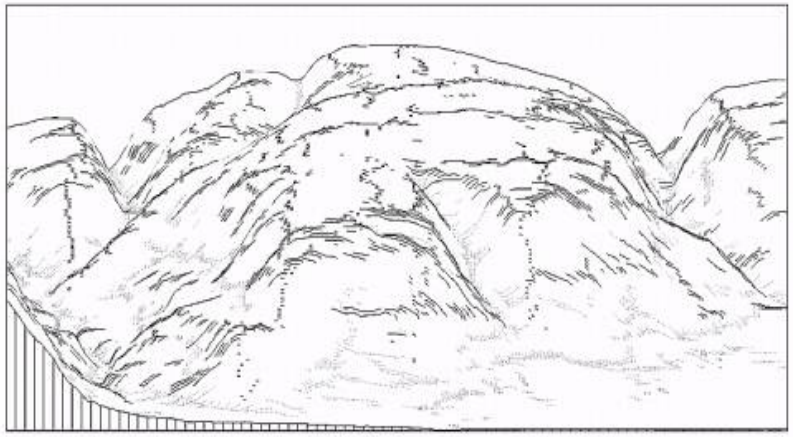


RDP



However, this consensus broke down when it came to selecting between the sketches generated by the two algorithms.

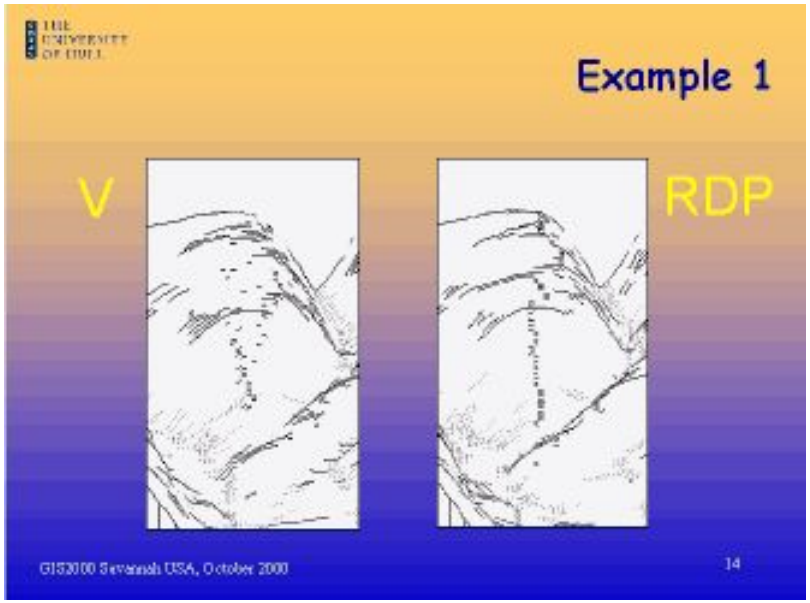
Here is the sketch resulting from using Visvalingam's algorithm for filtering cells. Compare this with the RDP sketch below.



Most people could not tell the difference between the two sketches and, when pressed, chose the RDP sketch. In his thesis, Kurt therefore stated that either algorithm could be used but that he preferred my algorithm because it brought an element of randomness to the sketch.

When I resumed this study in 1998, only three people (our female secretaries) instantly said that there was a difference and preferred my sketch. They felt it had more points on it (which was not so) and that it portrayed the surface better. They did not provide an argument in support of their statements.

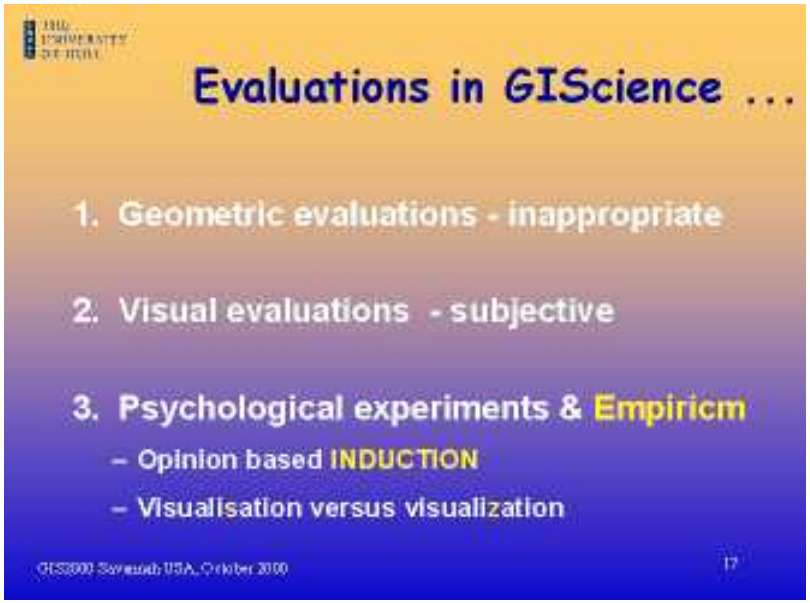
I personally felt that the RDP sketch was clumsy compared with the Visvalingam sketch, such as in the portrayal of this spur.



Although there are odd P-strokes that seem to be detached from the terrain surface in the Visvalingam sketch, the majority of marks bind into a single surface. The terrain surface appears slope into the picture even without perspective projection. In contrast, many marks on the RDP sketch seem to be detached from the surface. The marks on the right edge of the central plateau, for example, look like squiggles on the full sketch. Similar squiqqles can be seen elsewhere on the sketch.

Although the RDP sketch lacked coherence, many people saw the two sketches as similar. It is well known that the perceptual system separates 2D drawings into figure and ground. Just as figure-ground differentiation gives weight to the figure, it could be that misfits are projected into the foreground where they may be studied or ignored. It could be that those who saw the sketches as the same were ignoring the misfits in much the same way in which we look through dirt and raindrops on the window.

These misfits on the RDP sketch occur where the algorithm has mislocated important breaks of slope. If this is the case, than other extreme point methods for generating DEMs may also be picking the wrong points

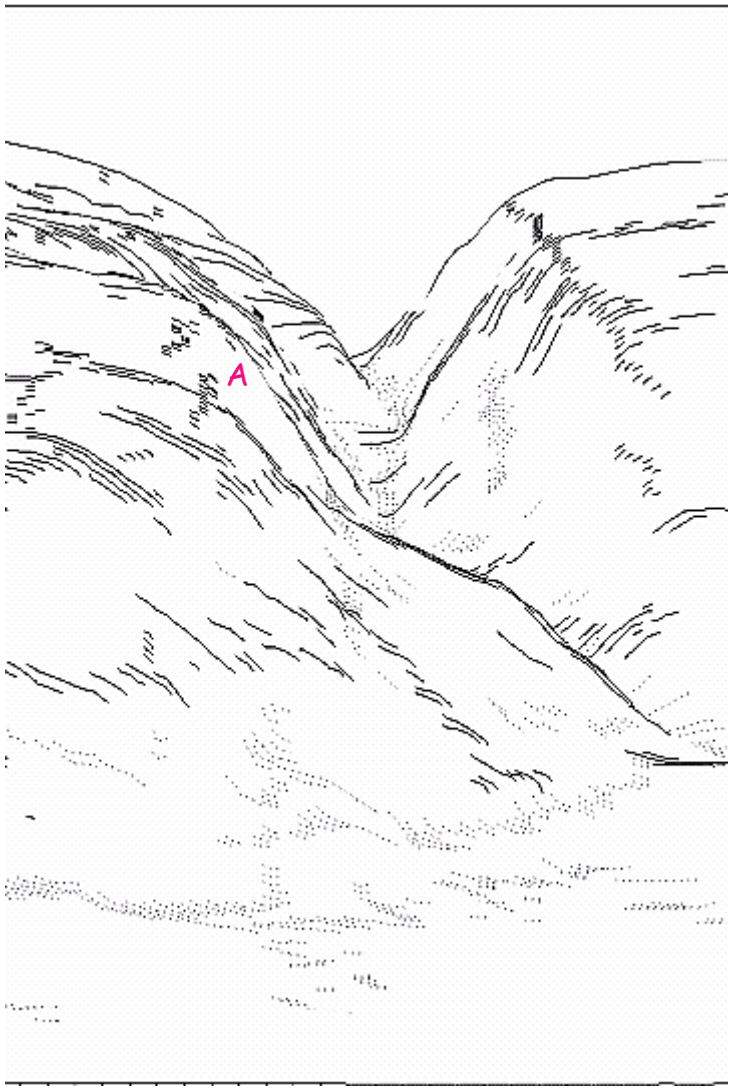


Evaluation of algorithms

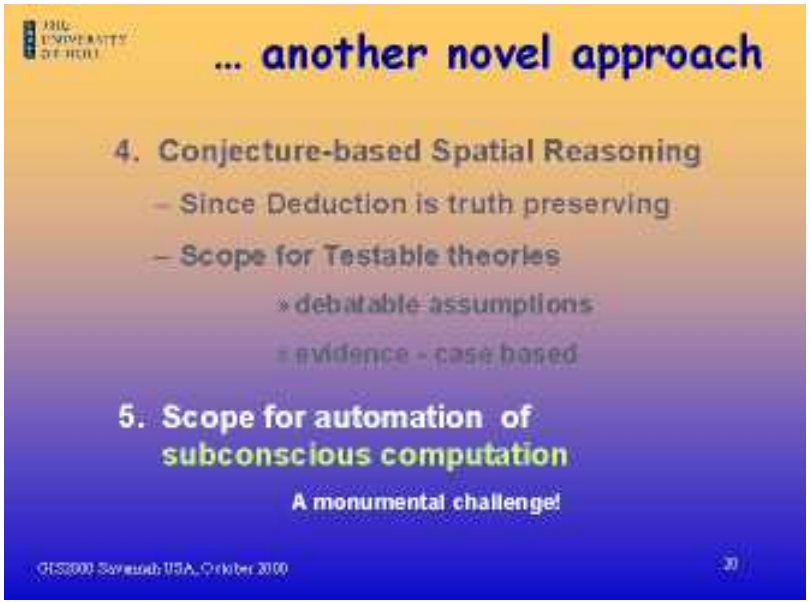
As we venture beyond approximation into caricature, we need to look at how we could evaluate competing algorithms.

- Current mathematical evaluations based on geometry are inappropriate.
- On the other hand, visual evaluations are too subjective.
- Psychological experiments rely on inductions based on empirical evidence. However, this smacks too much of the philosopher's All Swans are White example. Induction is never conclusive. Here, we do not even have tangible facts, only opinions to go on. Mental visualisation, unlike computer visualization, is a subjective process (Visvalingam, 1994).

However, this case study shows that there is scope for conjecture-based spatial reasoning. Unlike induction, deduction is truth preserving. It provides us with some scope for evolving testable hypotheses based on explicitly stated assumptions, case-based evidence and logical arguments. The kind of reasoning we could pursue is indicated below; a more detailed analysis is provided in Visvalingam and Dowson (2001).



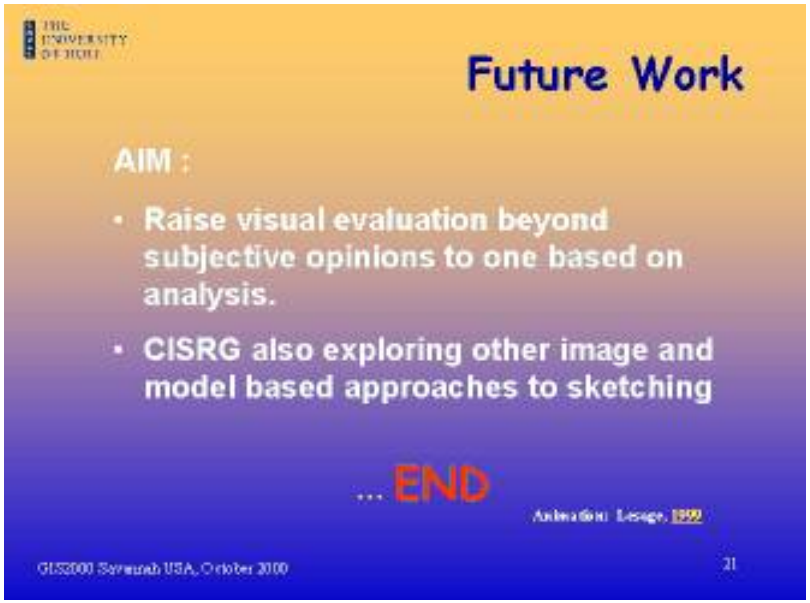
1. Perception of sketches assumes that the surface of terrain is continuous.
2. The early visual system groups runs of strokes, on Gestalt principles of continuation, into linear syntactic units. The long primitive indicating the shoulder (below A) appears to command higher priority. This may be because long primitives which are akin to silhouettes are given higher priority than others.
3. The angled primitive, which appears over the top of the shoulder (to the left of A), commands a lower priority.
4. Since the base of this primitive is in front of the shoulder, the entire primitive is perceived as being in front since it makes more sense. The primitive can only be seen as being in front if the pitch or pose of the primitive is tilted towards the user. Thus, the upper part of the primitive is not SEEN as lying on the surface although we KNOW that, by definition, all P-strokes must lie on the surface.
5. When some marks become detached from the surface, some other marks may also appear to float. For example, the angled primitive to the upper left of the primitive.



Such inconsistencies occur because the RDP algorithm mislocates the plateau edge. The subconscious mind perceives such inconsistency in the placement of marks. Some people seem to ignore the output of the subconscious and appear to be focusing only on some of the layers which form the sketch. Others have a gut feeling that 'something is wrong' but are unaware of the precise reasons, because the computation is within the subconscious.

If expert perception is based on knowledge-based subconscious computation, then there is some scope for basing the evaluation of sketches and of algorithms on logical consistency; conceptually, it is no different to cartographers ensuring that contour interpolation is consistent with drainage patterns. Hence, the title of the talk - sketch-based evaluation of line filtering algorithms.

This is a monumental challenge. Even if we do not automate the computations, qualitative spatial reasoning can lead to the re-discovery of unstated principles. This is one way in which GIS, as a science, can inform systems development.



Future Work

We are using image and model-based approaches to investigate other problems in sketching. Pierre-Loup Lesage (1999) has demonstrated that there is scope for image-based real-time exploration of sketches of terrain data. His movies in Lesage and Visvalingam(2002), show another practical benefit of sketching, namely the availability of white space for showing other information. 2D thematic maps generalise the topographic base to focus attention on the thematic content. 3D maps similarly need to generalise the terrain base to make room for thematic content.

So, sketching is indeed a form of generalisation. We need to take visual evaluation of algorithms beyond subjective opinions into deductive reasoning.

Acknowledgements

Thanks are due to past research students, especially Phil Wade (for implementation of the Douglas-Peucker algorithm), Duncan Whyatt (for evaluation of line filtering algorithms) and Kurt Dowson (research on sketching). All three projects were supported by EPSRC studentships; Scott Wilson Kirkpatrick and Partners, a UK- based consulting firm of civil engineers, were the CASE collaborators on Kurt Dowson's project. Two recent research students, John Whelan and Jenny Herbert, assisted with the preparation of figures for publication.

References are listed in full in the following free to download online papers:

Lesage, P_L (1999) "Towards Real Time Sketch-Based Exploration of Terrain: An Investigation of Image Processing Operators", Department of Computer Science, University of Hull, Unpublished MSc Thesis by research. Supplementary video demonstrations @@@@

Visvalingam, M and Dowson K (2001) "Towards Cognitive Evaluation of Computer-drawn Sketches", The Visual Computer 17 (4), 219 - 235. https://doi.org/10.1007/PL00013407

Preprint of paper: https://hydra.hull.ac.uk/resources/hull:8355

Lesage, P-L and Visvalingam, M (2002) "Towards sketch-based exploration of terrain", Computers and Graphics, 26(2):309 – 328. https://doi.org/10.1016/S0097-8493(02)00058-4. Supplementary material includes example mpeg videos.

Preprint of paper: https://hydra.hull.ac.uk/resources/hull:8356