Visualizing Geomorphometry: Lessons from Information Visualization

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1. Introduction

Has geomorphometry really changed in the last 30 years? As someone who mainly researches in the field of information visualization and GI Science, I ask myself this question whenever my research takes me back into the realm of digital elevation model analysis where I started my career 20 years ago.

In the 1970s Ian Evans was proposing the use of quadratic interpolation of DEMs for the systematic measurement of the first and second derivatives of elevation for general geomorphometry (Evans, 1972, 1979, 1980). Modern geomorphometry still uses the techniques and approaches he proposed for slope and curvature measurements over 30 years later. At about the same time David Mark was advocating the systematic use of gridded elevation models and computer based parameterisation of those models as the bases for geomorphometric analysis (Mark, 1975a,b). Again, this forms the basis for modern geomorphometry, albeit with larger DEMs at finer resolutions.

It can be argued that modern hydrological geomorphometry is equally based on the approaches established in the 1980s, such as flow accumulation, channel delineation and watershed partition (e.g. Jenson, 1985; Band 1986; Hutchinson, 1989). Little appears to have changed since then other than the use larger datasets or minor modifications to algorithms such as moving from ***D8*** to ***D∞*** flow models.

Reviewing Hengl and Reuter’s text *Geomorphometry*: Concepts, Software and Applications (2008), it is clear that one aspect of geomorphometry has changed in the last 30 years or so, almost beyond recognition. The visual presentation of geomorphometric analysis has evolved from monochrome low resolution overplotting of line printer output to multi-megapixel full colour output. Yet if we think of graphical output as solely a mechanism for presentation, geomorphometry will fail to exploit the true power of recent development in visualization.

In parallel with the development of graphical techniques has been the emergence of *information visualisation* and *visual analytics* – research disciplines that focus on the use of graphics as an intrinsic part of the data analysis process. The speed at which graphical output can be created, along with graphical interaction means that visualization of data can be used as part of the analytical process, feeding back to the way we handle our data and draw conclusions from it. This paper will argue how we can learn from the developments in information visualization and visual analytics in order to enhance the way in which we undertake geomorphometry.

2. Information Visualization and Visual Analytics

Information visualisation as a discipline emerged during the 1990s from the need to formalise the approaches used to handle the increasingly large and diverse digital datasets becoming available. Building on traditions of scientific visualization, statistical graphics, computer science, human computer interaction and cartography, the discipline has overseen the development of new graphical tools, new styles of graphical interaction, empirical evaluation of usability and new theory. More recently, the emerging field of visual analytics has focussed on the integration of visual tools and analysis through graphical interaction. While not exclusively geographical, there are a number of developments in these fields that may benefit geomorphometry.

2.1 Techniques for representing data

Most geomorphometric graphical output tends to be map-orientated, usually with some form of raster mapping with a possible vector overlay. While undoubtedly an effective approach, especially when assessing spatial relationships, there is scope to consider the wider range of techniques used in information visualisation. For example, a large branch of information visualization is concerned with representing tree and graph structures, and in particular providing representations that can handle many thousands or millions of nodes and edges (e.g. VisualComplexity.com, 2009; Holten and van Wijk, 2009). The importance of channel and feature networks in geomorphometry means that the discipline could benefit from many of the network visualisation solutions that have been proposed.

2.2 Scalability

Thomas and Cook (2004) in their influential book *Illuminating the Path*, identified the grand challenges for Visual Analytics. Repeatedly, the notion of *scalability* was identified as being one of the most significant challenges. This encompasses *information scalability* which in a geomorphometry context suggests that we need to be able to develop systems that can handle very large datasets both at a fine spatial and temporal resolution. Geomorphometry would benefit from techniques for tiling, caching and filtering very large datasets used commonly in visual analytics. *Visual scalability* addresses the need to show visually many millions of items simultaneously. There are many techniques in information visualization that try to address this need including reprojection, dynamic filtering and aggregation. Display scalability identifies the need to be able to display graphical representations at a range of output scales from mobile devices in the field to mult-panel wall displays. Perhaps one of the most interesting developments in information visualisation is that which addresses *human scalability* – the ability for many people to interact and contribute simultaneously to the visual analysis of a geomorphometric dataset. An interesting example is provided by Microsoft's *Photosynth* software (Microsoft, 2009) allowing multiply sourced photographic images to be integrated and projected into a common space for exploration.

2.3 Embedding Interaction

One of the key approaches to addressing issues of scalability is to allow filtering of data in order to reduce data and visual complexity. Filtering is often achieved successfully via interactive selection of subsets or aggregations of a dataset. Embedding this interaction as part of the process of query refinement is central to information visualization, encompassed by Shneiderman's 'visual information seeking mantra' - o*verview first, zoom and filter, then details-on-demand* (Shneiderman, 1996), but frequently not applied in geomorphometric analysis.

A second context in which interaction is frequently used in information visualisation is in animated transitions between reprojections of datasets (e.g. Heer and Robertson, 2007). This is particularly important when more abstract projections of data are involved where spatial context can become lost. In geomorphometry, transitions between spatial and thematic projections of data offer potential for new insights for geomorphological insight.

2.4 Integration of graphical presentation, query and analysis

Finally, one of the lessons of successful information visualisation is that visual interaction and presentation is most effective when it is integrated in the hypothesis generation – testing cycle. In other words visual representation of data is used as much in the generation of ideas and analysis of results as it is in summarising findings. This requires a reconsideration of the design of software we use for performing geomorphometry as well as the way in which we use it. It requires true graphical interaction, integration with numerical analytical techniques and quick interactive rendering.

3. Conclusions

Geomorphometry has seen a gradual evolution over the last few decades. Based on established principles of DEM analysis, it has experienced little radical change over the years. Datasets have become larger, analysis quicker, but the approach taken to using geomorphometry software has varied little over the decades. Yet, with a huge proliferation of relevant digital data, and massive increases in computing power, we have the scope to radically change the way we perform geomorphometry. In this paper, it is argued that the way in which that might be successfully achieved is to incorporate modern ideas from the fields of information visualisation and visual analytics. Emerging from disciplines where dataset sizes are increasing by many orders of magnitude, and where there is increasing need to perform analysis and filtering of data, there are many lessons to be learned from these fields of study. Considering how scalability, interaction and analytical integration can be incorporated into visual geomorphometry offers scope for radical development in the tools we use to understand the landscape.

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