Matterhorn on the Horizon: Identification of Salient Mountains for Image Annotation

Martin Tomko[1], Ross S. Purves[1]

[1]Department of Geography, University of Zurich, Switzerland
Tel. (+ 41 44 635 5256) Fax.(+ 41 44 635 6848)
martin.tomko|ross.purves@geo.uzh.ch, www.geo.uzh.ch/~mtomko

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1. Introduction

Information retrieval searches indexes to identify relevant content for a particular query. While in the case of plain or structured text documents, the index is typically generated from document text, image search is often based on assigned keywords. Adding keywords to images to allow their effective retrieval is an important element of the work of commercial image libraries, and one associated with high costs (keyword annotation is laborious) and benefits (well annotated images are retrieved by customers and thus purchased). The Tripod project (Purves et al., 2008) aims to exploit landscape photographs tagged with location information (for example coordinates and a direction) and automatically annotate such images based on spatial data and Web content related to image location.

Topographic eminences are a frequent and highly salient element of landscape photographs – for example, (Edwardes & Purves, 2007) found that *hill* was one of the most common concept terms used in the description of images in Geograph. Names of salient hills and mountains are thus important keywords in the annotation of landscape photographs. This is especially true for mountains belonging to the horizon line – they stand out against the background formed by the sky (they are therefore salient), they often have a recognisable silhouette and they provide a clear structural element in the photograph.

The question then is how to identify and name visually salient mountains visible from a specific vantage point? Note that often the summit itself need not be visible, but the mass of the mountain would still be named by a human. Our hypothesis is that terrain analysis methods alone allow for accurate identification of salient mountains.

We present a method based on a sequence of analytical steps, assigning toponyms to mountain-top regions using relative drop, computation of horizon lines based on viewshed analysis, and identification of the most salient points on the horizon based on a hierarchical decomposition of the projected horizon. In the approach presented we explicitly assume free visibility to the horizon line, in other words, we do not consider occlusion of the horizon by vegetation or man-made structures, as discussed by Tomko et *al.* (2009).

2. Background

Viewshed computation on digital elevation models (DEMs) is a popular terrain analysis technique, central to the identification of salient mountains. It has been researched by the GI community from many perspectives, such as algorithms and DEM data structures (De Floriani & Magillo, 2003), accuracy and veracity of viewsheds (Maloy & Dean, 2001), and applications, for instance, in visual impact assessment, (Ervin & Steinitz, 2003). Fisher (1996) proposed an extension to the binary raster viewshed by classifying raster cells as either visible, invisible, on local horizon or on global horizon. We use such a classification in our image annotation approach, as detailed in Section 3.

Outdoor enthusiasts and geomorphometrists alike are interested in assessing the prominence of mountains. Classifications derived from elevations of peaks relative to the surrounding terrain are popular for their computational simplicity and relative objectivity (Grimm & Mattmüller, 2004; Helman, 2005; Podobnikar, 2009). There is, however, no direct relationship between such derived mountain prominence and the apparent salience of an observed peak. In a given horizon line, the summit of the peak may not be directly visible, and typically, local minima are formed by perceivable overlaps of the silhouettes of closer and more distant hills and not by defining saddles. As noted by Fisher et *al.* (2004), the extent of mountains is larger than the summit, and it is hard to delineate. The visibility of the mountain massif, however, seems a sensible element to refer to in image annotation – in other words we name the region of mountain top, not merely its summit.

Chippendale et *al.* (2008) combined DEM and image content analysis to evaluate the salience of features found within artificially constructed landscape images. Their approach does not, however, provide details about the algorithms used and furthermore requires the use of, typically, computationally expensive image content analysis. As such, it is not well suited for real-time image annotation.

3. Method

The method proposed relies on the computation of the enriched viewshed from the image origin, consequent identification of the cells belonging to the most salient apparent peak by hierarchical decomposition of the global horizon and finally by matching the cells belonging to the salient peak with the containing mountain-top regions identified by DEM analysis using relative drop.

We use the freely available SRTM DEM 90m dataset for viewshed computation and the identification of the mountain-top regions. The SwissNames toponym database for Switzerland (containing toponyms from 1:25000 topographic maps) is used to relate mountain-top regions with the names of the mountains constituting the regions.

An enriched viewshed is computed for a given vantage point specified by WGS84 coordinates automatically extracted from the EXIF metadata of a georeferenced image. The computation can be limited to a certain distance and an oriented field of view. Points that belong to the global horizon are selected and ordered by azimuth. We store the horizon line in a vertical coordinate system defined by the azimuth and the elevation angle of the observed cell. The horizon line is smoothed to remove artefacts from the viewshed analysis and DEM data. It is then searched for local minima and maxima, and the average relative height of each of the maxima, defined as a height difference between the maximum and the surrounding two local minima is computed. The result is a hierarchical list of the maxima with the largest height difference on the horizon line, related to the apparent prominence of the peak.

The cell identified as belonging to the most salient local maximum of the horizon line is related to the peak region it belongs to. The mountain-top region dataset used contains 531 regions (polygon geometries) over the whole of Switzerland, formed by mountains over 800m in altitude with a relative drop to the nearest saddle of over 250m. The regions do not represent a complete tessellation of the area. As any given mountain-top region can be generated by multiple named peaks (e.g. auxiliary summits, such as in the massif in the right of Figure 1), we select the peak observed under an azimuth closest to that of the most salient horizon maximum. The identified peak's name is used in image annotation, together with the indication of the peak's position in the image (Image left, middle or right).

4. Example Output and Further Research

Figure 1, showing a typical mountain scene from the Swiss Alps, has been automatically annotated with the toponym *Chöpfenberg*, with the position of the detected mountain indicated as image left. Indeed, the notable rocky mountain that occupies the left side of the image background is Chöpfenberg.

Figure 1. A view of Swiss Alps, Chöpfenberg in the background on the left.

The method selects salient mountains exclusively by analysing the horizon line (Figure 2). Further optimization is possible by considering only toponyms from topographical maps of a certain scale (e.g. 1:100 000 vs. 1:25 000,) to avoid selection of subsidiary summits. Such a selection allows for de-facto cartographic generalisation in salience estimation. People are likely to consider further aspects - specific shape of mountain silhouette, texture, geological and cultural significance to name a few - when selecting mountains for annotation of images. These considerations are subject to future research.

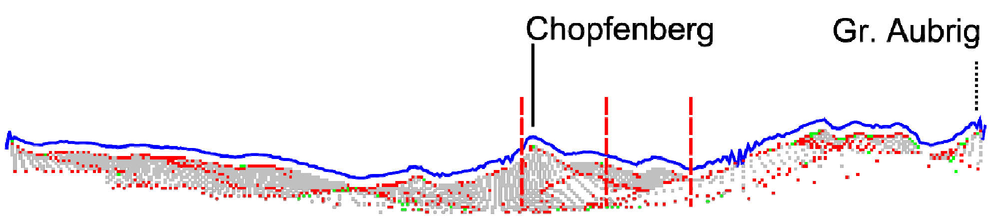

Figure 2. The 360^{o} horizon containing the scene from Figure 1 (extent indicated by dashed red lines for margins and center), constructed from a viewshed with limit view distance of 3.8km. The location of the *Chopfenberg* indicated by the black line, a second salient summit (*Gross Aubrig*) indicated further towards the right is outside Figure 1.

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Biography

Martin Tomko is a post-doctoral research assistant at the Department of Geography of the University of Zurich, where Ross Purves is a lecturer.