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Quantifying visual prominence in social landscapes

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ABSTRACT

Humans have a cross-cultural tendency to attach strong social meanings to visually prominent landforms. The ability to identify prominent landforms is thus important for understanding how people perceive and relate to a landscape. This is particularly true for historical landscapes, where the relationship between viewer location and view may be one of the few recoverable elements available to reconstruct landscape meaning. Quantifying prominence, however, is a methodological and conceptual challenge, especially if prominence is to be measured from particular ground locations rather than from a planar view. An approach is suggested using a line simplification technique borrowed from cartography that is repurposed to identify prominent points on a horizon line. By combining prominence values with information on the number of viewers present in different vantage points at different points in time, it is possible to reconstruct a visual prominence history for landforms in a region. This approach provides some quantitative rigor to phenomenological approaches that can be overly descriptive and insufficiently transparent. A case study from the American Southwest demonstrates the utility of the method.

1. Introduction

Cross-cultural evidence indicates that humans tend to attach strong social meanings to visually prominent landforms like mountains or volcanoes – as territorial markers, as sacred places, and as visual anchors (Ashmore, 2008; Eliade, 1959; Tacon, 1999:36–37; Tuan, 1974, 1977). The natural landscape, then, is not just passively viewed but actively assigned meaning by viewers based (among other things) on visual qualities of the landscape (Heft, 2013). Yet mountains, because of their size and difficulty of access, defy the efforts of all but the most industrious societies to inscribe a significant human footprint on them.[1] Consequently, the material remains from events that involve mountains directly tend to be rather ephemeral and often not diagnostic as to group identity or even time period (e.g., Welch, 1997). In other words, there is often little tangible evidence of the importance of mountains to a population other than their imposing presence on the landscape.

Visibility is therefore a key element for understanding cultural meanings assigned to landforms. Vision in fact is the most powerful of the senses for communicating information about the structure of space (Llobera, 2007:52). Phenomenology – the use of universal human sensory experiences (such as vision) to infer how people may have interacted with their surroundings – thus provides window into culturally constructed relationships between people and their environment (e.g., Johnson, 2012; Van Dyke, 2007). Yet too often phenomenological approaches are descriptive rather than quantitative, allowing personal and cultural bias to inform the attribution of meaning to experience (Fleming, 2006; Pickles, 1985). Quantifying ways in which the human body experiences its physical surroundings is one means of increasing the rigor of a phenomenological approach, though of course the techniques and variables chosen to quantify still reflect the perspective of analyst.

Quantifying landscape visibility begins with identifying what people could see from a particular location. Determining line of sight visibility among various natural and cultural places has been made easy by geographic information systems (GIS) software, but this ease has arguably limited the creativity of questions asked about ancient "visualscapes" (Llobera, 2003, 2007). A significant limitation is that simple line of sight or viewshed analyses tend to treat visibility as a purely physical, binary phenomenon – portions of the landscape are either visible or not. Such binary reconstructions often fail to account for limits of visual acuity, fall-off in clarity with distance, the effects of object-background clarity and color on vision, and other issues (Wheatley and Gillings, 2000).

In this study, a method is proposed for quantifying the visual prominence of landforms. The goal is to identify landforms whose

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[1] Mountain shrines, while relatively common cross-culturally, rarely leave a significant footprint. Hillforts of the Iron and Middle Ages in Europe represent substantial constructions but on relatively low, accessible hills rather than mountains per se. Only in a few exceptional cases, like Inca mountain estates, was there large-scale construction on mountain tops in the ancient world.

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size and shape attract a viewer's attention at the expense of other landforms and function as visual "anchor points" (Golledge, 1978). This study also models overlooked social aspects of "viewership" that affect how meaning is assigned to parts of the landscape by viewers. Relevant viewership variables include the *scale* of viewing (the number of people who can see a landform); the *duration* of viewing (fleeting or long-term); and the *context* of viewing (e.g., from one's own house, on a pathway, etc.).

The proposed method of quantifying visual prominence employs a line simplification technique borrowed from cartography. Line simplification was originally developed to reduce the computer memory needed to store large line files (e.g., a national road system) by discarding extraneous line vertices that are not essential to describing a line's shape. Here, line simplification has been repurposed to identify points on a horizon line that should be *retained* to preserve the essential shape of the line – that is, those parts of the horizon line that are most prominent. The strength of the method is its ability to generate unique prominence measurements for different viewing locations in a computationally efficient and intuitive way. The method is applied to a case study of the historical landscape of the American Southwest to demonstrate its utility, but the approach is potentially relevant across a range of fields including visual impact assessment (Smardon et al., 1986); landscape architecture (Kaplan et al., 1989); historical and archaeological reconstructions of human–land relationships (Johnson, 2012; Van Dyke, 2007; Zedeno, 2008); and human and animal wayfinding behavior (Golledge, 1999), among others.

2. Defining prominence

Elevation of a summit above sea level is the simplest and most familiar way to describe the prominence of a landform, but absolute elevation does not often correlate well with subjective assessments of "visual impressiveness". Minimally, prominence measures should differentiate "local elevation extremes" (Podobnikar, 2012) from points that rise only modestly from a high-elevation base. Visually impressive peaks tend to be isolated rather than clustered; Maizlish (2003:1), for example, measures prominence as "the elevation of a summit relative to the highest point to which one must descend before reascending to a higher summit." The shape of a landform also affects its visual prominence; steep-sided, symmetrical peaks register more strongly than gently sloped, irregular ones (Earl and Metzler, 2010:1). Quantifying three-dimensional peak shape through morphometric analysis can be quite complex; Sinha (2008) reviews more than 40 quantitative parameters that can be used to represent perceptual characteristics of eminences (see also Graff and Usery, 1993).

It is useful to distinguish between two approaches to quantifying prominence, what is termed here "global" and "local" prominence. In global approaches prominence is measured in a planimetric view, essentially expressing how big of a bump a landform makes on the planet's surface. By definition, global prominence measures are not tied to specific viewing locations; for a given global prominence metric, a landform has a single prominence value. Global prominence measurements are especially useful in cartography, where automated identification of mountains is desirable. Examples of global prominence metrics include Podobnikar's (2012) automated morphometric procedure that filters peaks on the basis of shape (e.g., sharp, blunt, oblong, circular), horizontal distance between peaks, and a measure of relative relief based on a "multidirectional visibility index"; Earl and Metzler's (2010) Omnidirectional Relief and Steepness (ORS) measure which takes into account the steepness (angle) of a peak in all directions and the relative height of the peak above its surroundings; and Sinha and Mark's (2010) method which quantifies topographic gradient and aspect.

Local prominence, in contrast, measures visual significance from a particular human observation location. Airplane trips and satellite imagery aside, humans typically view large landforms from the ground, and they always do so from a particular vantage point. This "groundedness" of local prominence distinguishes it from global prominence, and arguably makes it more meaningful in many social contexts. Local prominence recognizes that a landform must first be viewed by people before it is defined as prominent. The locations of mountains are obviously fixed, but the vantage points from which a given landform was actually ever viewed by a person is only a small subset of the total potential viewpoints. The importance of taking into account the nature of different viewers and vantage points when assessing prominence is reflected in the USFS Landscape Aesthetics Handbook (USFS, 1995:4–2), which notes that "a large number of viewers with a high concern for scenery, who view a landscape in detail for a long period of time, may substantially increase scenic importance of that landscape…conversely, a small number of viewers with low concern for scenery, who view a landscape fleetingly, may substantially decrease scenic importance of that landscape."

Most attempts to quantify local prominence have employed a raster-based approach in which a digital elevation model (DEM) is used to compare topographic and/or visual attributes of an observer location to its surroundings. Raster-based approaches have the advantage of maintaining three dimensional topographic detail available in high resolution DEMs, but this detail can also present conceptual and computational challenges in identifying visually discrete landforms on a continuous surface. In one example of this approach, Llobera (2001) defines prominence as the "height differential between an individual and his/her surroundings, as apprehended from the individual's point of view", expressed quantitatively as the percentage of locations (raster cells) that lie below the individual's location within a certain radius (see Christopherson, 2003 for an archaeological application of this method). Elsewhere, Llobera (2003:37–38) employs a similar method to calculate both topographic prominence (by measuring differences in altitude) and visual prominence (by measuring differences in summed viewsheds calculated from multiple viewpoints, termed the "total viewshed"). The summing of visibility attributes from different locations and/or radii creates a measure which approximates the human perception of prominence for near and distant landforms. Total viewshed values, however, vary depending on the radius around the vantage point used in the calculations, and with large landscapes and/or large numbers of observer points the method can be very computationally intensive. The analyst must also determine how clusters of cells with high prominence values will be aggregated into discrete landforms and distinguished from nearby clusters.

3. A horizon-based model of local prominence

Visual cognition research suggests that for far-distance views, the *horizon* is the dominant feature of the visual landscape rather than individual landforms per se. In far distance views a sense of depth is difficult to discern and the landforms comprising the horizon register visually as a "vertical backdrop" (Wheatley and Gillings, 2000:16; Higuichi, 1983). As a high contrast (light/dark) boundary between land and sky, the horizon serves an important role in orienting the body to one's environment. The abstraction of the horizon into a solid plane enables the human visual system to quickly register scene information – the "scene gist" – (Herdtweck and Wallraven, 2010) and use the angle of declination from the horizon to estimate distance to foreground targets (Sedgwick, 1983).

"Far" distance is variably defined, but psychophysical limits on human visual acuity combined with atmospheric distortion put an