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Using geotagged photographs and GIS analysis to estimate visitor flows in natural areas

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ABSTRACT

Protected area management requires detailed information about visitors' travel patterns. Unfortunately, methods commonly applied to obtain this information (e.g. monitoring, simulation) are expensive and time consuming. As a result, for many protected areas worldwide there are no reliable data upon which management actions (e.g. trail maintenance, introduction of use limits) can be based. Today georeferenced material shared on the Internet (e.g. geotagged photographs, GPS tracks) provides a new valuable source of information about people's movements, though its low density (e.g. few geotagged photographs per unit area) in natural areas has discouraged applications in such contexts so far. We propose a new approach that uses geotagged photographs to identify popular locations, and a gravity model to estimate the volume of visitor flows from access points (e.g. parking lots, bus stops) to those locations. The model, which assumes volumes to be proportional to the popularity of access points and destinations, and inversely proportional to the travel time for going from one to the other, is set up in a GIS environment and calibrated by means of actual visitor counts over a set of locations in the study area.

Results of a first application to the Dolomites UNESCO World Heritage Site (Italy) are encouraging as the model provided good estimates and a consistent map of visitor flows. The method enables park managers to roughly estimate visitor flows over large trail networks with only limited field work required. Future applications may include the analysis of off-trail movements to predict the intensity of trampling.

Introduction

Knowing the distribution and flows of visitors is fundamental to the management of natural and protected areas. Detecting the overcrowded sections of a trail network, defining policies to guarantee standards of quality or mapping the recreational opportunities offered by a natural site are only some examples of a broad set of management tasks that require detailed information about visitor travel patterns. This is normally acquired through a variety of monitoring techniques, such as: manual counting; surveys; mechanical or infrared counting; etc. (Muhar et al. 2002; Arnberger & Hinterberger 2003; Cessford & Muhar 2003; Arnberger et al. 2005). Unfortunately, all these techniques rely on field work, which makes them expensive if not impracticable whenever the area to be monitored is particularly large and the network of potential visitor routes is extended. As an alternative to monitoring, simulation models have been employed for their ability to describe visitor movements in great detail without requiring the material effort that is associated with traditional monitoring techniques (Cole & Daniel 2003; Lawson et al. 2003). However, simulation models may call for complex computer programming in order to adequately describe the system, as well as field work for calibration. These difficulties are the reason why visitor monitoring is still inadequate in many protected areas worldwide and, to date, cost effective methods are needed to support management actions (Cole & Wright 2004; Hadwen et al. 2007).

In recent years, Web 2.0 applications, by enabling people to easily share geographically referenced information about their movements (e.g. photos, GPS routes, etc.), have greatly contributed to the development of the so-called volunteered geography (Goodchild 2007) and eventually unveiled new perspectives for the monitoring and estimation of visitor flows. Websites like Flickr (http://www.flickr.com) or Panoramio (http://www.panoramio.com) allow Internet users to upload and view photographs, and to quickly retrieve their embedded data (e.g. geographical location of the photographer, date, authorship and number of views). These photographs, which are often referred to as geotagged photographs, are digital footprints left behind by people moving across the globe. Various authors have taken

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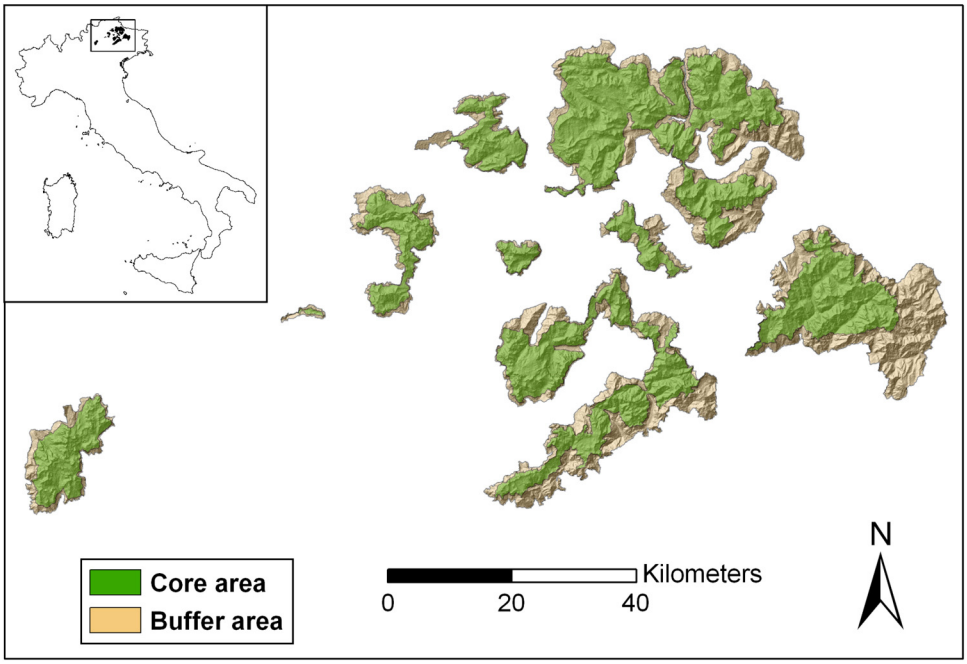

Fig. 1. The Dolomites UNESCO World Heritage Site and its location in Italy. The site is made up of nine separate units and includes core areas, for nature conservation, and buffer areas, protecting core areas from external disturbances.

advantage of these features to assess the popularity of places and detect people's movements (Girardin et al. 2008a, 2008b; Antoniou et al. 2010; De Choudhury et al. 2010; Jankowski et al. 2010; Vrotsou et al. 2011). Among these, Girardin et al. (2008b) used a large dataset of images to quantify visitor flows from one attraction to another; De Choudhury et al. (2010) extracted photo streams of individuals and aggregated them to generate tourist itineraries; Jankowski et al. (2010) analysed a large dataset of photographs to identify places that are frequently visited, and extracted sequences of photos from single photographers to detect photographers' movements in space and time. Common to all these approaches is the detection of travel patterns as flows from one popular location to another as a way to assess the popularity of various attractions and extract sequences followed by people to visit them. While extremely supportive in many contexts (e.g. tourist cities), this is typically not the kind of information required for protected area management. Rather than a mere quantification of visitor flows between locations, park managers and administrators need to know how such flows are distributed over the trail network (i.e. not just how many visitors go from A to B, but how many visitors travel on each trail between A and B). This information can provide relevant insights into the likely effects of visitation on the environmental and recreational conditions of an area (e.g. potential trail degradation, disturbance to wildlife, overcrowding, etc.), and it is therefore essential to define adequate actions (e.g. introduction of use limits, maintenance operations, etc.) to manage that same area.

The use of geotagged photographs to estimate visitor flows in natural areas for management purposes is characterised by one critical issue, namely the gap between the detail of the information required and the amount of information available in the geotagged photograph database. More specifically, while park managers and administrators need visitor flow information on the entire trail network, visitation rates in natural areas may be too low to result in a suitable density of geotagged photographs. This applies particularly to remote territories, where only few people travel every year, as well as to itineraries whose natural characteristics (e.g. dense forest cover) do not encourage people to take pictures. Hence, methods are needed that can generate estimates of visitor flows, even in the presence of few and unevenly distributed geotagged photographs. This study proposes a novel GIS-based methodology for the estimation of visitor flows in natural areas that uses geotagged photographs to identify popular destinations, and a gravity model to estimate flow volumes as a function of access and destination points' popularity, and the effort required to travel between those points. While showing the strengths and weaknesses of the methodology, we describe how and under which conditions it can be used as a management tool. The methodology, which improves the one introduced by Orsi and Geneletti (2012), is tested with data from the recently established Dolomites UNESCO World Heritage Site, located in the eastern Italian Alps.

Study area

The Dolomites UNESCO World Heritage Site is located in north eastern Italy at latitudes 46°03′–46°45′ N and longitudes 10°46′–12°46′ E, is made up of nine separate units and covers a surface of 141,903 ha plus an additional 89,267 ha of buffer areas (Fig. 1). The site, which was established in June 2009 in recognition of the aesthetic and geomorphologic value of dolomitic mountains, features 18 peaks over 3000 m of elevation and beautiful mountain landscapes characterised by vertical walls and deep valleys. An extended (hundreds of kilometres) and well maintained trail network along with good infrastructures, including several cable cars and chairlifts, allows hundreds of thousands visitors to explore the site every year, though numbers vary greatly both between and within units. The tourist presence is mostly concentrated in the months of July and August (high season), while it decreases considerably in June and September (low season). Today no systematic monitoring is performed across the site and actual visitor flows are only measured at some locations, where visitor counters are installed.