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Analysing hiker movement patterns using GPS data: Implications for park management

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ABSTRACT

In natural areas, park management organisations need to cater for economic, environmental, recreation and social demands and values. However, multifunctional land use also creates conflicts. Increased numbers of people using an area could exceed its ecological carrying capacity. The recreational quality of areas could be negatively impacted by conflicts in recreational behaviour. Therefore, park managers require spatio-temporal data on visitor flows, but there appears to be a shortage of suitable visitor data. If there are data available, these often do not deliver the information required by managers and there is little guidance on appropriate monitoring variables. This paper therefore combines user movement analysis with environmental and ecological factors for natural resource management. Through a case study we describe the entire working process from field data acquisition to usable park management information. GPS and itinerary data from 138 visitors to the Drents-Friese Wold National Park (the Netherlands) were collected to estimate visitor densities and distribution patterns within the park. Data acquisition is efficient in the working process, but careful error handling is a time consuming but necessary part of it. We introduce the definition of 'hard' and 'soft' errors to make spatial analysis more flexible. We show that walking speed, trip time and spatial distributions varied between park visitor groups. Classification and Regression Tree (CART) analysis showed that factors such as the presence of marked trails, distance to facilities but not land use (such as forest or arable land) explained visitor distributions. Patterns differ between respondent groups based on group size and composition, which is also true for itinerary variables such as walking speed and trip time. The combination of high resolution location data with itinerary information from respondents provides a good impression of the different walking preferences of different respondent groups. We conclude therefore that combining GPS data with itinerary information is a useful tool in profiling different natural park visitors. This is useful information for park managers in steering tourists and in catering for different visitor demands in natural parks.

1. Introduction

In natural areas, park management organisations need to cater for economic, environmental, recreational and social demands and values (Geneletti & Van Duren, 2008). Therefore, park management goals not only focus on nature conservation and nature development and redevelopment, but also include recreational targets. However, multifunctional land use also creates conflicts. An increase in the number of people using an area could mean its ecological carrying capacity is exceeded (e.g. Hadwen, Hill, & Pickering, 2007; Lyon, Cottrell, Siikamaki, & Van Marwijk, 2011; Wimpey & Marion, 2011). An area's recreational quality could be negatively influenced by conflicts in recreational behaviour (Ligtenberg, Van Marwijk, Moelans, & Kuijpers, 2008; Orellana et al., 2012).Therefore, park managers not only need information on ecological and environmental values, but also require spatio-temporal data on visitor flows. Analysing tourist behaviour – such as places visited, time spent and facility use – can help managers adapt infrastructure and facilities to offer more diverse options to different visitor groups (Dye & Shaw, 2007; Holyoak & Carson, 2009; Wolf, Hagenloh, & Croft, 2012) or to route visitors to a range of park locations to avoid overcrowding and to achieve greater matching of visitor and interest (Lyon et al., 2011; O'Connor et al., 2005). Moreover, spatial visitor flow information could be used to define ecological zones and facilitate recreation routing to avoid ecological carrying capacity overload in natural areas (Freuler & Hunziker, 2007; Lyonet al., 2011; Orellana et al., 2012).

There appears to be a lack of sufficiently detailed visitor data for natural areas suitable for supporting park management definitions (Wolf et al., 2012). Where data are available, these often do not

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deliver the information needed by managers (Hadwen et al., 2007) and there is relatively little guidance on the monitoring variables required (Wolf et al., 2012). This paper therefore combines user movement analysis with environmental and ecological factors for natural resource management. Using a case study, we describe the entire working process from field data acquisition to usable park management information. The novelty of our paper lies primarily in its interdisciplinary character. We bridge a gap between GI technology and methodologies on the one hand, and a real-world problem from a park management perspective on the other. Secondly, special attention is paid to data quality and error handling. We distinguish between 'hard' and 'soft' errors. Thirdly, this paper illustrates the use of the non-parametric Classification and Regression Trees analysis (CART) to assess the visitor density as a function of landscape characteristics. Fourthly, the paper demonstrates the value of itinerary information combined with GPS data in distinguishing between different visitor groups.

In the paper, we first provide a background of GPS tracking in Section 2. In Section 3, we introduce the Drents-Friese Wold National Park as study area. In Section 4, the methodology is outlined describing the full working process from data acquisition via data quality to analysis. It also includes a description of the different datasets used. Section 5 describes results and discussion of the analyses, including hard and soft error handling, differences in walking behaviour between groups and spatial distribution patterns. We finalise the paper by concluding remarks and recommendations on the working process, data quality, spatial movement patterns and the possible use for park managers.

2. GPS tracking

In recent years, (agent-based) computer simulations have been applied to assess the expected visitor distributions in natural areas (e.g. Lawson, 2006). For model validation purposes, empirical field visitor data are required (O'Connor et al., 2005; Van Marwijk, 2009; Orellana et al., 2012). GPS techniques are widely available to obtain field data. GPS data acquisition is usually fast and yields large, detailed datasets, but the use of these data is often limited to visual (e.g. Taczanowska, Muhar, & Brandenburg, 2008) or exploratory analysis (e.g. Chen et al., 2011). Several authors have shown that GPS or local spatial transmission/receiving techniques are suitable for further spatial analysis. Their focus is on the method or technique(e.g. Laube & Purves, 2006; Taczanowska et al., 2008), the entire sample (e.g. Ligtenberg et al., 2008), the individual (e.g. Chen et al., 2011), or on separating group behaviour solely based on spatial patterns (Dias, Edwardes, & Purves, 2008; O'Connor et al., 2005). Although the possibility of separating groups based on motives and group composition is mentioned, its application is limited. Some researchers explicitly choose between time–space activity diaries (Xiao-Ting & Bi-Hu, 2012) or GPS data logging (O'Connor et al., 2005), but the literature available on analysis that combines GPS data logging with (qualitative) itineraryinformation is limited (e.g. Van Marwijk, 2009; Wolf et al., 2012). Itinerary information is used to divide respondents into different demographic or motive groups, but not to statistically test the validity of the group separation itself. In addition, the quality analysis and error handling of GPS data are often limited (Van Marwijk, 2009).

Van Marwijk (2009), Wolf et al. (2012) and Xiao-Ting and Bi-Hu (2012) provide a general overview of the advantages and disadvantages of different techniques for assessing visitor flows in natural areas. These techniques include mental mapping, GPS-logging, space–time diaries, interviews afterwards, anecdotal evidence and direct observation (e.g. following visitors). Since the costs of GPS loggers have decreased significantly in recent years (O'Connor et al., 2005), quantitative empirical data can now complement the techniques mentioned above. By supplying GPS devices to individual tourists, high resolution data can be obtained (Taczanowska et al., 2008) with little effort from respondents, making data collection less time consuming than other methods (Shoval & Isaacson, 2007). GPS loggers also provide additional information such as duration of stops, speed and off-trail behaviour (Dias et al., 2008; Taczanowska et al., 2008; Wolf et al., 2012).

A disadvantage of the use of GPS loggers is the limited accuracy of signals in densely built-up areas and closed-canopy environments, because a direct line of sight between satellites and the GPS logger is required (Shoval & Isaacson, 2007). In addition, due to the high volume of data – some of it with errors and missing data – data cleaning and analysis is time consuming (Van Marwijk, 2009). A practical drawback is the need for the research participants to start and finish at designated locations so that the GPS loggers can be distributed and collected at the end of the data collection period (Taczanowska et al., 2008). While there are privacy issues associated with this type of research, Taczanowska et al. (2008) have shown that only a few visitors actually refused to take part in a project for this reason. Another point of concern is the extent to which the visitors' awareness of the GPS receiver could influence their walking behaviour (O'Connor et al., 2005). For example, visitors who do not follow rules and regulations are unlikely to participate in a research project, biasing the data obtained (Taczanowska et al., 2008).

3. Drents-Friese Wold National Park

3.1. Case study

In 2011 the managing organisations of the Drents-Friese Wold National Park started updating their park management plans (Elzinga, 2011), which aim to connect the location-specific nature and landscape values with socioeconomic targets for the park. This involves enhancement and restoration of the area's natural and cultural historical values. One aspect of the plans is to create silence and tourist zones. Four different zones with different ecological values and visitor density acceptance have been defined. An estimate of current visitor densities and hiker behaviour is therefore useful as baseline assessment, which makes the National Park a useful area for this study.

3.2. Study area description

Drents-Friese Wold National Park (6000 ha, Fig. 1) is one of twenty National Parks in the Netherlands and was founded in 2000. The main aims of the park are fourfold (Oranjewoud, 1998): 1. intensification of nature protection and nature redevelopment; 2. promotion of nature-based recreation, 3. stimulation of education and 4. stimulation of research on biotic and abiotic values and recreation in the area.

The managing organisation of the Drents-Friese Wold National Park is a co-operative composed of four bodies: the State Forestry Commission (Dutch: *Staatsbosbeheer*), the National Society of Natural Monuments (*Vereniging Natuurmonumenten*), and the 'Het Drentse Landschap' and 'Maatschappij van Weldadigheid' foundations. The area consists of a landscape mosaic of pine and broad-leaved forests, heaths and open wind-blown sand areas. Biodiversity values are high in the area. The park is also an important recreational area: it is widely used for hiking, cycling and horse riding. Tourist facilities include a visitors' centre focussing on natural values, benches and picnic tables and several signposted trails. The trails range from those accessible to people with physical impairments to rough paths. Most facilities are situated close to car parks, the visitors' centre and signposted trails (see Fig. 2).

The area is zoned based on ecological values (Oranjewoud, 1998). The first zone consists of open, sparsely forested areas, such