Potential and limitations of GPS tracking for monitoring spatial and temporal aspects of visitor behaviour in recreational areas

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Abstract — The application of satellite based navigation systems such as the Global Positioning System (GPS) to record spatial/temporal aspects of visitor behaviour has received more attention in recent years. The aim of this paper is to discuss the potentials and the limitations of GPS-tracking, based on empirical data collected in the Danube Floodplains National Park in Austria (Nationalpark Donau-Auen). A total amount of 485 hiking itineraries were collected in the field using Garmin e-Trex devices. After returning the GPS receiver visitors were interviewed and additionally asked to draw their route on the map. 372 complete records (GPS tracks plus map sketches) were thereby obtained for further analysis. The highly detailed spatial resolution of the data allowed deriving more exact route characteristics compared to traditional data collection methods such as trip diaries. GPS-tracking was more accurate than map sketches in areas with poorly defined trail network. Some respondents were not able to report the exact route, due to insufficient map reading skills or orientation problems in the outdoor environment. In such cases, in particular, the GPS approach proved its intrinsic advantages. Nevertheless, some limitations of the GPS use have also been identified. In particular, problems with the quality of the satellite signal in areas covered by dense deciduous forest turned out to be a major limiting factor for GPS-tracking in the presented National Park setting.

Index Terms — GPS, GPS tracking, spatial behaviour, monitoring methods, visitor flows, recreation

1 Introduction

Satellite based navigation such as the Global Positioning System (GPS) can be used to capture and to register spatial-temporal features of visitor behaviour in recreational areas [1], [2], [3]. The intensive development of GPS navigation and tracking technologies in the last decade led to reduced hardware costs and improved quality of the analysis software [4].

This paper explores the potentials and the limitations of GPS-tracking for visitor monitoring, illustrated by practical examples from a case study carried out in the Danube Floodplains National Park in Austria. (Nationalpark Donau-Auen)

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2 Methods

The results presented in this paper are based upon empirical data collected from the Lobau – the westernmost part of the Danube Floodplains National Park in Austria that lies inside

the city limits of Vienna. This study only focused on hikers. A total amount of 485 personal hiking routes were collected in the field using 55 Garmin e-Trex devices (SiRF II). After returning the GPS device visitors were interviewed and asked to draw on a map the hiking route that they took on that particular day. The complete sample size (GPS track combined with survey data) was 372. Each of the collected GPS tracks contained spatial and temporal information about a hiker's itinerary, stored as a set of trackpoints. The location of a visitor defined by geographic coordinates of the WGS84 reference system was recorded in a constant interval of four second. The primary data were pre-processed in order to eliminate the outliers from the dataset. The analysis itself focused on the comparison of the distribution of the trackpoints and the routes sketched on the paper map by the interviewees.

3 SELECTED RESULTS

3.1 Individual routes

The following route characteristics were derived from the GPS data: route length and trip duration, direction of movement, walking speeds, as well as the overall number and duration of stops. At the same time several route characteristics were generated based on the survey form and the sketched routes. In this case the route length and the duration of visit were taken into account. Table 1 presents several examples of route attributes, with distinction of the data collection technique.

The paths of travel reported by visitors differed in some cases from the GPS records. Currently, we shall examine several quantitative and qualitative methods that analyze the similarities between the respective routes. One of the methods considered in this study consists of calculating the GPS trackpoints that overlap with the reported routes. Another possible solution is application of the map matching technique to assign the recorded track to the trail network and analyzing the corresponding sequences of the reported path segments. Figure 3 illustrates an example of a GPS track and a corresponding trip sketch. In this case, there is a visible spatial difference between the two data collection methods.

TABLE 1

SELECTED ROUTE CHARACTERISTICS

	Min.	Mean	Max.
Survey & Map Sketch			
Route length (m)	1129	5226	21283
Trip duration (min)	27	108	420
GPS Tracking			
Route length (m)	896	5281	22978
Trip duration (min)	30	98	367
Number of stops	1	5	24
Duration of stops (min)	2	23	152
Average speed (km/h)	1,0	3,3	5,6
Average speed in motion (km/h)	1,4	4,1	8,23

Length N = 227, Duration N = 226, Stops & Speed N = 200

3.2 Visitor distribution

GPS data might be also used for analyses at an aggregate level to investigate the distribution of visitor flows in an area of a nature reserve. Figure 4 shows an output of

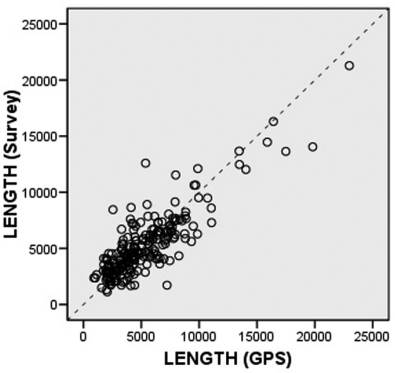

Fig. 1. Scatter plot of the route lengths recorded by GPS vs. calculated basing on the route sketches. The correlation coefficient r = 0.850, p < 0.01

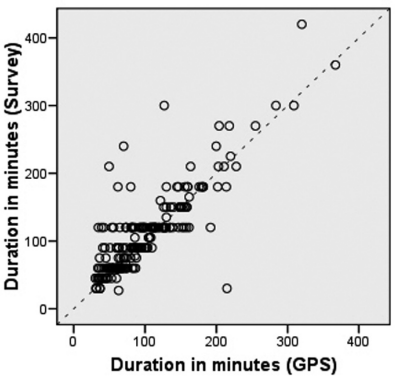

Fig. 2. Scatter plot of the trip durations recorded by GPS vs. reported by visitors. The correlation coefficient r = 0.843, p < 0.01

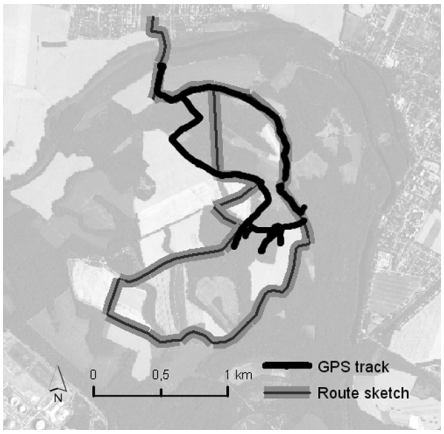

Fig. 3. An example of a recorded track (GPS) and the route reported by the same visitor.

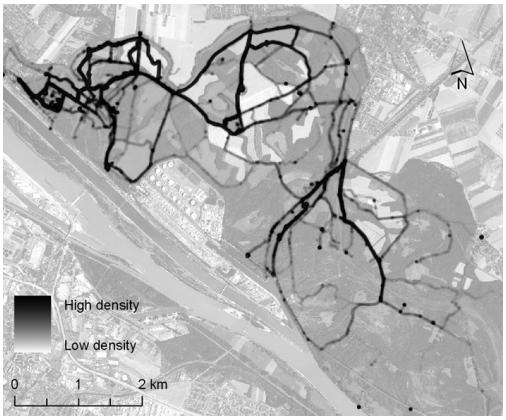

Fig. 4. Spatial distribution of visitor flows in the Lobau - result of a density analysis, based on a dataset of 416646 trackpoints.

the density analysis, based on the dataset of GPS trackpoints. Dark colours indicate high intensity of public use. The majority of hikers used the existing trail network. However, the use of unauthorized shortcuts and wild paths was identified during the analyses of data recorded by GPS devices (see figure 5).

Several spatial-temporal aspects can be analyzed at a more regional level, for instance temporal changes of public use during the course of a day or the localization of places where park visitors tended to take rest. Figure 6 depicts the prevalent resting places of the study respondents and the duration of their rest- time.

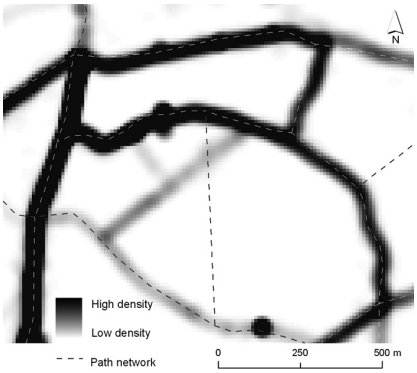

Fig. 5. Spatial distribution of visitors in the Lobau. Density analysis based on GPS data revealed the presence of several non-documented shortcuts and wild paths in the area. The dashed lines indicate the trail network based on the topographic map 1:25.000.

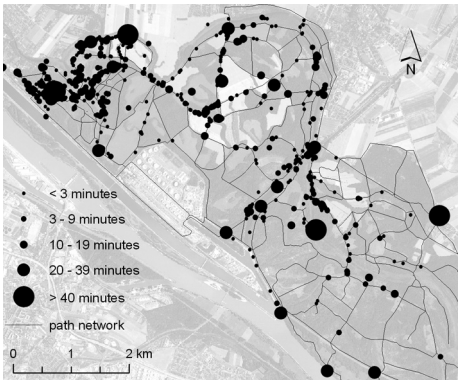

Fig. 6. The map of places where the respondents stopped during their hike in the Lobau. The size of a symbol indicates the duration of stop.

4 Discussion

4.1 Potential of GPS tracking

The presented research showed several practical applications of GPS tracking for monitoring spatial-temporal aspects of visitor behaviour in rural and/ or wilderness settings. The major benefit of this data collection method is the high resolution of data documenting human behaviour measured in space and time. Such information offers new dimensions for analyses involving the spatial-temporal trajectories [5]. Besides the information that can be gathered using traditional data collection methods, such as route lengths and trip itineraries taken from map sketches or analogue trip diaries, several new characteristics of recreational activities can be acquired using this technology. Documenting the speed of movement, duration of stops and location of resting places, as well as identifying off-trail use can only be reliably gathered due to the use of GPS tracking. The route attributes presented in this paper are similar to other studies employing GPS technology to track people's motion [1], [3], [6]. The traditional monitoring methods can be confirmed and enhanced by the corresponding digital records of visitor behaviour [2].

Several studies reveal the ability of GPS to record a track much more accurately than the respondents were able. [7]. In the presented study there were several examples supporting this thesis. However, the definite conclusions have not yet been drawn.

4.2 Limitations of GPS tracking

Although GPS tracking demonstrates quite a number of advantages as a tool for collecting data pertaining to individual visitors, there are also some limiting factors that inhibit the use of this method in outdoor settings. The major problem encountered in this case study was related to the quality of data. Several cases of data loss were observed, usually caused by signal disturbance due to dense forest cover. Only 59 % (N = 286) of the tracks had sufficient quality to fully derive individual route attributes. Another limiting factor experienced during the course of fieldwork were the logistics of data collection that favored the 'loop' type of hiking itineraries. This was due to the fact that the visitors, which had indicated their wish to exit the Lobau at different gates than those staffed by interviewers, could not be equipped with GPS devices.

Only a few visitors refused to take part in the project, mostly due to ethical reasons. They considered this kind of research as disturbing their privacy during their leisure time. However, the large majority of hikers had a positive attitude towards the study. It can be assumed that visitors accepting to carry a GPS are more likely to adhere to visitation rules (such as not hiking off the marked trails), or vice versa, visitors not adhering to the rules will most probably refuse to participate in such a study, thus causing an intrinsic bias in the data set.

5 Conclusions & outlook

GPS-tracking is an increasingly promising data collection method, gaining in importance in the fields of transportation, urban planning and architecture. It also has potential as a tool used for monitoring recreational use in outdoor environments. The intensive development of new technologies gradually overcomes the major limitations discussed in this paper. A higher level of accuracy is already guaranteed by the 'new generation' GPS devices equipped with the SiRF III chips. The technology becomes cheaper and ever more accessible, which duly encourages its more widespread use. There are several examples of matching data collection processes and tourist services using the Location Based Services (LBS) technology, for instance the WebPark system in the Swiss National Park [8] or the BALANCE system [9] being developed for the Lobau area in the Danube Floodplains National Park in Austria. There is a need for further development of

data processing, analyses and visualization methods, which can inspire formulating new research questions and innovative management solutions.

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