Combining GPS-tracking and graph theory for evaluating the functionality of hiking trails in recreational areas

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Introduction

Areas of high natural value belong to the most attractive recreational destinations. Balancing needs of visitors and site capacities is considered to be the major challenge for planners and managers of such amenities (Bell, 1997). Comprehensive understanding of human spatial behaviour and the actual use of recreational infrastructure can support effective planning of outdoor leisure settings. Strategic allocation of infrastructure and provision of information are important tools to manage the direction of movement as well as recreational experience of visitors.

The aim of this paper is to present a new method of evaluating the functionality of a trail network combining GPS-tracking and graph theory. The main focus is placed at the assessment of the overall trail connectivity as well as at the relative importance of network nodes, as key locations affecting way finding of recreationists.

Study Area

The study is based on empirical data collected in the Lobau recreational area in Austria. The Lobau is the westernmost part of the Danube Floodplains National Park (Nationalpark Donau-Auen) that lies inside the city limits of Vienna. This respectively small recreational area (2400 ha, 2km x 10km) attracts approximately 600 000 visits per year (Arnberger et al. 2000). Hiking and cycling are the two major recreational activities practiced in the area. The total length of paths and trails in the Lobau is 130 km.

Methods

Two types of data were used in this study: the physical structure of a trail network and a record of trip itineraries (GPS tracks) of recreational area visitors. The trail network has been digitized using ArcGIS software and verified using GPS during a field-work. In order to investigate the actual use of trails in the Lobau a GPS-tracking approach has been applied (Taczanowska et al., 2006). 482 trip itineraries (GPS tracks) of individual visitors were collected during 4 sampling days in the case study area. 60 GPS devices (GARMIN e-Trex) were distributed at the entrance gates among the National Park visitors.

Data analysis consisted of five steps: 1) Pre-processing of GPS data; 2) Creating the structural network (undirected graph); 3) Creating the functional network (directed graph); 4) Calculating network connectivity indices; 5) Calculating the importance of network nodes (Measurements: Input degree; Output degree; Input Closeness; Output Closeness; Betweenness). The pre-processing of the collected GPS data as well as the analysis of the structural and functional trail networks have been done using Matlab modelling environment. Some specific network properties such as parameters describing the importance of nodes and the graphic representation were carried out using the Pajek (version 1.28) software. Figure 1 shows an example of a directed graph based on a visitor's trip itinerary. The directed graph for the entire Lobau area is composed of all accurate GPS-tracks (N=314).

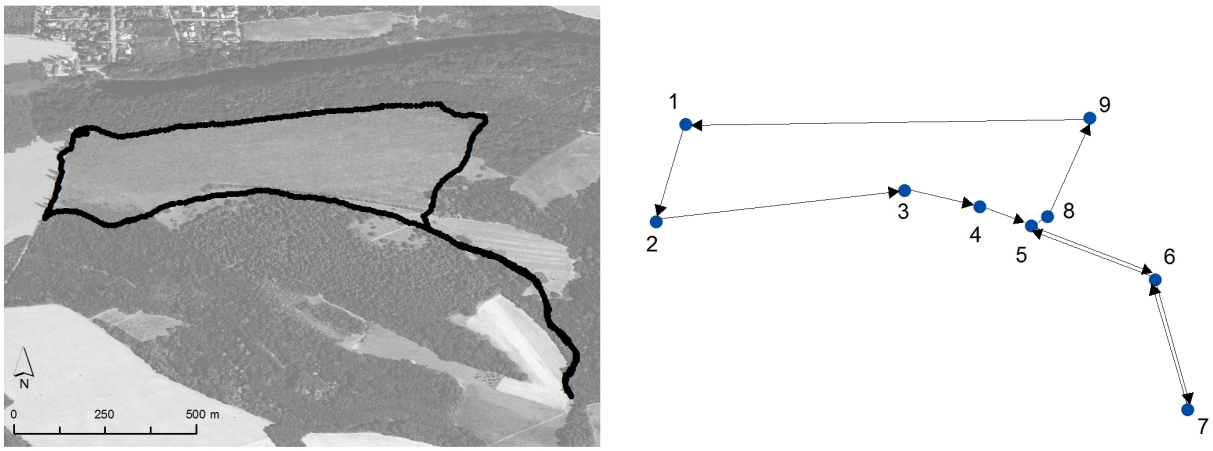

Figure 1. Example of a directed graph based on a visitor's trip itinerary (GPS track) in the Lobau area.

Results and Discussion

Basically, it can be observed that the network of the existing paths in the Lobau has a high connectivity. It belongs to the delta network type (Taaffe & Gauthier, 1973), characterized by a high density of linkages relative to the number of nodes. Such structure enables an efficient flow of visitors through the network, offering many route choice possibilities. However, the investigated trail network has not been evenly used by the area visitors. Due to a good access to the Lobau in the northern and western part of the area visitors tend to use trails located close to major entrance points. The south-eastern part of the Lobau ("Untere-Lobau") is less frequently used.

The calculated node centrality measurements show clear differences in the importance of network nodes. “Output and Input degree” parameters reflect the intensity and the direction of use at each node location. There is a clear disproportion of use between the north-western and south-eastern parts of the Lobau. The directions of use are balanced at most locations, which means that the nodes are used in both directions and there is no dominant “collector” or “sender” nodes in the Lobau area.

From the management point of view the “Betweeness” parameter might be especially valuable. Nodes lying on the communication paths between different area locations are regarded to be important. The higher the betweenness value, the more paths may cross a given node. The result for the Lobau network shows that in this respect the most important nodes are located in the northern and central part of the area.

Conclusions & Outlook

The main contribution of this study is combining GPS-tracking and analytical methods based on graph theory to better understand the structure and the function of a trail network in an outdoor recreational site. Identification of the important network nodes can be supportive while planning locations of sign-posts, on-site maps, interpretative-trails or resting places. Furthermore, knowledge concerning connectivity parameters helps estimating whether the trail network enables effective flow of visitors to the desired destinations.

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