Methodology of assessing walking accessibility of the recreation zones in mountainous area by applying data of the high-resolution aerial surveying with UAV and cadastral maps

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SUMMARY

Authors of the research propose the methodology for studying conditions of the pedestrian infrastructure by applying advanced geoinformation technologies. The known algorithms of computing the raster maps of the cost of travelling, speed of pedestrians’ walking in the mountainous area by applying the Tobblers’ hiking functions, and development of the isochrone maps are supplemented with the high-resolution models of the area. These models include orthophotos, digital models of the visible surface, and a raster model of the relief, which are created basing on the materials of aerial surveying with unmanned aerial vehicles. The data about the underlying surface are obtained from aerial images, and the map of obstacles for travelers – also from aerial images and cadastral maps. Noteworthy is the fact that modern technologies of aerial surveying with UAV enable creating highly detailed digital models of the area, which are suitable for engineering tasks, but are excessively detailed for the landscape study. Thus, there is a need to perform additional program procedures for generalization of the relief model for the goal of routing. When archive materials of aerial surveying are available, there is a technical possibility to compare efficiency of the engineering arrangement of the recreation zone, particularly changes in the conditions of the route passing, efficiency of designing the viewing platforms and parking areas, etc. The recreation zone in Skhidnytsia resort-town located in Carpathians was chosen as the research object.

Keywords: geography of tourism, geoinformation systems, pedestrians, recreation zone, application of UAV
Introduction

Mountainous area is traditionally the location for tourism and recreation. In particular, it is used to organize hiking tours of different complexity and duration, and recreation area is often the site of arranged pathways for learning local history and relaxing. The properly organized activities contribute to attracting more tourists, motivate the public to active living, provide safe and comfortable conditions for guests. Modern information technologies offer a wide range of options for the professionals engaged in organization of the tourism and recreation activities. It is worth noting about application of geoinformation technologies (GIS) for laying tourist trails in the area, their proper equipping, current servicing during the tourist season, safety, etc. Common users can apply the analytical tools for individual planning their routes, as well as navigation equipment of domestic use. Both these groups can effectively create the route by applying GIS tools. A designed itinerary of passing a tourist road in the mountainous area by a specific target group of tourists (or by one tourist) hereafter will be called a “tourist route”.

Professional geoinformation technologies provide great opportunities for solving the tasks of routing based on the actual, reliable spatial data and specialized computer algorithms. Today, there is access to the digital models of the terrain created by the remote sensing of the Earth, aerial surveying with unmanned aerial vehicles, information about the object location based on the system of satellite positioning. A wide range of consumers is oriented on specialized web-services, which use simplified algorithms to assist in designing tourist routes without excessive details. Both variants are relevant but need more studying and improving for the conditions of the Ukrainian Carpathians. Authors of the work focus their attention on the technologies of geoinformation analysis of walking accessibility in the area of the National Park called Skolivski Beskydy, which is located near the resort-town Skhidnytsia.

Method and Theory

The advanced geoinformation technologies provide a wide range of options for specialists and common users when planning trails and laying tourists pathways (Babiy et al., 2019). For automatic designing tourist routes, they can use GIS software tools to model the ways (Turk, 2018). In that context, the typical procedure includes:

- Creating a Map of cost that is a raster structure with the cells containing information about the cost of passing the route. On the top of cost, the lower values are better (because they represent smaller cost) and it is considered when laying the trails automatically.
- Developing Isochrone maps of passing the wild area or pathways from one or several identified start points. These are the cartographic lines demonstrating similar periods of times spent to pass the space referring to the set points.
- Developing an optimal (in terms of time and energy spent by a tourist) route between the set points of the start and finish.
- Composing a corridor of optimal time spent between the two points in the area.

In geoinformatics, modeling of walking accessibility of the area and solving the problems of routing based on the model is conceptually performed by using the data about Digital Elevation Model (DEM), maps of soils of the topographic layers of the vector map with description of buildings, fences, hydrographic net, vegetation. Review of the scientific literature confirms that traditional methodologies of raster modeling are actively supplemented as to the impedance (opposition to move), caused by relief, available obstacles like water flows, vegetation, etc. Some researchers also add legal restrictions in the form of cartographic layers, as well as areas of potential contacts with wild animals, sites of no cell phone signal available, etc. Several studies are devoted to the time component of walking accessibility, which variates depending on the climate and night conditions. A group of researchers aim to consider differences in age, level of training, physical conditions of tourists, exhaustion during the trip (Páez et al., 2020; Merlin et al., 2023).
The deciding parameter, which is required for a correct laying of trails, is the speed of walking in the mountainous area. This parameter is described in the specialized literature, particularly of military topics and immediate response services (Zatelli et al., 2021). On average, a regular healthy person can walk 300-350 meter uphill and 400-600 meter downhill per one hour, with the maximum speed of 4.5 km/hour when walking down the 5% slope. However, it is difficult to measure the mathematical dependence of the tourist speed \( W \) outside the pathways, where local conditions can significantly differ. In that case, the overall functionality can be presented as:

\[
W = F(\text{terrain slope \& height, veget.type \& density, human's physical condition, lighting, weather})
\]  

(1)

Some parameters are defined empirically from the systems of references, some of them can be obtained from information services (weather, visibility, time of the day), whilst characteristics of the relief, soil, vegetation and present obstacles are taken from already composed online maps of the area (Gentilucci et al., 2019). Nevertheless, it is often recommended to use a simplified model of calculation, as for example ArcGIS, which computes how much time it will be needed for a tourist to walk out of the dangerous zone or emergency situation.

Correction of the computed parameters and those taken from the systems of reference is usually done by applying both decreasing or increasing coefficients. GIS tools are often used to correct the covered distance with consideration of the vertical factor. In the scientific and applied literature, the Tobblier’s hiking function for calculating the hiking trails has got great popularity. The function determines the hiking speed \( W \), taking into account the slope angle \( S \), by the formula (2):

\[
W = 6.0 \cdot e^{-2.5 \cdot \frac{\Delta h}{\Delta x}}
\]  

(2)

where: \( W \) – Speed (km/h); \( \Delta h \) – difference of heights; \( \Delta x \) – distance; \( \text{Slope} = \frac{\Delta h}{\Delta x} \).

Before using the equations (1) and (2) for calculations in GIS, it is necessary to get a raster Digital Elevation Model (DEM) with the resolution being proportional to the scale of the studied area and accuracy of solving the tasks of the route designing. For a large area and approximate values, it is convenient to apply public regional DEMs with the spatial resolution ranging from 25 to 90 meters of physical land. For a more detailed local studies within parks, resorts, it is more reasonable to use DEMs with the spatial resolution ranging from 0.4 to 5 meters of physical land, although there are no clear recommendations in the literature. The first analytical process involves using DEM data to create a raster map of the slope steepness, which identifies the slope angle in degrees, radians or percents in each pixel. Almost all of the above-mentioned information products, namely maps of cost, isochrone maps, search for the optimal ways are obtained by the standard means of geoinformation systems, which are well-described in textbooks and manuals, and therefore, not presented in details in the present paper.

In the recent researches, it is often recommended to get data about the relief and other topographic characteristics of the area by applying the methods of aerial surveying with Unmanned Aerial Vehicle (UAV) and portable GNSS equipment (Boone et al., 2023).

**Results**

The research is focused on the study of walking accessibility of the recreation area, which includes a pedestrian zone and a park in the central part of the town, a summer theatre and mineral water pump room. It is the most often visited place. The town street network of the area is complemented with the arranged and spontaneous hiking trails.

The authors of the research used cadastral maps to identify obstacles and zones forbidden for visiting by vacationers, as well as orthophotos and DEMs, obtained by means of aerial surveying with unmanned aerial vehicles in 2019. Parameters of that surveying are published in the work (Hlotov et
al., 2021). Spatial resolution of the DEMs equals to 25 m of physical land, accuracy of the defined marks of heights is \( m_z = \pm 0.33m \). The orthophoto has resolution of 10 m of physical land and accuracy of the identified plan coordinates \( m_{x,y} = \pm 0.2m \). During the photogrammetric processing in Pix4D program, we also obtained a digital model of the DSM visible surface and a classified cloud of 3D points that enabled assessing geometric parameters of the vegetation and buildings. Those spatial data, as well as data about the tourism infrastructure collected immediately in the resort area have been used to develop analytical models in GIS, which can serve as a basis for designing hiking routes and walking paths for the resort guests and travelers. Similar materials of 2014 are not available.

The authors have computed cost of passing the way from the point of viewing platform in the center of the recreation area towards the central part of the town. Types of the underlying surface have been determined by decoding the orthophotos, whilst surface of the area restricted for visiting by vacationers – from the cadastral map. The calculations were done in QGIS program, and the results were composed into a series of maps, which demonstrated the cost of travelling, time accessibility referring to the studied point (isochrones), assessment of visibility of the area from the viewing platform (Fig. 2).

The geodata of 2014 and 2020 were used to assess transformations in the network of hiking trails, particularly arrangement of coating, construction of stairs, changes in profile and the planned curvature. The engineering arranging of the area provides more convenient travelling, but has reduced duration of the walk by 9% on average for all age groups of vacationers. Thus, such reduction has
shortened the time the guests spend in the park. Extension of the trails in the restricted area of the recreation zone is a problem for landscape designers.

Having analyzed results of the research of the travelling duration, one can conclude that the correct choice of the coefficients and the proper design of the surface of the cost of travelling are of significant importance when modeling hiking in the mountainous area. With the available data of aerial surveying with UAV having resolution of 10 cm, such coefficients can be chosen only where there is certain experience of decoding the types of underlying surface on the aerial images. It is also confirmed that the DTMs with the spatial resolution of 1 m are proper for solving the set tasks.

Conclusions

By applying GIS tools, the authors of the research have computed the raster field of the cost of hiking in the recreation zone, designed the way over rough terrain by applying the Tobbler’s hiking function, composed isochrones referring to the viewing platform. The further studies will be focused on development of recommendations as to improvement of the network of educative and curative trails in the area of Skhidnytsia resort and adjacent territory of the Skolivski Beskydy National Park. Most of the analytical solutions can be implemented by applying the principles of open data and software. These results will be presented to the public of Skhidnytsia town and stakeholders.

References


