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# PROCEDURE OF BUILDING A WAVE ALGORITHM MASK IN ORDER TO FIND RATIONAL ROUTES WHILE SOLVING THE EMERGENCY SERVICE TASKS OF THE STATE BORDER GUARD SERVICE OF UKRAINE

*The paper proposes a procedure of forming terrain masks for rational planning of the routes. Proceeding from the geoinformation system data and using mathematical apparatus, the procedure makes it possible to build terrain masks required for the wave algorithm operation.*

***Keywords:*** *radio communication, route, software, State Border Guard Service, geoinformation system.*

## Introduction

Modern information telecommunication technologies enable significant improvement of the efficiency of solving many applied problems related to emergency service activities (ESA) of the State Border Guard Service of Ukraine (SBGSU), particularly to those of rational route planning. In [1 – 3] it was determined that for solving rational route planning problems the terrain mask formation is required. This mask determines the expediency of using certain terrain areas for laying a route.

In [1 – 4] the indicators are determined which could be taken into account for building the terrain mask and which describe the following aspects: the order of building the state border protection by the emergency service; provision of radio communication; weather conditions combined with cross-country ability of vehicles over different types of terrain. Absence of a scientific-methodological apparatus that could be used for calculating those indicators on the basis of the data from geographic information system (GIS) of SBGSU as well as the necessity of their comprehensive consideration determines **relevance** of this work.

Thus, **the aim of the research** is elaboration of the terrain mask construction procedure in order to provide rational planning of routes while solving the tasks of SBGSU ESA.

## Main part

According to [2 – 5], each element of the terrain mask is determined as follows:

1. Geographical coordinates of the terrain region are determined by the indices of the terrain mask element and its discretization;
2. In accordance with the information from GIS, it is determined whether this region belongs to the territory of Ukraine. If not, the corresponding element is assigned a zero value;
3. From the database of SBSU GIS the type of terrain is determined. If the terrain is impassable for the vehicle used, corresponding vehicle is assigned zero value;
4. If the mask element in accordance with items 2 and / or 3 is not assigned zero value, then the following should be done: a complex probability index of availability of radio communication is calculated; using GIS, membership function of the vehicle travelling speed over the corresponding terrain area is calculated taking into account weather conditions; complex normalized indicator is determined (for pessimistic, optimistic and the most probable variants) [5 – 7].

$$\widetilde{M}_{i,j} = w_1 \cdot (254 \cdot P_{con}(i,j) + 1) + w_2 \cdot (254 \cdot (1 - \frac{\widetilde{v}_{i,j}}{v_m}) + 1), \qquad (1)$$

where $\widetilde{M}_{i,j}$ is an element of the terrain matrix *M,* which is the number that determines the advantage of the corresponding terrain element in building the route; $P_{con}(i,j)$ – probability of the availability of radio communication in (*i,j*) square area; $w_1, w_2$ – weighting coefficients that determine the importance of radio coverage and passability of the terrain in the composite index (normalizing requirement $w_1+w_2=1$ is used); $v_m$ – maximal travelling speed; $\tilde{v}_{i,j}$ – travelling speed of the vehicle in the terrain region taking into account weather conditions in $(i,j)$ terrain square area (determined taking into account expert estimates as described in section 2).

It should be noted that $\tilde{v}_{i,j}$ is a fuzzy value determined by a membership function.

In order to determine $w_1$ and $w_2$, the method of expert estimates was used. As a result of its application, it was determined that $w_1=0.27$ and $w_2=0.73$.

To calculate (1), $v_{i,j}$ must be obtained for each terrain element. Respectively, for obtaining $v_{i,j}$ the method of expert estimates is proposed to be used. Using this method, minimal, maximal and the most probable motion speed over the terrain of each type is determined for all variants of vehicles and weather conditions. Substituting these speeds into (1), we obtain the values of corresponding elements for three terrain masks.

However, for calculating (1) we must have $v_{i,j}$ for each terrain element in accordance with the type of this terrain, the vehicle and weather conditions. Therefore, in order to provide automated calculations of (1), the masks of speeds $v_{i,j}$ are proposed to be built for various vehicles and weather conditions [6 – 7]. For building the masks **it is proposed** to use visualization means of ArcMap program included into GIS of SBGSU – ArcGIS.

ArcMap is the main ArcGISDesktop application for performing all cartographic tasks such as creation and publication of maps, map analysis and data editing.

A map in GIS of SBSU is composed from the layers having a number of properties with which you can work and which could be set. For this in the table of contents of ArcMap program you should select the Properties command in order to view the LayerProperties dialog box.

In the LayerProperties dialog box symbols, signs, representation rules and other options could be set. E. g., you can specify that lakes will be painted as blue polygons, patches of land – in the colors based on the values of the code that describes the type of soil, parks – by green fill, etc. The following additional properties of this layer could be also set in this window:

• a scale for the layer to be visible;
• a partial set of the data source objects that will be represented;
• location of the layer data set;
• properties of the attributes, links and connections for working with tabular information.

ArcMap implements the possibilities for geographical data set representation with the applicaton of symbols and graphs. As far as spatial objects are concerned, symbols are assigned to each object on the basis of attributive values, and for visualization of each layer definite methods are used. E. g., water objects and rivers could be represented using a single color (blue). Roads could be shown on the basis of their class. Seismological events, such as earthquakes, could be represented by means of calibration symbols on the basis of the magnitude value. Polygons could be classified taking into account the land tenure.

ArcMap proposes considerable number of visualization methods for creating the above representation of layers. Geographical information is shown by means of symbols and image representation methods. Key aspects of layer representation include assigning map symbols on the basis of spatial object attributes and the use of attributive fields for texts in the map. Often symbols are assigned to the objects on the basis of classification (e. g. classes of roads). In other cases for representation of quantitative information numerical data could be classified. E.g., population density, population age groups in each region or the cost of land in a settlement could be shown. For performing classification of numerical data of the objects one of the standard ArcMap methods may be employed, or user's own ranges of classes could be set manually.

In ArcMap there is a possibility to select the required visualization mode:

– representation using a single symbol;
– representation of the objects in accordance with the categories;
– representation of the objects taking into account quantitative indices;

– representation in accordance with several attributes.

Conditions can be used for limiting representation of certain objects (e.g., only field roads are to be represented).

For symbols, with which vector objects are represented (from SBSU GIS database, the color of contour could be determined and for polygonal objects – the fill color.

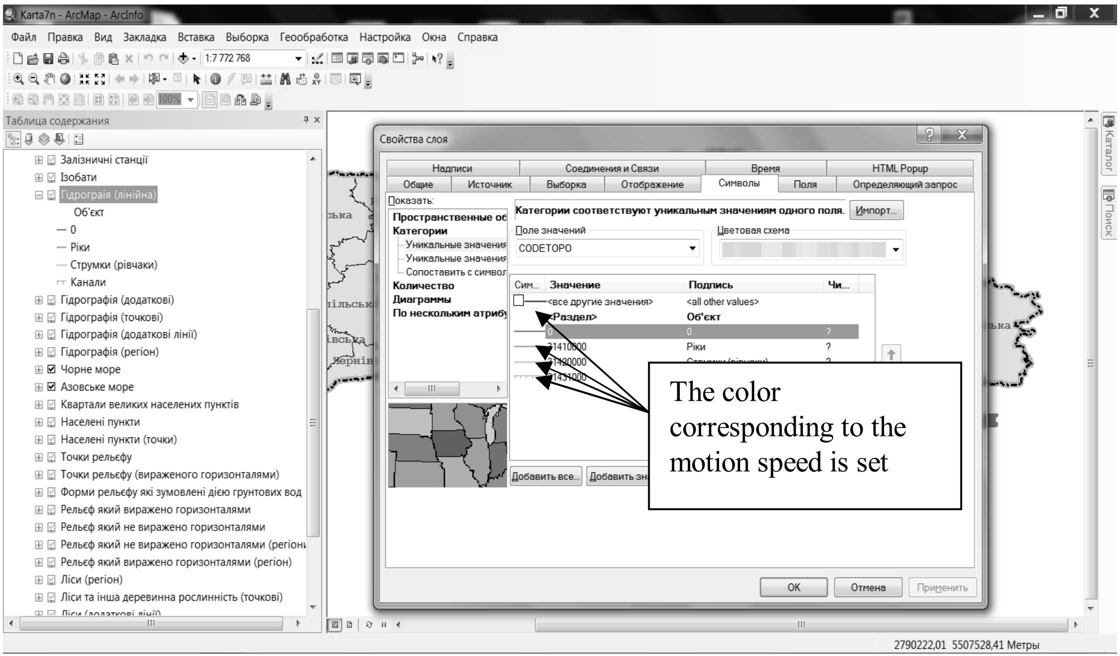


Fig. 1. Selection of the layer visualization mode

These capabilities of ArcGIS are proposed to be used for automatic terrain mask formation. For this, in ArcMap program (Fig. 3.11) for each variant of combination of transport means and weather conditions 3 documents are created, where a corresponding $\widetilde{v}_{i,j}$ · component is determined for each layer describing the terrain.

After selection of the required scale and terrain region the resulting mask component is saved in a graphic format (without distortion of the image). On the obtained graphic file a component is "superimposed", which takes into account radiocoverage, and then a corresponding mask is formed. The resulting mask is saved in a graphic format and is used for determing rational route. ArcMap is also used for visualization of a common map, against the background of which the routes are demonstrated. In this case, however, parameters, corresponding to a common cartographic visualization, are set.

When a transport means variant and weather conditions are selected in the program, three masks are read from the corresponding graphic files (file names have a standardized form that corresponds to the vehicle and the variant of weather conditions). After determining coordinates of the start and destination, the program, using a wave algorithm, finds three routes that form a fuzzy route.

Thus, **the procedure of terrain mask formation includes the following steps** (Fig. 2):

– using the method of expert estimates, motion speed of vehicles used for border protection is determined for various weather condition and different terrain types (minimal, maximal and the most probable speed is determined);

– using the ArcMap program, files with terrain description are formed (for different transport means in various weather conditions three files are formed for each variant);

– scaling and positioning of the map area and, with the application of ArcMap, export of both the map itself and of the previous masks with passability of the terrain for all variants of vehicles and weather conditions;

– using (1), calculation of the final terrain masks, that take into account radio communication coverage of the terrain, and saving them in graphic files (graphic format without image distortion is used).

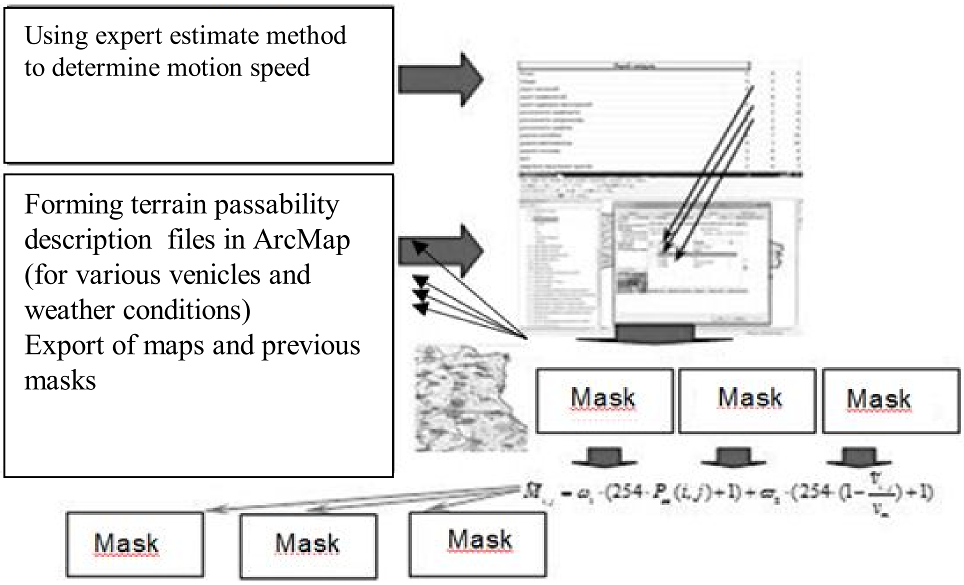


Fig. 2. Procedure of forming terrain masks

## Conclusions

The paper proposes a procedure of forming terrain masks for rational planning of the routes while solving the problems of SBSU emergency service activities. The procedure makes it possible to build terrain masks required for wave algorithm operation on the basis of information from GIS of SBGSU.

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