Creation of optimal cross-country route using GIS

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Abstract. Nowadays the systems for routing are well distributed. However, they all involve routing along existing roads. The article considers the options for the construction of transport routes over cross country, taking into account the technical characteristics of vehicles. The information in this article can be used to solve the problem of the creation of the software designed to develop an optimal route for the movement of technical equipment, taking into account a wide range of features of movement on the ground. In addition, the article discusses possible options for the improvement of modern navigation systems.

1. Introduction

Nowadays most of the existing open solutions for the search and construction of an optimal route for vehicles are focused on the use of the transport network and do not take into account such characteristics of movement as specific capacity, performance, etc. In addition, the difficulties arise when planning the movement of vehicles in the case when, for objective reasons, it is necessary to divide possible routes into small sections with places without roads in general. Often the inability to choose the optimal route of travel is a significant limitation of the applicability of wheeled vehicles. For example, the article [1] describes a method for treating a dusty surface of an water-borne array using an aerosol unit. At the same time, in order to be able to automate the movement, it is proposed to abandon the use of a truck as a tractor in favor of a rail platform, which entails a significant increase in capital costs.

Any modern navigation software includes a navigation program and a map database. The study of existing solutions in the field of navigation showed that they have a similar set of functions. From the point of view of a user, the main differences of navigation software products are in a different set of supported maps, and as a result, certain restrictions are imposed on the possibility of using the software.

Therefore, there is a need to develop a system for the automated search for the optimal route of vehicles with possible consideration of the peculiarities of movement in inaccessible areas based on generally available versions of electronic area maps. The optimal route search system should be cross-platform, suitable for working under various operating systems in local networks under various operating systems and have a simple and intuitive user interface that makes the program suitable for poorly trained users.
2. Creation of road graphs for various types of vehicles
Sometimes in order to reach the destination for objective reasons, it is necessary to divide a possible route into small sections with significantly different routing conditions.

The initial information for problem solution is the initial coordinates and destination coordinates, as well as geographical information describing existing roads in a particular area and area characteristics. The criterion for the choice of a route is time of arrival at the destination. As a tool for data processing, we selected graph theory models that provide a full description of the technique for the construction and optimization of routes.

During the routing on the basis of digital maps, all services use the principle of building a road graph on a digital map.

\[ G = (V,E), \]

where \( V \) – is a lot of vertices or nodes; \( E \) – is the set of graph edges.

The vertices \( V \) are crossroads, road junctions, edges \( E \) are the sections of roads connecting them. Each face of the graph corresponds to its own cost of moving along the face, set during the problem statement.

In fact, it is a digital vector map consisting of topologically connected arcs and nodes, the location and properties of transmit the routes and organization of ground transport which with a given accuracy and completeness. Such maps can be obtained on the basis of remote sensing materials by manual or automated digitalization [2, 3].

A graph of roads and road constructions is created as a separate layer of a user map without dividing it into stock lists. The road graph contains two main types of objects - arcs and nodes.

The branches, by the analogy with streets, are divided into branches with one-way and two-way traffic. As a rule, the directions and positions of the branches coincide with the axes of the roads, while the topology is maintained at the points of contact. The real one-way direction of movement should coincide with the direction of digitization of the one-sided branch.

With the use of this method, we can unambiguously describe any type of road infrastructure and take into account all types of intersections, overpasses, tunnels, etc.

Accordingly, the problem to be solved is as follows:

We have:
1) Vector area map.
A general map of the area can be represented as a set \( K \). This set consists of \( M \) graphic objects

\[ K = \{Q_m\}, \ m = 1, \ldots, M \]

Certain cartographic information is assigned to each object \((Q_m)\), which can be described as follows:

\[ W_m = <N_m(V_k)_m, A_m >, \ V_k = (x_k, y_k), A_m = \{a_p\} \]

where \( N_m \) – a parameter that determines the object which belongs to one of the classes (forest, hydrography, etc.);
\( \{V_k\} \) – set of coordinates \((x_k, y_k)\) of the object \(Q_m\);
\( A_m \) – thematic data attached to the corresponding object \(Q_m\), the \( a_p \) elements of which characterize the current state of the object (for example, ice thickness).

2) Digital landscape model

\[ H = \tilde{O}(x, y) , \]

where \( H \) – height at the point with coordinates \((x, y)\).

That is, a digital landscape model allows evaluating the altitude of each point on the surface.

3) The conditions imposed on the ability to move around the area.

In this regard, it is necessary to take into account the performance of area. The restrictions imposed on this area can be divided into the following types:
3. **Problem solution of route optimization**

As it was mentioned above, the current task of the traffic optimization of equipment is the task of optimal routing, taking into account several parameters at the same time, characterizing the features of the trafficability of road sections and the technical characteristics of the equipment.

Current navigation systems have the following disadvantages:

- all (open) geographic information services form a road network on their maps and, accordingly, create routes based solely on the use of several basic coefficient arrays;
- the shortest routes are constructed on the basis of only two possible estimates - the total duration of the route or the total time it took to travel.

In addition, during the analysis of possible routes, we need to use a wider data set:
- a road graph should be created taking into account the possibility of increased performance of vehicles;
- taking into account the technical characteristics of individual vehicles.

During the search of the optimal route of travel, it is necessary to use estimates for several factors, including:
- technical characteristics of a vehicle (performance, clearance, power, etc.);
- area characteristics;
- the route to travel.

According to the above mentioned aspects, we can say that it is necessary to solve the problem of optimal routing from the starting point $A(x_A, y_A)$, $A \in Q_m$

To destination $B(x_B, y_B)$, $B \in Q_m$,

taking into account the area and technical characteristics of the vehicle during the construction. The optimality of the route is determined by the minimization of traveled distance and energy costs.

It is necessary to solve the following tasks:

1. The creation of road graph on the basis of a digital map. The road graph is available for the movement of equipment having specified technical characteristics. This graph should be multi-valued, i.e., allow the introduction of multiple parameters to describe branches, in particular:
   - the length of the route in km;
   - performance ratios for individual vehicles;
   - coefficients that allow taking into account the effect of area properties on the movement of the vehicle, as well as their possible dependence on weather and climatic conditions.
2. The calculation of the value of the optimality criterion for each route.
3. The selection of the best route out of the calculated.

The selection of route, taking into account possible movements over cross country, is most often determined by its cross-country performance. If we are talking about non-urban environment, then the performance depends on many factors, including the altitude of the area, its swampiness, etc.

During the assessment of performance, the following coefficients are taken into account:
• slope angle in the direction of the intended movement;
• soil density;
• forest density;
• power of vegetation;
• depth of the water barrier, taking into account the density of the bottom;
• depth of snow cover;
• ice thickness.

The solution to the problem of optimal cross-country routing should include:

• The ability to manually form performance zones.
• The approximation by elementary sections (ES) of performance zones, in order to simplify the graph creation logic;
• The formation of a graph on the set of ES, the properties of which immediately indicate the features of the area and the necessary technical characteristics of a vehicle capable of crossing a given section of the route;
• The calculation of the route and its display on the map of the area.

In fact, we can say that we need to form all possible ways of movement (branch of the graph) from the starting point to the destination on a given section of the map. The formed branches of the graph will be the routes, while each of the branches will have a certain weight, which depends on the length of the branch itself, energy costs (for example, fuel consumption).

In order to solve the problem of optimal routing of technical means, it is necessary to generate data that meets the requirements of the selected algorithm, i.e., to describe the set of vertices of the graph and obtain estimates of individual routes and the route as a whole that do not contradict the conditions of the problem, select a route with a minimum total weight.

4. Conclusion

The task of the article was to develop a software package for the optimization of land vehicle movement. The initial data is the initial coordinates and destination coordinates, as well as geographical information that describes the existing roads and the characteristics of the area. The criterion for the selection of the route is the time of arrival at the destination. The approach based on graph theory was proposed as the main toolkit for the work with road network.

The improved software for the selection of the best routes for vehicles will increase the efficiency of various services that provide vehicle traffic in the conditions of restrictions on the performance of certain sections of the area.

It is important to use GIS of other systems, in particular, natural-industrial one [4].

References

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