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III. TECHNOLOGIES OF GEODESY, CADASTRE AND GEOGRAPHIC INFORMATION SYSTEM

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INNOVATIVE METHODS OF USING LASER SCANNING AND GEOINFORMATION SYSTEMS FOR DESIGN OF COMMUNICATION ROUTES

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Abstract. The article substantiates the use of laser scanning and Geoinformation systems (GIS) for the design of connection roads repairs. Choosing a particular way to organize data in GIS is key. The choice of data model directly determines many of the functionality of the GIS being created. The organization of data in GIS directly determines the applicability of certain technologies of data entry. To the same extent, it affects the achievable spatial accuracy of presenting the graphic part of information, the ability to obtain high-quality cartographic material, and the organization of map quality control. To a large extent, the way data is organized in GIS also determines the achievable performance of the system, for example, when executing a query or visualizing it on the screen. The ability to work with large amounts of data or with accurate data over large areas is also related to the ways and forms of data organization. The convenience of editing and updating data, the ability of an organization designed to work in multi - user editing mode, and the creation of databases distributed over a network - all this is also primarily related to the organization of data, and secondly to specific software.

Keywords: geoinformation systems (GIS), laser scanning, design of communication routes, connection roads repairs, innovative methods.

Introduction

Laser scanning, which appeared on the Ukrainian market of Geodetic services about 10 years ago, is gradually finding application in solving an increasing range of tasks. This is the operational control of the construction of engineering structures and monitoring of their condition during operation, design of connection roads, 3D-modeling of complex architectural objects. All this can be used to create a three-dimensional information content of geoinformation systems.

1. Analysis of recent research and publications

Currently, the general state of the road network and the economy as a whole are forced to focus on repairing existing connection roads, and reduce the design of new directions to a minimum (Karedin & Pavlenko, 2018).

As you know, connection roads repair projects can be of different types and levels of complexity. Most often, the implementation of projects for major repairs or reconstruction of connection roads is more difficult than designing a road in a new direction (Kuzmin & Bilyatynsky, 2006).

In this case, it is especially important to automate certain time-consuming and time-consuming processes, for example, such as determining the volume of alignment (Credo-Dialogue – CREDO software products, n.d.).

Depending on the condition of the existing highway and the actual tasks assigned to the designer, the following types of work can be performed during major repairs (Державні Будівельні Норми України, 2015; 2008, 2018):
- strengthening of the existing landbed;
- alignment of the existing landbed;
- milling;
- disassembly of the landbed;
- extension of expansion ditches;
- cutting existing roadsides;
- filling up the roadbed;
- repair of roadbed slopes, etc.

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2. The main part of the study

In major repair projects, the variant development of the route in the plan and in the longitudinal profile takes a lot of time, but the design of crossbars occupies a special place in terms of labor intensity. Depending on the initial conditions and customer requirements, design solutions may differ significantly both on individual sections along the length of the highway, and on different sides of its axis. This means that you will have to develop different types of road surface construction and cross-section profiles of the roadbed, and identify areas of their application. At the same time, it is necessary to analyze the constantly changing situation with a fairly small step of cross-sections.

The relationships of individual tasks should be combined into a common capital repair technology, and its effectiveness should be evaluated by finding the optimal design solution.

In order for the Geoinformation system to recognize elements of an existing highway (roadway, roadside, etc.) and correctly identify repair measures, it is necessary to encode the above-mentioned elements, i.e., create appropriate area-based thematic objects based on them (Figure 1).

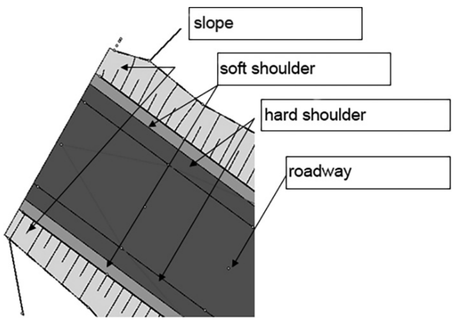

Figure 1. Area-based thematic objects of connection roads

To do this, it is enough to have the borders of elements of an existing highway (edges, edges, and soles).

A Geoinformation coding system is a set of commands, parameters, and attributes designed to enter and accumulate information about topographic objects, using which:

– establishes the relationship between the object and its description in the classifier;
– objects are linked to the definition of land plots on the ground;
– a description of the geometry of complex linear and area objects is formed;
– sets the semantic description of objects (Fedorov, 2015).

The composition of the encoded information allows you to:

– determine the parameters of infrastructure objects (coordinate type and attitude to terrain),
– create structural lines and terrain contours.

Encoded information is transmitted in the form of so-called code strings as part of files (Zatserkovny et al., 2017), received from electronic total stations. Code string elements can be selected from the device's code library, if the device has this option. Code fields or strings (depending on the instrument type) are imported into the system along with the measurement data. During the correction process, code fields (strings) are decoded, topographic objects are formed and displayed in the graphical window, and semantic characteristics of objects are filled in.

In the future, it is necessary to digitize the terrain and situation separately, and based on the obtained high-accuracy digital terrain model, it is possible to carry out design work.

The technology of designing the reconstruction of connection roads based on the obtained data is characterized by high productivity, accuracy, and the ability to build cartograms for milling, leveling, and disassembling sections of the destroyed surface with simultaneous photo recording of its state linked to the survey coordinates.

The detail of the information received is very high and sufficient to perform work on territory planning, determining the volume of earthworks, economic assessment of projects, etc.

The laboratory's scanning system allows you to perform laser scanning with a high degree of detail (36,000 dots/SEC.) and high accuracy (0.02 m in post-processing). The combination of types of laser scanning allows you to create digital models of the surface of an existing highway and roadside lane with sufficient accuracy and detail necessary for designing repairs, and form topographic plans of various scales (Державні Будівельні Норми України, 2014).

Based on the results, it can be noted that the use of laser scanning technologies significantly reduces the time for collecting topographic information, although processing the obtained materials (including noise removal) and digitizing the 3D model significantly increases labor costs compared to traditional methods.

Comparison of engineering research technologies in terms of labor costs (Державні Будівельні Норми України, 2010) is shown in Table 1.

Solving problems of improving the methodology for designing construction, reconstruction and repair of connection roads and creating specialized CAD software modules are closely related. The functionality of the software and hardware complex responsible for designing repairs directly depends on the chosen method of designing construction, reconstruction and repair of connection roads (Державні Будівельні Норми України, 2008, 2018).

When using the laser scanning technique (Shevchenko et al., 2006) surfaces of linear objects in the creation of projects for the construction, reconstruction and repair of connection roads the preparation of high-quality design solutions consists of several stages:

Table 1. Comparison of engineering research in terms of labor costs

Type of work	Direct labor costs, man-hours	
	Tachyometric survey	Laser mobile scanning technology
1 Creating of a planned high-altitude justification:		
- creation of a planned high-altitude justification using receivers	128	128
- laying of theodolite courses	128	128
-geometric leveling of points of planned height justification	24	24
- laying the high-rise basis	–	32
2 Survey of the infrastructure object	448	12 (8 + 4)
3 Processing of the obtained materials and digitization	248	480
4 Report generation	264	264
Total	1240	1068

- restoration of the design axis of the highway (axis, edge, edge, sole of the roadbed, etc.). Due to the complexity of restoring the design axis, it is proposed to use a new concept for connection roads, the median line is a line passing through the geometric center of the top of the roadbed (on homogeneous sections);
- forming the design surface. A fundamentally new approach in the design of road surface repairs is to work with spatial surfaces.

We are talking about combining the design processes of transverse and longitudinal profiles into a single design surface, which, in turn, is formed taking into account various limitations and assumptions (which meet the requirements of the current regulatory literature).

The main assumptions are defined as:

- fluctuations in the transverse slopes of the roadway (±5%);
- driving turns based on the situation, the "geometry" of the road surface in the area of curves in the plan.

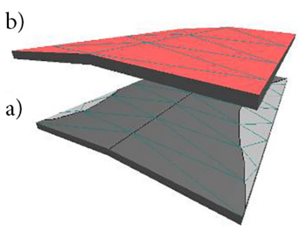

Figure 2. Fragments of layer-by-layer digital surface models: a) digital model of the milling surface; b) digital model of the design coating surface

In the CREDO system-dialogue (Pospelov et al., 2007) it is possible to create layer-by-layer digital models of railway repair projects for transmitting 3D leveling of road construction equipment to systems (Figure 2).

To do this, you need to get a layer-by-layer digital model of the entire structure and export it to the format *dxf. Export parameters are configurable and can be saved as a schema, which can be used in the future and not waste time on re-executing settings.

The layer-by-layer digital model formed in this way can be used for road construction with 3D leveling systems (Figure 3).

Figure 3. Example of construction of connection roads with 3D-leveling systems

As an example (major repairs of a highway in a 3D automated control system), a sequence of technological operations is given (Baigulov et al., 2013).

First, a detailed digital model of the existing roadway is created. Based on the results of preliminary optimization of the design profile, a cartogram of alignment of only those fragments of it is created, the correction of which by milling is not advisable.

After alignment, a digital model of the roadway is created again with partially corrected defects in the longitudinal and transverse profiles. Taking into account these updated data, they again find the optimal position of the project profile and create a digital model of the base of the project roadbed. The data of this digital model is transmitted to the controller of a milling cutter equipped with a 3D automated control system. The milling cutter controlled by it "cuts off" the remaining irregularities of the existing coating and some excess leveling layer.

The base leveled in this way ensures a constant thickness of the new coating and contributes to the continuity of its functioning. This technology provides an almost perfect final quality of major repairs with rational use of resources (Tursunov et al., 2011).

The CREDO-Dialogue system allows to evaluate various characteristics of the longitudinal profile using curvature graphs and deviation graphs from the norms, as well as evaluate the evenness of the initial and design road surface using the IRI method (Gorb & Gorb, 2009).

The calculation algorithm considers the movement of a calculated vehicle at a constant speed along the profile line. As part of the project, the equality indicator is calculated, the IRI equality graph is plotted, and text files with source data are created.

The geodata database model supports an object - oriented vector data model. Support for various types of geographical features is built into the geographic information system. These types of objects include simple objects, geographical objects, network spatial objects, and other, more specialized types of spatial objects. The model allows you to define mutual relationships between objects, as well as rules for maintaining the integrity of data transmission and editing between objects (Shipulin, 2010).

Conclusions

The object-oriented data model treats real-time geographical objects as database objects. Objects are represented by spatial linear objects, such as connection roads, infrastructure objects, and land plots.

The geodata database model defines a general model for geographical information. Advantages of the geodata database in providing opportunities:

- centrally store and manage geographic data in a single relational database management System (DBMS);
- model the behavior of spatial objects;
- apply complex rules and attitudes to data;
- maintain spatial data integrity in a consistent, accurate database;
- function within a multi-user access and editing environment;
- scaling of created design solutions;
- integration of spatial data with other databases;
- support for custom functions and behaviors (Shipulin, 2010).

Based on the above, we can distinguish the following tasks of system data organization:

1) converting information as descriptive information into models;
2) reducing a set of spatial data to a single integrated information model;
3) classification of source data and models when converting them to an integrated model;
4) identification of data in the process of converting data into an integrated model, which preserves their individuality;
5) establishing additional links between geodata based on their integration;
6) unification of source data and creation of the ability to process and analyze data measured in different scales and with different dimensions in a single system;
7) creating a base for solving the main problem of Geoinformatics – establishing spatial relations between spatial processes, objects, phenomena and their characteristics.

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