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Digital Transformation of Network-Centric Geo-Visualization Transport Infrastructure

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***Abstract*—The article describes the digital transformation of geo-visualization of network-centric management in the environment of the intelligent transport geographic information system ITSGIS with subsequent visualization and deployment of geo-objects of the transport infrastructure on an electronic map. The task of network-centric management of transport objects and processes is considered as a digital transformation with visualization of geo objects of the transport infrastructure. Methods of managing transport objects, processes, and a methodology for conducting a simulation experiment within the framework of a designed decision support system for managing transport infrastructure in local areas of coordinated management are considered. The described intellectual transport geographic information system "ITSGIS" is distinguished by the availability of developed means of supporting the simulation environment, which provide ease of modification and expansion of the range of research tasks based on patterns and neural networks. ITSGIS is based on the digital transformation of geo-visualization of network-centric management, on modern information technology, which combines the possibility of interaction of various geo objects with a database, including transport infrastructure, with data visualization on thematic layers of an interactive geographic electronic map. Certification of the transport network allows you to show in detail the scheme of the settlement, the coverage of roads, the length and status to which this road belongs.**

Keywords*—*Intelligent transport geographic information system, "ITSGIS", network-centric management

I. Introduction

As a digital transformation with the visualization of geo-objects of the transport infrastructure in the environment of the ITSGIS intelligent transport geographic information system, the problem of network-centric control of transport objects and processes is considered. Methods of managing transport objects, processes, and a simulation experiment are considered within the framework of a designed decision support system for managing transport infrastructure in local zones of coordinated management [1-3]. The described intellectual transport geographic information system «ITSGIS» is distinguished by the presence of developed means of supporting the simulation environment, providing simplicity of modification and expanding the range of research tasks based on patterns, neural networks.

Within the framework of network-centric management, the tasks of stratified zonal control of transport processes were solved: local control at the stage and intersection, coordinated control on highways with the development of control actions for various types of zoning of the transport infrastructure [4,5]. For large areas, from the point of view of the territory of the management district, coordinated management is divided into tasks:

- division of the district into special zones and the operational formation of coordination programs for each of them;
- synchronization of coordination programs (provided that the control cycles are equal or multiple).

II. Methodology of Digital Transformation of Geovisualization of Network Central Management

The tasks of system management of objects and processes of transport infrastructure are interconnected.

Network-centric model $M_{Network\_Centric}$ The ITSGIS transport infrastructure management system is based on the principles of object distribution and control zoning. The network-centric management model is the basis of the decision support system for network-centric management of objects, zones and the transport infrastructure itself - a model of formalized synthesis of network-centric management. The semantics of the properties of the network-centric model: self-organization, openness, weak hierarchy in the decision-making circuit and the ability to generate goals within oneself, multi-agent. Models of objects of transport infrastructure interact in a single information space [6-9]. The network-centric principle of management is the construction of control zones intended for making management decisions and exchanging information between zone control centers (Figure 1).

Improving the adequacy of the transport infrastructure management model is regulated by the spatially-coordinated binding of objects, processes, network-centric control zones [10-12]. Storage, manipulation, analysis of geospatial and semantic data of models can be carried out with a high degree of efficiency in the environment of ITSGIS, which ensures the adoption of the optimal decision when constructing a geographic information model of the infrastructure of an urbanized area that updates changes in the transport infrastructure in real time.

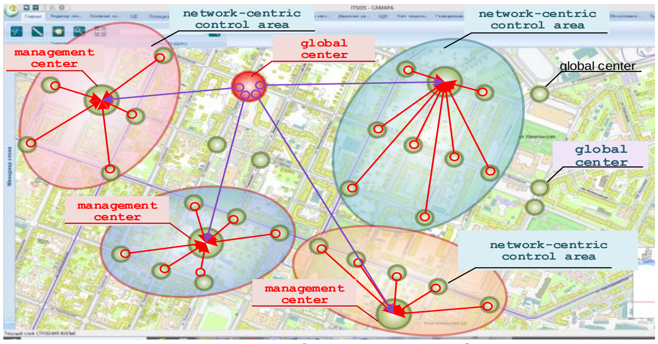

Fig. 1. Network-centric geospatial zoning and management through management centers

In the process of supporting decision-making in the management of transport infrastructure based on a network-centric principle, it is understood the synthesis and decomposition of control zones, in which current augmented reality is exchanged by information between classes of objects filling this control zone. Objects deployed in a zone can receive data on the goals and processes in which the objects participate, and the processes of other zones that indirectly affect each other.

Control Area Functionality $\tilde{A}$ defined as: $\tilde{A} = f\left(\tilde{A}^a, \tilde{A}^r, \tilde{A}^f, \tilde{A}^s\right)$, where $\tilde{A}^a$ – semantic, $\tilde{A}^r$ – geospatial, $\tilde{A}^f$ – functional, $\tilde{A}^s$ – familiar control zone.

Semantic decomposition declares the formation of a zone $\tilde{A}^a$ based on the semantics of objects located in the research area, based on the identity of the zones, according to the magnitude of the influence exerted by the investigated object on other objects of this or other classes being analyzed. Semantic decomposition allows synthesizing thematic layers of the electronic map of the geographic information system, which displays static objects and dynamic processes, based on the adopted decisions of the system. Thematic layers collected from groups of objects of the same class are united by thematic semantics. Decomposition based on appropriate semantic zoning patterns Pattern $\Rightarrow$ PA_Zone, involves clustering objects according to the principle of uniformity according to the characteristic characterizing an object of a class, for example, by its location in the zone, by its semantics. Objects of the class "Track", "Sidewalk", "Path" will fall into a cluster and generalized by a new class – "Transport_net". The semantic deco position is based on restrictions governed by the immanent properties of class objects.

Geospatial decomposition is based on the semantics of the distribution of objects according to the principle of topological homogeneity, which characterizes the spatial attributes of an object deployed in a control zone $\tilde{A}^r$. Geospatial topological decomposition based on geospatial zoning patterns Pattern $\Rightarrow$ PGeo_Zona, involves clustering objects according to the principle of uniformity according to the characteristic characterizing an object of a class deployed on an electronic map. Geospatial decomposition regulates three equivalence classes of topological control zones: point $\tilde{A}^D$; linear $\tilde{A}^S$; polygonal control zone $\tilde{A}^P$.

Functional decomposition regulates the functional identity of objects, which characterizes the type of function of the influence of the semantics of an object on the choice of a plug-in for managing transport infrastructure in a given zone $\tilde{A}^f$. Decomposition on this basis defines local, coordinated or systemic management. Let be

$\tilde{A}^f = \left\{ \tilde{a}_i^{\,f} \right\}, \left(\tilde{A}^f \neq \varnothing\right)$ – functional area of transport infrastructure control, containing the following subsets:

$\tilde{A}^L \subset \tilde{A}^f$ – many zones of local management;

$\tilde{A}^C \subset \tilde{A}^f$ – many areas of coordinated management;

$\tilde{A}^T \subset \tilde{A}^f$ – many system management zones.

Among the tasks that arise in the control zone, the most common are the tasks of monitoring the characteristics of transport infrastructure objects:

- changing the width of the roadway, analysis of the quality of the roadway, geometric parameters of the tracks, etc.;
- deployment of technical facilities for managing transport facilities and processes;
- the presence of incidents, accident, transportation of dangerous and bulky goods, disruption of the functioning of communal facilities, etc.;
- vehicle motion parameters: driving to a traffic signal prohibiting signal, violation of the speed limit, crossing stop lines, forbidden marking lines, etc.

The described intellectual transport geographic information system “ITSGIS” allows us to solve the problems of digital visualization of geo-objects of network-centric control [13-16]. In order to avoid adverse situations on the road, much attention should be paid to the certification of the transport network, which allows keeping track of public roads. The object of research in this problem is the technical accounting and certification of the transport network, the passportization database, which includes the characteristics of roads, walkways, footpaths, etc., subject to technical accounting.

The transport network on an interactive electronic map in the environment in the system “ITSGIS” includes a set of various types of streets, roads, sidewalks, road structures suitable in their technical condition for the movement of rolling stock of motor vehicles . The creation of a transport network passport is developed in ITSGIS in a specialized plug-in - in an automated information system for transport network certification. The cartographic basis of the plugin is the graphic part of the plugin, and the part that includes the semantics of the geo objects of the plug-in transport infrastructure of the plug-in is textual. The semantics of the transport network passport include data stored in the ITSGIS database: the boundaries of the beginning and end of the road, information about the street name of the settlement, the length of the road, the width of the subgrade and the type of coating (asphalt, soil, etc.).

Certification of the transport network determines the presence of viaducts and bridges, industrial buildings that make up the road, pedestrian crossings, tro-tour and pedestrian walkways, culverts, the length of the curbs by type of reinforcement, the number of exits by type of cover and intersections with railways and roads.

The main difference between the ITSGIS Intelligent Transport Geographic Information System and non-electronic maps is that an interactive electronic map is not a static picture. Each geo-object displayed on the thematic layers of ITSGIS corresponds to the infrastructure object of the settlement, which can be analyzed, obtained semantic and geographical information from the database. So, one of the basic functions of the automated information system for the certification of the transport network "ITSGIS" is to obtain information on a geo object selected on an electronic map. For example, by pointing the section of the road of the transport network on the city's electronic map in ITSGIS, you can get detailed information about the name of the street, the length of the road, the width of the road on this section, the material of the section, the degree of wear, its owner, etc.

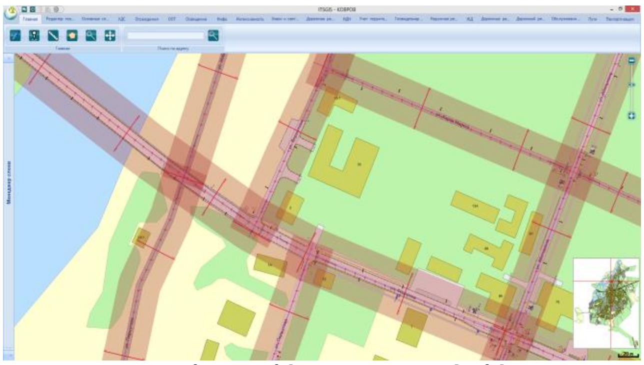

Fig. 2. Certification of the transport network of the city

The legend of thematic layers of certification of the transport network of the ITSGIS plug-in is intended for obtaining information about the method of visualization of complex geospatial data on an interactive electronic map, as well as for setting the visibility of certain data sets. According to the developed standards, roads come with such coatings as asphalt concrete, soil, crushed stone and gravel, cement concrete (slabs) paving stones. Also, there are roads on the bridge over the railroad tracks, over the reservoir, over the highway, over special facilities. Each type of road has a certain status: exists, is required, to dismantle, temporary, under repair, paid. This status allows you to visualize these sections of roads on the "ITSGIS" thematic layers.

When building a transport network passport, ITSGIS implemented various types of functionality:– obtaining information about geo objects on the map: the user selects a geo object on the map and receives semantics about the specified object:

- image enlargement / reduction is carried out up to a certain size of the geo object allowed by GOST;
- panning / geo-video route: viewing video information with geo-referencing to coordinates in WGS-84 in various directions;
- measuring distances / areas : this functionality allows you to calculate both single and complex size of the length and area of geo objects;
- creation of new / editing of existing geo objects: this functionality allows you to create or change both geometrical, geological and semantic data of geo objects;
- building a passport of the transport network section: the semantics of the section are formed taking into account various geo objects included in the territory of the axial line of the road (figure 2) with visualization of the territory (pink strip) with detailing for pickets.

III. Conclusion

ITSGIS is based on the digital transformation of network-centric geo-visualization, i.e. based on modern information technology, which combines the possibility of interaction of various geo objects with a database, including transport infrastructure, with data visualization on thematic layers of an interactive geographic electronic map. Passportization of the transport network allows you to show in detail the scheme of the settlement, the coverage of roads, the length and status that this road belongs to.

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