System Analysis and Processing of Transport Infrastructure Information

Nikita Ostroglazov
Samara University
Samara, Russia
nickitaost@gmail.com

Oleg Golovnin
Samara University
Samara, Russia
golovnin@ssau.ru

Tatyana Mikheeva
Samara University
Samara, Russia
mikheevati@its-spc.ru

Abstract

The article describes the approach to system analysis and processing of the transport infrastructure information. The approach consists of two stages. The first stage is the collection of data on the transport infrastructure using an automotive laboratory that captures video from the road and connects objects via the GPS / GLONASS system. The second stage is the analysis of information, during which the transport geographic information system ITSGIS is used. The proposed approach provides a complete cycle of working with information: collecting, storing, processing and analyzing the transport infrastructure information. The application of the approach allows reducing the labor intensity and improving the quality of monitoring the transport infrastructure.

1 Introduction

Transport infrastructure is an essential part of the transport system. Achieving sustainable economic growth and improving the quality of life of the population depends largely on the level of development of transport infrastructure [1]. In order to rationally allocate funds for the development and maintenance of roads and streets, to optimize traffic management on roads, accurate and reliable information about the condition is needed in order to increase traffic capacity and traffic safety of vehicles and pedestrians, roads and transport infrastructure [2]. To this end, work is underway to check, diagnose, certify and inventory transport infrastructure [3].

It is necessary to have effective methods for assessing the state of the transport infrastructure to improve it. The ability to quickly and reliably assess the impact of changes is one of the most important tasks [4]. The choice of various options for the development of transport infrastructure requires the development and application of information models of the transport infrastructure, taking into account the mutual influence of indicators adapted to current modern conditions [5]. Operating with heterogeneous data arrays of different spatial-temporal resolution obtained in the study of transport infrastructure is carried out by integrated systems consisting of three components: a geographic information system (GIS), a database management system and a system for processing research data [4, 6].

The aim of the work is to develop an approach to determining the characteristics of the transport infrastructure and determining their mutual influence on each other. The proposed approach uses the principle of system integration, based on the synergistic interaction of intellectual geographic information system, software and hardware complex and the media knowledge base of the transport infrastructure, based on the relational database management system and the cloud-based data storage [7].

2 Collection and processing of transport infrastructure information

An approach that involves the implementation of two main stages of work was developed to collect information about the transport infrastructure [2]. The first stage is data collection. Transport infrastructure data is collected using the automotive laboratory, which allows digital continuous video recording of the road at a speed of 40-80 km / h and linking objects using the global GPS / GLONASS positioning system. The second stage is the analysis performed in the environment of the intellectual information system ITSGIS [8].

2.1 Hardware and software for data collection

The mobile lab equipped with 6 IP cameras, each of which forms a stream of video data with a resolution of 60 frames per second FullHD, IP66 protection level from dust and water penetration, GPS / GLONASS receiver with high positioning accuracy, a laptop, a switch that supports technology Power over Ethernet to power cameras over standard twisted pair.

The GPS / GLONASS receiver provides the system with the ability to get accurate coordinates and time. Data is transmitted to the laptop from a GPS / GLONASS receiver with a frequency of 10 Hz. According to the data obtained using the receiver, the route transmitted by the mobile laboratory is reproduced with high accuracy. The data is presented in NMEA 0183 format. Time in UTC format, coordinates in WGS-84 format, speed in nodes and altitude in meters are determined by recognizing GPRMC and GPGGA messages.

Software developed for the mobile lab provides:

- reading NMEA data from a GPS / GLONASS receiver connected to a USB port of a laptop through a virtual COM port;
- selection of map services (Google maps, Bing maps, ArcGIS, OpenStreetMap);
- display of current location and trajectory
- recording GPS / GLONASS data to a file on a laptop's SSD disk;
- using as a source of geodata of the Internet or a cache for work in an autonomous mode;
- capturing video from IP cameras and display the image on the laptop screen;
- coding and recording video on a laptop hard disk.

The software works in multi-threaded mode. a separate execution flow is allocated to work with each of the IP cameras and to record the GPS / GLONASS track. At each time point, the image from a specific camera is transmitted to the laptop screen in a reduced resolution and is recorded in a video file at a resolution of 1920 × 1080 peak-mudflows.

Cross-platform open graphic library OpenGL [9] displays images on the screen in order to reduce the load on the laptop processor.

The free open source library FFmpeg Capturing [10] allows you to record, convert and transfer digital audio and video in various formats.

The real-time streaming protocol RTSP controls the flow of video data, the TCP transport protocol transmits streaming data and provides reliable data transfer.

The software implements video coding using the X264 codec for coding video streams with the H.264 compression standard, which provides both high quality and high video compression ratio.

2.2 Data processing algorithms

For processing data on objects of transport infrastructure an algorithm of calculation the road curvature radius and an algorithm of calculation the visibility distance have been developed.

Algorithm of calculation the road curvature radius consists of the following steps:

Step 1. Obtain a point H, in which the trajectory of movement deviates from a straight line - the point of the beginning of rounding (Figure 1);

Step 2. Get the point K of the end of the turn;

Step 3. Construct a straight line HB, tangent to the trajectory at the point of the beginning of rounding;

Step 4. Draw a straight line BK tangent to the trajectory at the end of rounding;

Step 5. If the lines HB and BK intersect, find their intersection point (point B);

Step 6. Calculate the angle between the straight lines HB and BK (angle α);

Step 7. Calculate the distance T from the point of the beginning of rounding to the point of intersection of lines HB and BK;

Step 8. Calculate the rounding radius $R = T \cdot ctg\, \alpha/2$.

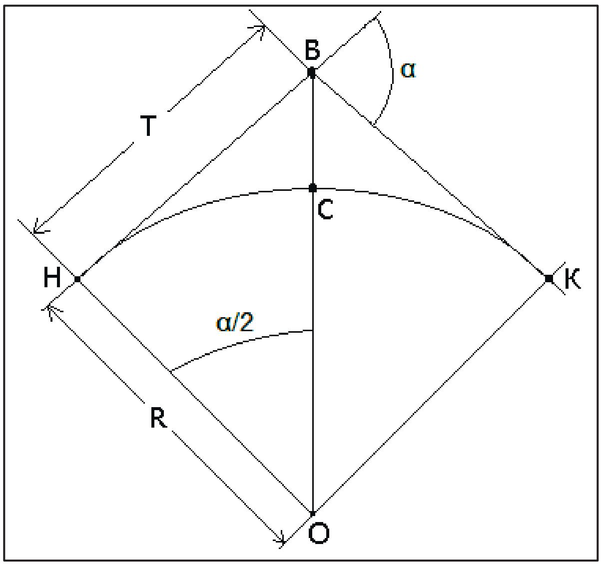

Figure 1. The rounding radius calculation

Algorithm of calculation the visibility distance consists of the following steps:

Step 1. Select the starting point O of the motion path. An observer is at this point at a height of 1.2 m above the road surface. The distance from the beginning of the road to the point O is m (Figure 2);

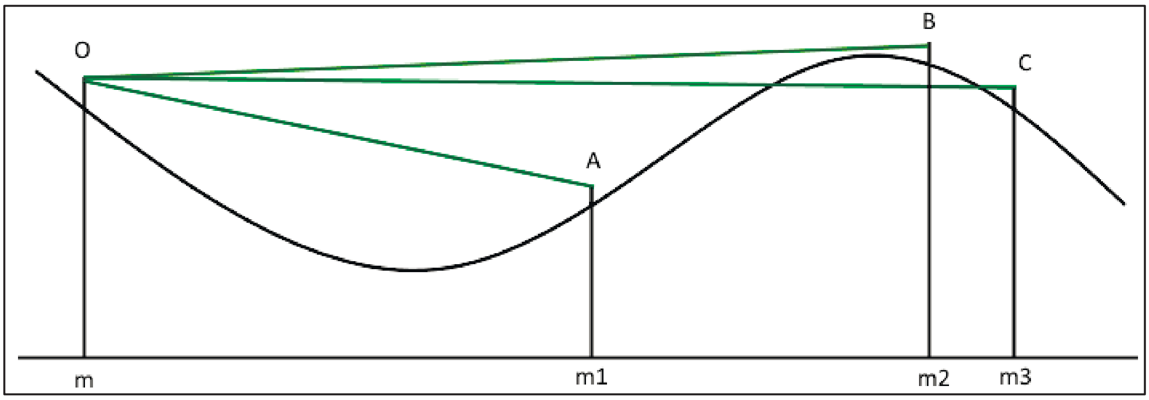

Figure 2. The visibility distance calculation

Step 2. Select point A of the trajectory after the point where the observer is located. The object of observation is at this point at a height of 0.2 m. The distance from the start to the point A is m1;

Step 3. Draw a straight line OA;

Step 4. If the straight line OA does not intersect the trajectory of movement, then move the object of observation to the next point of the trajectory and go to step 3;

Step 5. If the straight line intersects the trajectory of motion, i.e. if the object of observation is at point C, at a distance m3 from the beginning of the road, then this iteration is completed. The visibility distance at point O is equal to the distance between point O and the last visible point B, m2 - m. Move the observer to the point after the point O and go to step 2;

Step 6. If the distance from the point O to the point where the observation object is located is equal to the maximum visibility, then this iteration is completed, the visibility distance at the point O is equal to the maximum visibility. Move the observer to the point after the point O and go to step 2;

Step 7. If the observer is at the end of the trajectory, the algorithm is completed.

3 System analysis of information

The decomposition of the subject area into classes of objects has been made in order to develop an adequate information model of the transport infrastructure suitable for use (Figure 3). Attributes and their connections with each other are highlighted in the classes, allowing building a single information space [11, 12]. It is necessary to quantify the qualitative attributes at the data preparation stage. Each qualitative attribute is estimated by a relative index K, characterizing the level of the attribute being measured, and by a capacity M, characterizing the relative importance of the attributes. Relative indicators K and capacity M for each attribute of the model are obtained by expert estimates.

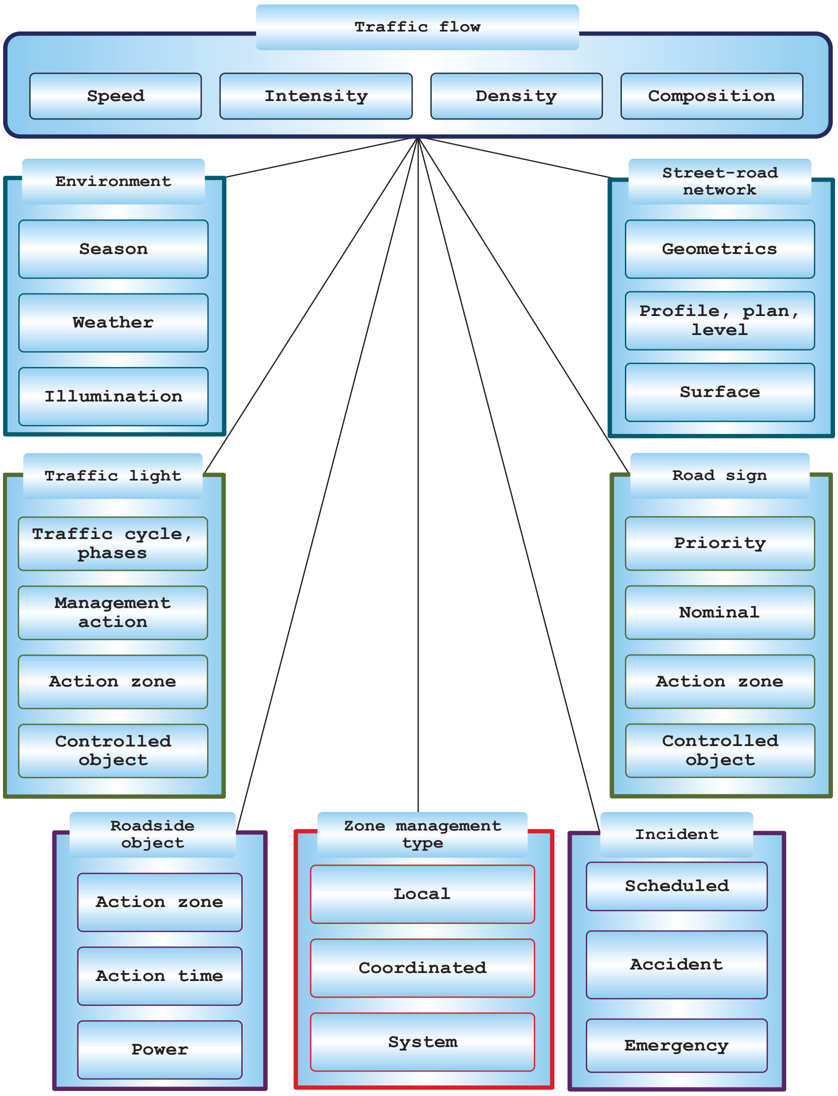

Figure 3. Decomposition of the transport infrastructure model

The method of feature selection is used to reduce the dimension of the analyzed model, remove irrelevant attributes, and solve the problem of multicollinearity. Multicollinearity means the presence of a strong correlated connection between the analyzed attributes that jointly affect the target vector of characteristics. Such a relationship makes it difficult to evaluate the characteristics and identify the relationship between the attributes and the target vector.

The applied attribute selection method uses a modification of the classical genetic algorithm:

Step 1. Initialization: the choice of the CF, random creation of the initial population of models.

Step 2. Checking the condition of the completion: the allowed number of iterations of the algorithm N is exceeded or the change in the sum of squares of the regression residuals SSE turned out to be unacceptably small.

Step 3. Selection: select F the best models with the minimum sum of squares of SSE regression residues.

Step 4. Selection: select F1 random models for crossing and mutation.

Step 5. Crossing: each allele is randomly filled with the genome of one or another parent.

Step 6. Mutation: a random, equally probable replacement of the current gene to 0 or 1 occurs for each model in each allele with a probability of P2.

Step 7. Return to step 2.

As a constraint imposed on the value of a certain attribute, there is a relation linking the attributes of class objects. Linear and nonlinear equations, inequalities, logical statements, set-theoretic constructions and table relations form relations. Attributes of class objects that are interrelated with respect to dependencies fall into two categories: dependent and influencing. The relationship between the attributes of different classes is carried out through the values of the attributes.

4 Approach to work

4.1 Work scenarios

Three scenarios for working with data: in the first, the geo-information system ITSGIS played the leading role, and in the second - the data processing system ITSGIS, in the third - the database Geo video route.

In case of a leading GIS (Figure 4), hybridization is carried out by integrating with the media database and embedding the components of the data processing system in the GIS. The components of the integrated system are embedded in the GIS as plug-in software modules - plug-ins. Plug-ins provide loading of research data from the geospatial-referenced media database and ensure the functionality of the data processing system in the framework of GIS. Media data is tied to existing geometric objects.

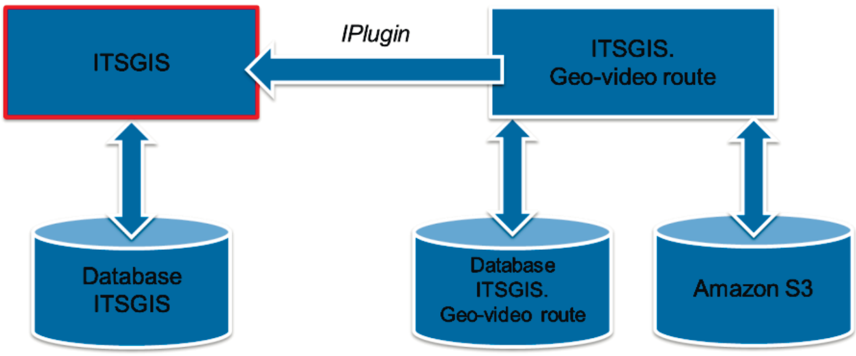

Figure 4. Leading GIS scenario

In case of the leading data processing system (Figure 5), embedding the GIS components allows mapping the laboratories movement paths, automating the dislocation of technical tools of organizing traffic on an electronic map. An electronic map allows using expert functions that operate with geometrical parameters of the road network and knowledge of the spatial-topological properties of objects on the road network.

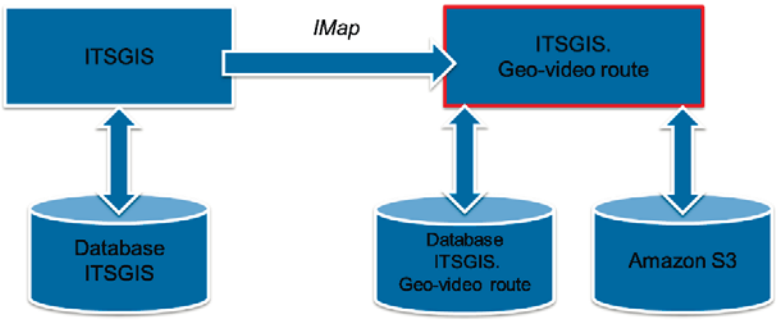

Figure 5. Leading data processing system scenario

In case of the leading database management system (Figure 6), the media database expands its functions by intelligent space-time data analysis and analytical modeling. GIS presents the results of analytical modeling graphically.

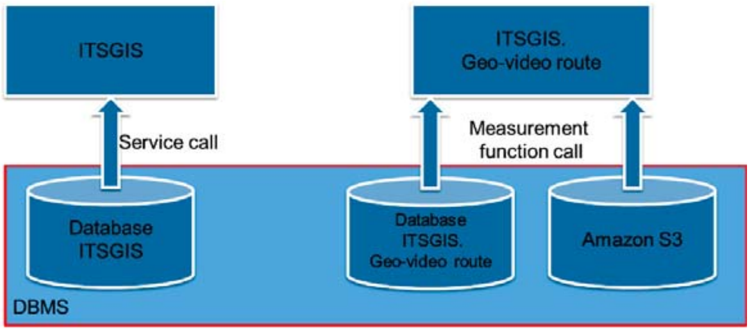

Figure 6. Leading database management system scenario

4.2 Analysis of road characteristics

The algorithms described in section 2.2 are implemented in a software module that provides:

- calculating the road curvature radius and displaying a graph of the curvatures radius (Figure 7);
- displaying of heights;
- calculating road inclines and displaying a slope chart;
- calculation of the distance of visibility and display of the visibility graph (Figure 8);
- accounting of road traffic management equipment;
- formation of consolidated statements;
- measurement of linear and area geometric parameters of transport infrastructure facilities over a video recording frame (Figure 9).

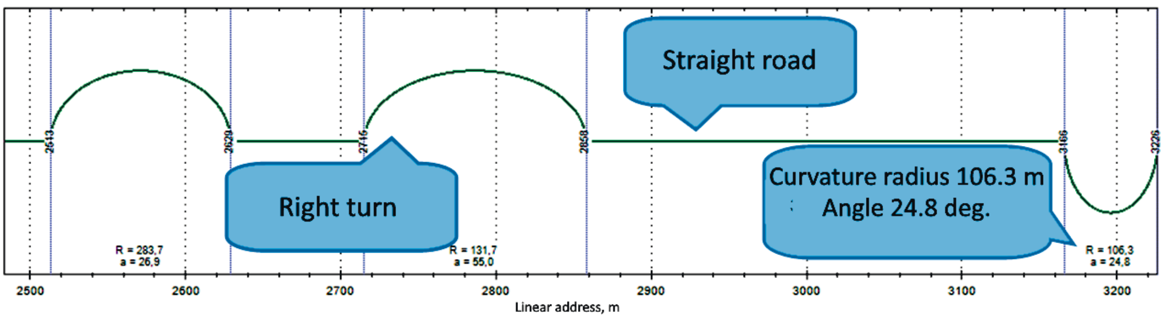

Figure 7. Graph of the road curvatures radius

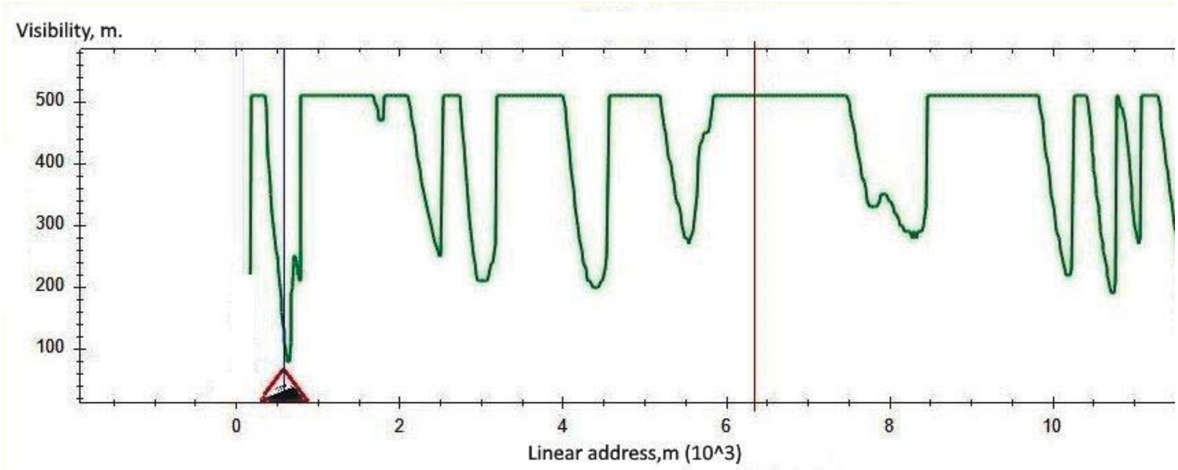

Figure 8. Limited visibility placed

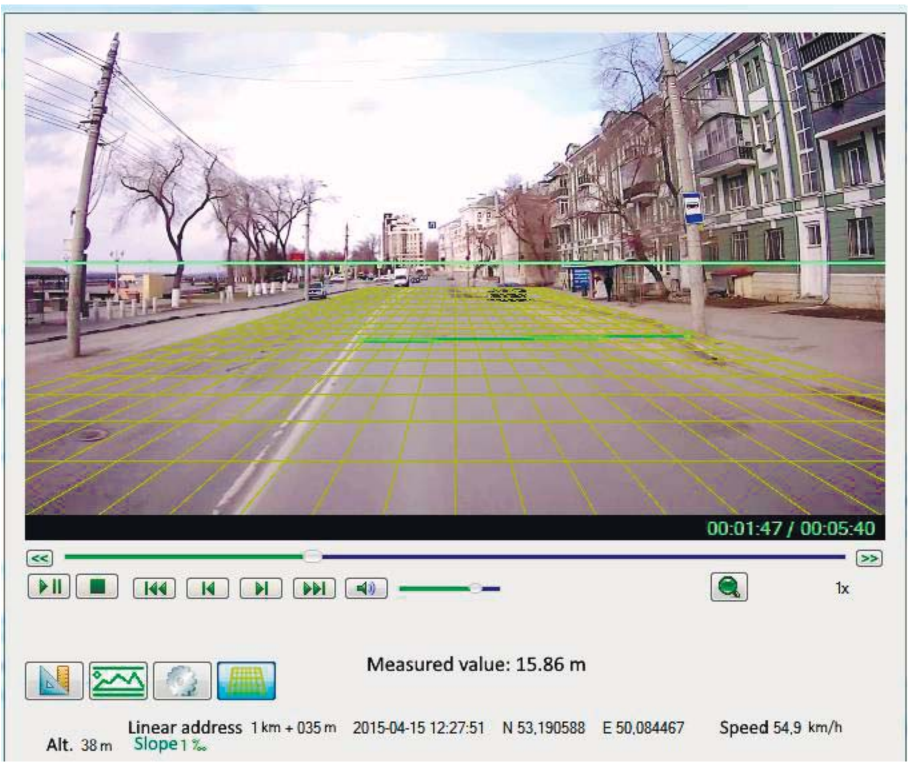

Figure 9. Road network parameters

4.3 Transport infrastructure on the map

The system of accounting geometrical parameters of the roadway allows you to add, delete and edit information in the ITSGIS geographic information system database [6] about the following objects (Figure 10):

- road signs;
- road marking;
- guiding devices (signal posts);
- pedestrian paths (sidewalks);
- road barriers;

- public transport stops;
- traffic lights;
- artificial lighting.

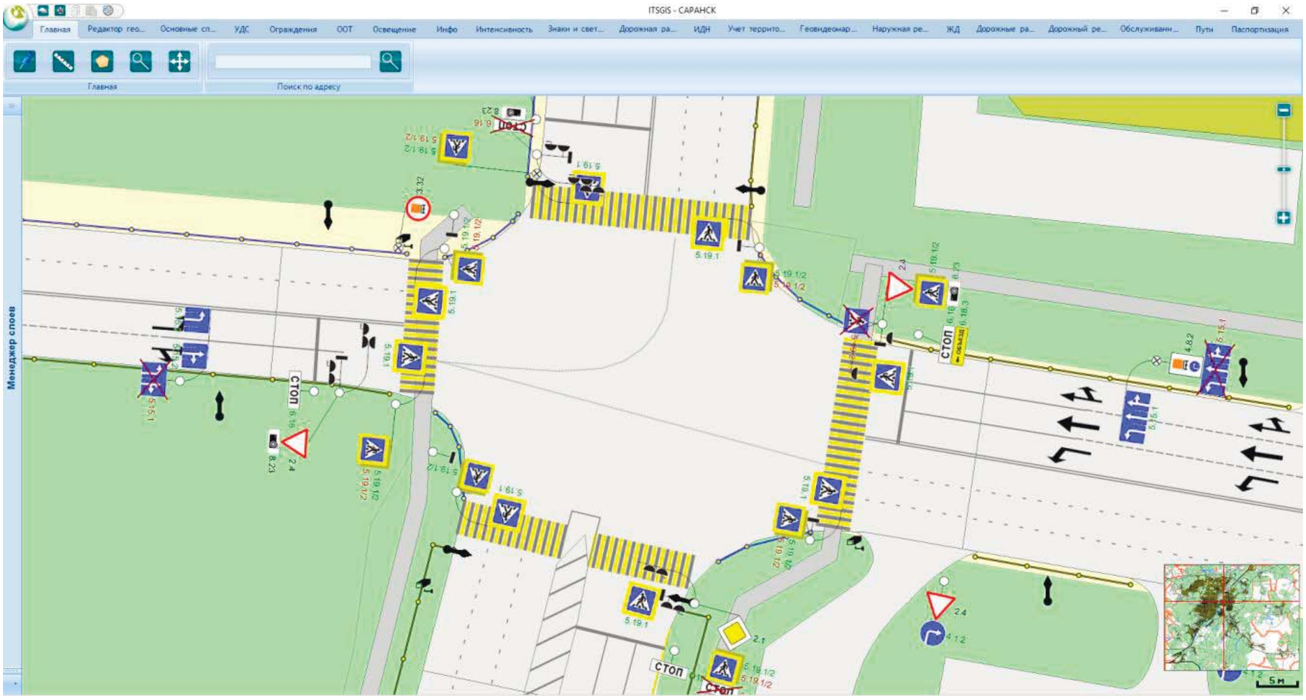

Figure 10. Transport infrastructure on ITSGIS map

Each object in the database stores location information in the World Geodetic Coordinate System (WGS-84) and the linear address relative to the beginning of the road in the format km + m.

5 Conclusion

The effectiveness of monitoring the parameters of the transport infrastructure can be enhanced by using modern tools of automation of technological processes for collecting, storing, planning and analyzing information: based on sensors and mobile laboratories, on technologies of satellite navigation systems, on data from cellular operators, data Earth remote sensing using time series forecasting models [13, 14, 15].

The developed approach to the system analysis and processing of information about the transport infrastructure allows, through the software implementation of algorithms, to automate the processes of collecting, processing and using information, reduce the workload of specialists, reduce labor intensity and improve the quality of monitoring.

The developed approach is for using in organizations that perform work on the maintenance and certification of roads, the organization of traffic on them. The results of the work introduced in the SPC “Intelligent Transport Systems” (Samara, Russia).

References

1. A.V. Skvortsov, V.N. Boykov. Common data environment as a key element of the information modeling of highways. CAD and GIS of highways, 2(5): 37{41, 2015.
2. T.I. Mikheeva, V.A. Klyuchnikov, O.K. Golovnin. Methods and procedures of transport infrastructure survey. Modern problems of science and education, 6: http://www.science-education.ru/120-16656, 2014.

3. C. Avram, E. Valente, A. Astilean, J. Machado, D. Radu. Formal Analysis of an Urban Road Traffic Model. CONTROLO-2016, Springer, 533{544, 2017.
4. S.M. Burkov, G.Ya. Markelov, I.N. Pugachev. Problems of system analysis and methodology for the formation of an intelligent management system for the city`s transport complex. Vestnik TSU, 4 (31): 83{90, 2013.
5. B. Kolosz, S. Grant-Muller, K. Djemame. Modelling uncertainty in the sustainability of Intelligent Transport Systems for highways using probabilistic data fusion. Environmental Modelling & Software, 49:78{97, 2013.
6. V.B. Robinson. On fuzzy sets and the management of uncertainty in an intelligent geographic information system. Recent Issues on Fuzzy Databases, 109{127, 2000.
7. O. Golovnin, A. Fedoseev, T. Mikheeva. Intelligent geographic information platform for transport process analysis. CEUR Workshop Proceedings, 1901:78{85, 2017.
8. Geographic information system ITSGIS Web Site, http://itsgis.ru.
9. OpenGL Web Site, https://www.opengl.org.
10. FFmpeg Web Site, http://ffmpeg.org.
11. M. Habib, B. Khoda. Attribute driven process architecture for additive manufacturing. Robotics and Computer-Integrated Manufacturing, 44: 253{265, 2017.
12. J. Zhuang, M. Hu, F. Mousapour. Value-Driven Design Process: A Systematic Decision-Making Framework Considering Different Attribute Preferences From Multiple Stakeholders. Journal of Solar Energy Engineering, 139(2):021001, 2017.
13. M. Kotsab, K. Raday. Integration of cartographic data into a single information system. Geodesy, cartography and aerial photography, 78:127{131, 2013.
14. Mikheeva T.I., Fedoseev A.A., Mikheev S.V., Golovnin O.K. Method of Transport Net Thematic Layer Synthesis via Remotely Sensed Imagery. Information technologies, 23:808{816, 2017.
15. Y. Li, Z. Luo, J. Yin, L. Xu, Y. Yin, Z. Wu. Enterprise Pattern: integrating the business process into a unified enterprise model of modern service company. Enterprise Information Systems, 11(1):37{57, 2017.