reviewed paper

Smart Navigation for Modern Cities

Nataly Zhukova, Oksana Smirnova

(Nataly Zhukova, PhD, St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences (SPIIRAS), 39, 14 Linia VO, 199178, St. Petersburg, Russia, zhukova@oogis.ru)

(Oksana Smirnova , PhD, St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences (SPIIRAS), 39, 14 Linia VO, 199178, St. Petersburg, Russia, sov@oogis.ru)

1 ABSTRACT

Modern cities face a continuous growth of car population, at that, the number of drivers also grows and most of them use various navigation systems while choosing the best route as well as at the traffic situations' assessment. .In this regard it is important to have a navigator that secures a quick and easy access to the required information and proposes alternative routes. Usability of the navigator depends on the simplicity of the graphic user interfaces and also on the available collection of maps. Usefulness of the information received by the users on their requests depends on how well the context of the request, like driver type, driver experience, used vehicle, weather conditions, road surface, is taken into account. When creating a new route it is necessary to consider the current situation on the road using operative data, the driver's preferences and also to forecast the traffic density of the roads that are in the route. To solve the above listed it will be necessary to use in the navigator certain artificial intelligent tools as expert system and inference machine.

The paper presents the smart navigator for modern cities developed based on intelligent geoinformation systems. Similar smart navigators have been already developed for solving problems of small navigation. It is suggested to create smart car navigators for modern cities using key solutions developed for small navigation.

2 INTRODUCTION

Intensity of life in modern Smart Cities aggravates year after year, as caused by many different factors, for instance, by scales and rates of the economic development, scientific and technical progress, character of the population growth and changes in the population structure. The high dynamics of the cities development affects all spheres of the citizens' life in the spheres of their professional and personal interests as well as in their daily needs. To go with the pace of the cities' life the citizens have to move around more and more. Emergence of new areas and as a result enlargement of the territories occupied by the cities increases the distances which citizens have to cover and makes their routs more complicated. Modern information technologies provide a wide range of various services for organization and support of communication between people such as mobile communication, electronic mail, video conferences that currently are used by everyone and turned into an important part of everyday life. Unfortunately they are still not able to completely substitute personal contacts.

For moving around the city both public transportation and private cars are widely used. Lately the popularity of public transportation has significantly increased due to the efforts of local authorities, nevertheless, many citizens prefer to go by car. The high population density in modern cities and the peculiarities of the cities architecture especially in their central parts are the main reasons of heavy traffic jams. Though many efforts are made in design and reconstruction of the roads' network not much can be actually done without causing an essential damage to the architectural shape of the cities. In most of the cities, especially big cities the traffic jam can be several kilometers long. Two main resources that now are of primary importance, namely, the resource of time and ecological resources are wasted in the traffic jams.

One of the efficient ways of dealing with traffic jams in the conditions of the modern cities is an improvement of the traffic flows organization. The usually applied arrangements of the traffic organization include a package of managing, legal, organizational, engineering and technical measures that directly or indirectly impact on the state of the traffic. According to the world practice the optimization of the traffic is able to increase the capacity of streets and highways by about 20% at simultaneous increase of the traffic safety by 10-15%. As an example the following measures that are widely used can be considered: reduction or even prohibition of building new objects intended for the financial and business spheres, limiting the number of constructed commercial and servicing objects; turning the street parking lots into multi-deck ones; construction of bypass roads, etc.

The given list of measures can be enlarged with one principal point that is able to impact on the traffic jams' situation. The jams can be reduced if it will be possible to organize the traffic flow within each local area according to the transport loading in the whole city accounting at that for various factors influencing upon the observed state of the traffic and its state in the near future. The organization of the flow is supposed to be continuously analyzed and accompanied by certain decisions generated for its possible improvement. In case, the overwhelming majority of the road traffic participants will lay out their routes following the proposed decisions it is reasonable to expect the jams' decrease.

Intelligent navigators can be used for laying out the routes according to the described approach to the of the traffic flow organization. Application of the intelligent navigators will allow considering the traffic participants as a self-organized flexible community. To meet the requirements to the laid out routes the intelligent navigators must possess a whole set of various complicated features: have access to various types of information, be context sensitive, be able to solve such complicated tasks as situation prediction and decision making support. The features can be provided by the wide use of knowledge. Knowledge can be considered at different levels of generalization. It can refer to knowledge about a single user, a group of users or the whole city. For dealing at the level of knowledge the acquired data and information intelligent technologies can be used.

It is also important to note that the software for intelligent navigators must be represented in the form of a line product, in which each of the products is oriented to the specified group of users.

In the paper an approach to the building of mobile navigations for smart cities based on the application of intelligent technologies is proposed. The paper is organized in the following way. In the third section the currently used mobile navigators are described, their main characteristics are compared and analyzed. Usage of the modern information technologies based on application of the artificial intelligence means is considered as a possible way to the essential improvement of the characteristics of the mobile navigators. In the fourth section the main problems of the intelligent navigation are listed and their possible solutions are proposed. The fifth section considers the problems of acquisition, application and management of knowledge that is the core element of the intelligent navigators. In the sixth section the experience in design and development of intelligent navigators for water transport like small vessels is proposed to be applied to developing the navigators for smart cities. In the conclusion the key ideas for prospective work on developing smart navigators are given.

3 INTELLIGENT TECHNOLOGIES FOR MOBILE APPLICATIONS

At present the navigation systems allow plotting a route from home to work, to school, to shops, to local destinations. Modern ground-based navigation systems include quite different functions and services. These systems make possible to:

- plot route and save it in the device memory;
- make real-time updates of traffic, speed limit signs, local events and showtimes;
- search for geographic objects on the map;
- add way points to the route;
- provide additional information about the objects on the map;
- provide voice-guided turn-by-turn driving directions;
- 3D visualization of the city and/or region.

Among the most popular navigation system are such systems as TomTom 1.8 (TomTom, http://www.tomtom.com), Magellan RoadMate 2.0 (Magellan GPS, http://www.magellangps.com), Garmin Street Pilot Onboard (Garmin, http://www.garmin.com) and TeleNav GPS Plus (Telenav GPS Navigator, http://www.telenav.com). Furthermore, some smartphones have build-in free navigation software. These include Google Maps Navigation 6.7.0, which operates with Android smartphones like HTC One X and Samsung Galaxy Nexus. In recent years the community-based traffic and navigation application Waze for iPhone (Free Community-based Mapping, Traffic&Navigation App, http://www.waze.com) is activity developed, thus, consolidating drivers in the given area who share real-time traffic and other information about roads. The main characteristics of these applications are given in Table 1.

Unfortunately, the navigation applications considered in Table 1 have some constraints. They are often cumbersome and have nonstandard user's interface. A lot of facilities and services of these applications are not obvious and easy accessible. Also the correctness of the operations depends on the relevance and correctness of real-time information.

GPS App Name	Vendor	Country	Price, $	Map Coverage	OS	Device
TomTom	TomTom	Netherlands	119–259	North, South & Central America, Europe, Middle East & Africa, Australia, New Zealand and Asia	Lunix, Windows Mobile, Windows CE, Symbian, iOS	car navigator, Smartphone, motorcycle navigator, built-in navigation system
Magellan RoadMate	Magellan Navigation, Inc.	USA	50–249	North America	Windows Mobile, Windows CE	car navigator, Smartphone, built-in navigation system
Navigon	Navigon GmbH	Germany	49.99–249	Europe	Android, Windows Mobile, Windows CE, iOS	Smartphone, navigation system
Garmin Street Pilot Onboard	Garmin International Inc	USA	49–150	North, South & Central America, Europe, Middle East & Africa, Australia, New Zealand and Asia	Android, Windows Mobile, Windows CE, iOS	car navigator, Smartphone, motorcycle navigator, built-in navigation system
Waze	Waze Mobile	Israel, US and UK	free	North, South & Central America, Europe, Middle East & Africa, Australia, New Zealand and Asia	Android, BlackBerry OS, iOS, Windows Mobile, Windows CE, Maemo	Smartphone iPhone
Google Maps	Google	USA	free	North, South & Central America, Europe, Middle East & Africa, Australia, New Zealand and Asia	Android	Smartphone iPhone

Table 1: Comparison of navigation information systems.

As distinguishing features of intelligent navigation systems in comparison with common navigation systems could be mentioned their abilities to receive information about traffic conditions, to improve the route choice, safety, comfort, sustainability in citizens' mobility. The development of such intelligent navigation systems and related technologies has been subjects of numerous projects. The majority of them are: SAFESPOT (Safespot, http://www.safespot-eu.org), SmartWay (SMART-WAY, http://www.smart-way.mobi), SESAR (SESAR, http://www.sesarju.eu), ERTMS (ERTMS, http://www.ertms.net), RIS (RIS, http://www.ripe.net/data-tools/stats/ris) and other.

Intelligent navigation systems use the following applied technologies: simple car navigation, regulation of traffic lights, cargo managment system, various announcing systems (including display boards), various road recognition systems and observation systems, as wellas systems that integrate information streams and feedback from heterogeneous sources, such as parking giudance and information systems, metrological services, swinging open bridges systems and other. And even more, the forecast technologies incorporating modeling and information gathering technologies are planned to be used in the intelligent transport navigation systems.

According to oral information provided by Andras Siegler, Director of the Transport Directorate of European Commission, DG Research and Innovation, development of such systems will allow to reduce congestion by 15%, CO2 emissions by 20% and road fatalities by 15%.

However, the development of the intelligent transport navigation systems faces some difficulties. At first, the creation of such systems is quite expensive. Also the process of building the intelligent navigation systems is a complicated process and requires a lot of resources.

4 CONCEPT OF INTELLIGENT NAVIGATION IN IGIS

Intelligent navigation is based on the following key principles:

- the information and knowledge required for laying out the routes is acquired from the actual data gathered from heterogeneous sources using intelligent technologies based on mathematical and statistical algorithms along with means of artificial intelligence;
- the routes are built and constantly improved according to the needs and desires of each user, the observed situation and possible ways of its development;

ISBN: 978-3-9503110-6-8 (CD-ROM); ISBN: 978-3-9503110-7-5 (Print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI

- implementation of ready technologies provided by IGIS;

Below each of the above principles are considered, and IGIS components required for its implementation are listed.

Actual data and information from heterogeneous sources is constantly gathered by IGIS. The information required for laying the routes out includes the information about the current state of the traffic flow as well as all other required information such as weather conditions, various public activities. Three types of external data and information are considered under an angle of the data importance at solving the navigation problems. To the first type refers the information essential for laying the routes out, to the second type – the information that influences directly upon the results of the routs design. Other gathered information is considered as the information of the third type. All available data are considered as data that potentially can contain useful information. In IGIS for providing actual information dynamic information model of the subject domain is used. The dynamic information model is organized in accordance with a certain system of rules. The totality of the model elements that at each instant of time contains data matching actual parameters of the objects and medium of their functioning (Zhukova N. et al., 2013).

The processing and analyses of the gathered data is organized according to the concept of data harmonization, integration and fusion (Popovich at al., 2005). The implementation of the concept at the technological level is provided by IGIS. The adaptation of the technologies for processing data of the certain subject domain, in particular the domain of the navigation in modern cities, is organized at the level of the applied algorithms. For data harmonization intelligent algorithms are used to reveal the information about the received data that can allow for representing the data in standard formats. For identifying the structure of the received data that is supposed to be done for solving the first problem algorithms based on calculation of correlation functions, and representation of the data in the form of graphs and calculation of distances between graphs are developed. Implementation of the technology of data integration assumes that intelligent algorithms are used for solving two groups of tasks. To the first group of tasks refer the tasks of preliminary data analysis, in particular, the tasks of denoising, removing single and group outliers, filling gaps, identifying and removing duplicate values. Intelligent algorithms are required for solving the considered tasks as the algorithms of the preliminary analysis that have been developed by now are highly sensitive to the features of the processed data and have to be adapted before application. The tasks of the data estimation and the tasks of calculating characteristics of the data belong to the second group of tasks. Intelligent algorithms allow for comparing the analyzed data with the historical data at the level of the initial values and at the level of the calculated characteristics and to make estimations taking into account all relative data, for instance, measurements of an object parameters can be analyzed jointly with the measurements of the parameters that refer to the same subsystem or to the relative subsystems. Data are the most complicated from the point of view of their implementation. It requires application of intelligent algorithms almost at all stages of data processing and analysis that correspond to the levels of JDL model (Hall et al., 2001; Streinberg et al., 1999). At the level of signal processing the intelligent algorithms are used for extraction of valuable information and knowledge about signals. At the level of objects and situations the knowledge about the signals and the knowledge about the subject domain are used for building descriptions of situations and the objects that are involved in the situations.

The main features of the intelligent algorithms that are used for data processing are the following:

- the algorithms are self-training algorithms. The processes of algorithms training assumes that the algorithms are trained using historical data and improved each time when new data or new results of data processing are acquired;
- the algorithms are adaptable. The settings of the algorithms are defined according to the features of the data that are processed and the requirements to the formed results;
- the algorithms are based on using. The algorithms are able to use all types of available knowledge – knowledge provided by experts, extracted from historical data and from the results of their statistical processing;
- the algorithms represent the results of data processing in standard formats and using the notions of the subject domain allow to use the results by a wide range of consumers;

- almost all algorithms are iterative and multistep. At each step some new desired knowledge of the defined type is acquired. Thus, the result of the algorithms can be considered as new knowledge about a limited part of the subject domain;
- the algorithms are able to support the technology of prospecting analysis that allows to acquire additional information that can be useful for data processing.

The processes of data harmonization, integration and fusion for solving applied tasks are supposed to be built dynamically. Static processes cannot be used as they depend on a list of factors not defined a priori, particularly, the quality of the data, the requirements to the results of data processing, the state of the environment and other. Also during data processing some new knowledge can be acquired.

The descriptions of the situations built using the actual data from the base for building routes in the intelligent navigators. For building routes the following problems are being sequentially solved:

- the problem of situation recognition;
- the problem of situation assessment;
- the problem of situation prediction;
- the problem of building alternative routes;
- the problem of selecting the route from the possible alternative roots.

When solving problems for building routes situations are considered as a structured part of reality (Popovich et al., 2008). The structure is represented as an aggregate of elements of an entity in their relationships with each other. Under the situation recognition a process aimed at identifying a priori defined situations in a flow of data and information is understood (Popovich et al., 2008). The purpose is to assist the decision makers in focusing on relevant information by filtering out situations of interest. The situation assessment assumes execution of a process that dynamically attempts at developing a description of current relationships between entities and events in the context of their environment (Popovich et al., 2008). It aims at fusing information from heterogeneous sources in order to recognize high-level relationships in a complex scenario, composed of several actors and circumstances. Situation prediction is a process that allows to define the state of the situation at the defined time in the future (Baumgarthner et al., 2009).

The general algorithm for building routs contains the following main stages.

Stage 1. At the first stage an attempt to find a similar situation that was earlier observed is made. The formalized description of the observed situation is compared with the descriptions of the situations from the historical database. The historical data base contains all initial data and information in a packed form and the results of their processing in the form that provides a quick access to the stored information. In case similar situations are found the information about the situations and their development is used. For comparing situations an algorithm based on calculation of distances is proposed to be used (Pankin et al., 2013).

Stage 2. The second stage is aimed at solving the situation assessment problem. The complex description of the situation is built on the base of the following information and knowledge: information about similar situations; information and knowledge provided by the model of the subject domain about the objects and their behavior; any other additional information provided by the external sources.

Stage 3. The situation prediction that is realized at the third stage is organized based on complex description of the situation and the descriptions of the behavior of the traffic participants at the groups' level. The parameters of the observed situations are recalculated according to the observed groups of traffic participants and their capacity. In case when the information about the development of the external factors that influence on the situation can be obtained it is also considered.

Stage 4. At the fourth stage the set of possible routes is defined according to the description of the behavior of the user for whom the route are built, the description of the observed situation and results of the situation prediction. Commonly several alternative routes are built.

Stage 5. At this stage each route from the defined set of routes is estimated and the routs are ranged according to the criteria that are defined by the user.

Implementation of the described algorithm for building routes is based on using the subsystem of scenarios implementation and on playing scenarios provided by IGIS. The inference machine and the expert system that are integrated in IGIS are also required for building routes.

5 KNOWLEDGE OF INTELLIGENT NAVIGATORS

The concept of intelligent navigation is based on application of knowledge about cities infrastructure, especially transport infrastructure, citizens and their behavior as well as knowledge about the environment. Knowledge about the transport infrastructure includes knowledge about external and internal transport and their interaction, street roads network, off-street transport network (ground-based, and underground); the networks of long-distance transport that go through the city; different kind of vehicles, terminals and stations. For each element of the information about the networks actual state, for example, the state of the road surface and related information such as the number of accidents is constantly updated. The knowledge about the environment is usually limited by the knowledge about the climate condition and relief. The knowledge about the city's infrastructure and the environment can be quite easily gathered. The process of acquiring knowledge about the behavior of the citizens is much more complicated and is usually organized with the help of a considerable number of experts and a set of specialized tools.

Solving problems in intelligent navigators using knowledge assumes that three sub problems are solved: the problem of knowledge application; the problem of knowledge management; the problem of knowledge acquiring. The problems of knowledge application and management can be solved using technologies provided in IGIS. The problem of acquiring knowledge is specific to the applied subject domain and is considered below.

Knowledge can be acquired using the following main sources. The first source of knowledge is formed by the subject domains' experts of that represent their experience in standard formats that are interpretable by means of artificial intelligence. Knowledge provided by the experts is the most valuable. The second source are various external knowledge based applications and systems that provide knowledge stored in their databases. This type of knowledge is the least reliable. The third sources are the historical data. The data that have been gathered over a considerable period of time can be processed using various algorithms for knowledge retrieval. This type of knowledge is the most relative to the list of the solved tasks.

The main problem of assimilation of knowledge received from the first two sources is whether it can be represented in different formats and using different notions. The problem of using different formats can be solved using specialized instruments for transformations. As a rule, such instruments are developed for each format or a group of relative formats. The problem of notions' interpretation and alignment taking into account their properties, and their relations is much more complicated. Though by now various tools for ontologies' alignment and merging have been developed, they are in fact able to solve the tasks of low and middle levels of complexity, and not the highly complicated tasks.

For mining or retrieving knowledge from the gathered data a wide range of intelligent algorithms have been developed that are based both on statistical and empirical procedures. Two types of knowledge can be retrieved from the historical data: knowledge about entities of the subject domain that includes knowledge about the objects, their properties and relations and the knowledge about the subject domain processes in which the entities are involved or which describe the behavior of the entities.

For the subject domain of the smart cities the algorithms that allow to acquire knowledge are of primary interest as they can be used for building descriptions of the citizen's behavior. The algorithms can be used for building descriptions of the typical behavior of a single user of the navigator and of the typical behavior of the group of users. These two tasks differ significantly and, thus, special algorithms are proposed for solving each of them. The specifics of the first task are that it is important to reveal and to take into account the preferences and the habits of each user. The second task assumes the generalization of the data and information for the groups. Each group may belong to another group or contain several subgroups. Below presented the main steps of the proposed algorithms, they are. The key idea of the first algorithm is to use the algorithms of associations mining for defining the typical elements of the user's behavior and to use process mining algorithms for building sequences from the elements. The sequences are represented in the form of scenarios that reflect the user's behavior under different conditions. The scenarios can be described using standard format oriented to the describing processes. The notions that are used in the scenarios have to be defined in the model of the subject domain. For describing the logical relations between objects and logic rules of their behavior both crisp and fuzzy production rules based on using the first order logic can be involved. One of the most complicated steps of the algorithm is the step of the built descriptions estimation and improvement. Both tasks are proposed to be solved using modeling tools. For estimating scenarios various conditions are imitated and the scenarios are played. For improving the scenarios they are modified and after that are estimated again. The process of the scenarios improvement and estimation is iterative and is stopped as soon as the required rate of the predefined set of the characteristics is achieved. To verify the scenarios a part of historical data is used. The result set of the scenarios is considered as the templates of the user behavior.

Step A (Systematization step) Systematization of the historical data
A1 Defining a subset of the historical data that correspond to the behavior of the defined user
A2 Estimating the amount of the available historical data and its quality
A3 Calculation of the data statistical characteristics
A4 Representation of the data in the structures oriented on application of intelligent algorithms
Step B (Mining step). Building descriptions of the behavior of separate users
B1 Defining the information and knowledge in the subject domain model that can be used in the algorithms for building descriptions of the users behavior
B2 Revealing typical elements of the users behavior using algorithms for mining associations in data
B3 Building short sequences of elements using algorithms of the sequential analyses
B4 Building sequences using typical elements and short sequences of elements
Step C (Formalization step) Representation of the descriptions in the form of scenario scenarios
C1 Defining the format for representing descriptions
C2 Defining the objects of the subject domain that are used in the descriptions
C3 Transforming the build descriptions into the scenarios using the defined format and the objects of the subject domain model
Step D (Estimation and improvement step) Estimation of the scenarios and their improvement
D1 Defining various situations in which the user can take part
D2 Imitating the defined set of the situations
D3 Defining a scenario or a set of scenarios that correspond to the imitated situation
D4 Playing the scenarios and estimating the results
D5 Modifying the scenarios and estimating the modified scenarios
Step E (Verification step) Verification of the scenarios
E1 Defining a part of historical data for scenarios verification
E2 Imitating the historical context for each of the scenario and playing the scenario
E2 Estimating the scenario and comparing it with the actual behavior of the user that was observed

Fig. 1: The algorithm for building the descriptions of the behaviour of a single user.

The key idea of the algorithm for describing the behaviour of the groups of users is to identify local groups of users with similar behaviour and to reveal the motives in their behaviour unlike the habits that are defined for separate users. Describing the behaviour of the group of users based on their habits causes a lot of contradictions that can be hardly solved. Motives are considered as a specialized sequence of actions that is reasonable and justified and that define the behavior of the users. Motives are represented in the form of scenarios. Local groups can be united in larger compound groups. For defining the behavior of the compound groups the descriptions of the behavior of the local groups are merged. The process of merging is based on application of the following set of rules: the scenarios that are similar for all groups are included into the set of scenarios of the compound group. The scenarios related to several groups are split into a set of sub scenarios from which elements that reflect the behavior of the users in all groups are selected. The sub scenarios from the remained subset are further decomposed unless they are represented in the form of separate typical elements. The scenarios build for the groups are estimated, improved and verified similar to the scenarios defined for separate users.

Step A (Systematization step) Systematization of the historical data
A1 Define typical sequences, typical elements, grouping
Step B (Mining step). Building descriptions of the behavior of the local groups of users
B1 Building local groups of users
B2 Identifying motives for the local groups of users
Step C (Formalization step) Representation of the motives in the form of scenario
C1 Transforming the motives into the scenarios
Step D (Mining step). Building descriptions of the behavior of the groups of users
D1 Defining compound groups of users on the base of local groups
D2 Merging scenarios defined for the local groups
Step E (Estimation and improvement step) Estimation and improvement of the scenarios for the local and compound groups of users
Step F (Verification step) Verification of the scenarios for the local and compound groups of users

Fig. 2: The algorithm for building the descriptions of the behaviour of the groups of users.

For implementation of the considered algorithms different intelligent algorithms can be applied depending on the amount of the available historical data and computational resources. For example, the first algorithm can be implemented using Apriori or Predictive Apriori algorithms, the second – using Simple KMeans or EM algorithms.

6 SOME ASPECTS OF THE MOBILE NAVIGATORS DESIGN AND IMPLEMENTATION

Transport infrastructure of the modern city is much diversified. It includes private and public land-based transport (cars, buses, and trams), underground transport (tram and metro), railway, air and also water transport (ferry, cutter, water bus). As known, many cities are located on the islands and have a well-developed water transport. Water transport also should be safe and comfortable for citizens.

Accordingly, it is necessary to develop intelligent navigators also taking into account the needs of such regions. Usage of mobile intelligent navigation system is an effective solution for providing safe navigation, as well as providing information assistance in vessels' control. The intelligent navigation systems use radar, automatic identification system to keep information about vessels and their location. In addition, the mobile navigation system uses decision support tools which provide:

- acquisition and processing of integrated information about the circumstances of the cruising from different data sources;
- providing contextual information and reference data upon the user's request or under the occurrence of certain situations;
- mapping of the nearest vessels' position equipped with mobile navigation system on the nautical maps;
- solving special navigators and service tasks.

The developed mobile intelligent navigation system is indented for mobile devices such as smartphones, laptops, tablets with the Android 4.0 operating system. To update the information model and download the function modules an access to the Internet is required.

The generalized structure of the mobile intelligent navigation system (MINS) is shown on Fig. 3. System includes the following elements:

- Cloud Services Platform – network of distributed servers that provides the set of the necessary services;
- Client integration platform – application, that provides the necessary interfaces for connecting modules that implement the required features and that are installed on the mobile device.
- Function Modules Repository – storage of functional modules, providing the capability to extend the functionality of the client's integration platform.
- By means of these structure components MINS supports a wide range of functions and services, that include:
- displaying the nautical chart showing the location of the users own ship and other maneuvering vessels;
- option of manual and automatic (AIS, radar) targets' drawing, target movement calculation;
- ship's routing between predetermined ports/points, at that, accounting for the navigational area features and the desired duration of movement/recreation;
- display and registration of the weather data at a point/on the route, broadcast of the storm warnings;
- calculation of the maneuvers aimed at the storm escape; speed and course calculations on the storm sailing;
- solving the tasks of maneuvering; positions' gaining and targets' passing;
- warning about dangerous maneuvers; entry into the closed/restricted areas, areas with special conditions for navigation, shallow water areas;
- advance warning of maneuvers on the route (time and turning point, speed changes, etc.);
- retrieve data about the locations of other vessels equipped with MINS.

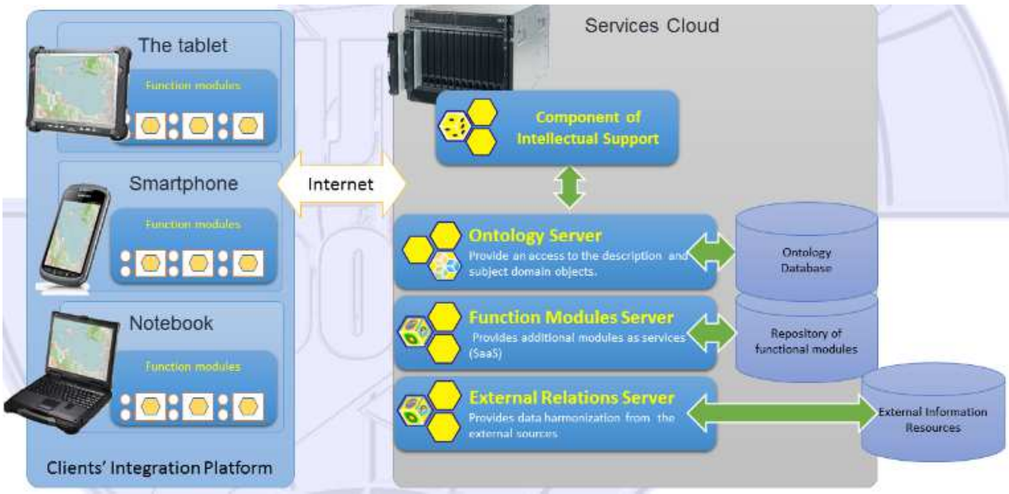

Fig. 3: General structure of the mobile intelligent navigation system for vessels.

Fig. 4 shows a map on which the vessels' icons, it routes (blue line) and additional information are plotted. The data on the map are updated in real time. By clicking on the vessel's icon additional information about the vessels, such as vessel's location (latitude and longitude), their lengths, widths, speeds, courses and names can be obtained. Various colors are used for displaying various vessels' types: green color for cargo vessels, blue – for passenger vessels, orange – for high speed crafts, grey – for unspecified vessels.

It is necessary to notice that the system is rather simple and easy in use; the user needs no additional knowledge and skills to start working with the system. Furthermore, the system can work in autonomous mode that allows using the system without a permanent connection with the server during a certain period of time.

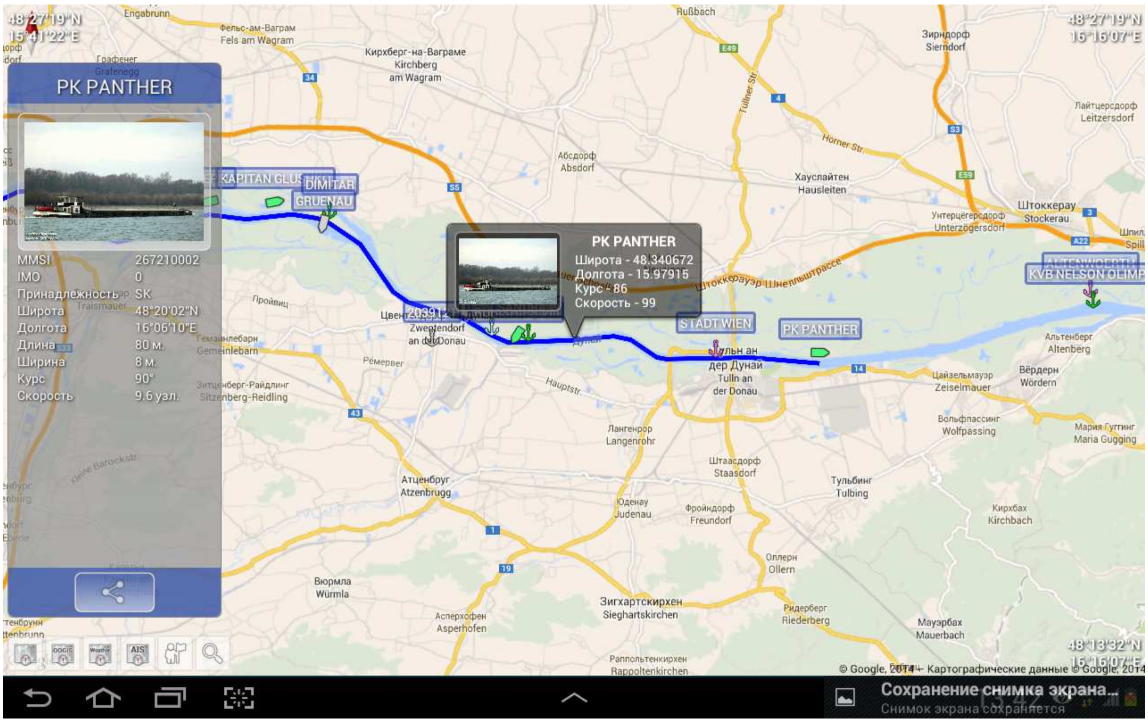

Fig. 4: Vessels' routes.

7 CONCLUSIONS

Intelligent navigation plays an important role in everyday life and affects the fundamental science and technological solutions. The approach described in this paper proposes to develop and to implement the intelligent navigators using the intelligent GIS technologies. The considered approach demonstrates the fusion of different technologies: navigation, GIS, Intelligent GIS and data analysis.

ISBN: 978-3-9503110-6-8 (CD-ROM); ISBN: 978-3-9503110-7-5 (Print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI

In the future the mobile intelligent navigation system will be improved and developed for city transport infrastructure, including street roads network, offstreet transport network, the network of long-distance transport and other. Mobile Intelligent GIS for general purpose aviation, pedestrians, tourists and disabled people (Audio-navigation) are planned to be developed.

8 REFERENCES

BAUMGARTHNER N., GOTTESHEIM W., MITSCH S., RETSCHITZEGGER W., SCHWINGER W. On Optimization of Predictions in Ontology-Driven Situation Awareness. In: Proceedings of the 3rd International Conference on Knowledge Science, Engineering and Management (KSEM '09), Dimitris Karagiannis and Zhi Jin (Eds.), pp. 297–309, Springer-Verlag, Berlin, Heidelberg, 2009.

ERTMS, http://www.ertms.net.

Free Community-based Mapping, Traffic&Navigation App, http://www.waze.com.

Garmin, http://www.garmin.com.

HALL D. L., LLINAS J. Handbook of Multisensor Data Fusion. CRC Press, 2001.

Magellan GPS, http://www.magellangps.com.

PANKIN A., VODYAHO A., ZHUKOVA N. Operative Measurements Analyses in Situation Early Recognition Tasks. In: 11th International Conference on Pattern Recognition and Image Analyses, pp. 449-453, Russia, Samara, 2013.

POPOVICH V., HOVANOV N., HOVANOV K., SCHRENK M., GOREV Yu., PROKAEV A., SMIRNOVA A. Situation assessment in everyday life. In: Proceedings of the CORP, pp. , 2008.

POPOVICH V., VORONIN M. Data harmonization, Integration and fusion: three sources and three major components of Geoinformation Technologies. In: Proceedings of the IF&GIS, pp. , St. Petersburg, Russia, 2005.

RIS, http://www.ripe.net/data-tools/stats/ris.

Safespot, http://www.safespot-eu.org.

SESAR, http://www.sesarju.eu.

SMART-WAY, http://www.smart-way.mobi.

STREINBERG A., BOWMAN C., WHITE F. Revisions to the JDL data fusion model. In: Proceedings of SPIE Conference on Sensor Fusion: Architectures, Algorithms, and Applications, pp. 430–441. SPIE, 1999.

Telenav GPS Navigator, http://www.telenav.com.

TomTom, http://www.tomtom.com.

ZHUKOVA N., IGNATOV D., SMIRNOVA O. Dynamic information model for oceanographic data representation. In: 20th international conference on conceptual structures, pp. 82-92, Mumbai, India, 2013.