# Improving Computer Support System for Drivers with Multiport Memory Devices

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Abstract: The deficiencies of existing methods and means of computer support in the positioning of vehicles have been identified. The objective function for assessing the effectiveness of decision making when choosing the positioning mode for a group of mobile objects on the roadway in the conditions of insufficient visual information is defined, with the criteria for estimating the quality and effectiveness being established. A stratified cellular model for roadways is developed, where the road is viewed as an extended object in the space, the borders of which are digitized by the satellite navigation system “GLONASS/GPS” with the required degree of discreteness and accuracy. The roadway model is realized as a multi-page dynamic array and is used in the developed simulation model of vehicle traffic control, with navigation data errors being taken into account. The platform prototype can be implemented on the basis of VRAM, WRAM, MDRAM, ZigBee-modems “ETRX2-PA”, driver support systems based on mobile computers such as GLONASS/GPS-modules of the “SIM68EVB KIT” type. The received results are recommended for creating computer support systems for drivers, and for managing vehicles in the conditions of insufficient visual information.

## 1 INTRODUCTION

In computer support systems for drivers of vehicles, special attention is paid to improving their performance. The requirements for methods and high-speed computer devices determine their implementation in the form of specialized hardware with the greatest possible extent of parallelism in their performance (Gonzalez et al., 2014; Park et al., 2013; Khasanov and Sarajkin, 2016). The number of parameters for computer support systems for drivers to be considered in case of positioning a group of mobile objects significantly increasing, it is urgent to provide control information to ensure a safe mode of positioning the entire group of mobile objects on the roadway (Khasanov, 2016). Quickly obtained control information determines the effectiveness and safety of operating vehicles.

Modern computer support systems for drivers are being gradually involved in a wide range of complex tasks in the process of operating vehicles. These systems are indispensable in extreme and dangerous conditions of insufficient visual information (Gusarov, 2011; Turenko et al., 2013).

The lack of visual information occurs in the process of moving vehicles because of insufficiency of actual visual information (for example, marking lines, road signs and landmarks) in bad weather conditions (fog, snow or sand storms), in extreme conditions of poor visibility caused by fogging or

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malfunctions of night lighting devices and (or) ventilation of vehicle windows (Turenko et al., 2013; Khasanov and Sarajkin, 2016).

The range of computer, navigation, optical, laser methods and devices used in motor vehicles is gradually reaching the level of aviation equipment (Broggi et al., 2012; Cheng et al., 2011). The task of highly precise positioning of vehicles has a special urgency for countries with extended road networks, with constantly changing relief, various weather and climate zones, the existence of road sections with missing or incorrectly done road markings, with missing roadway markers and signs (Cheng et al., 2015; Schätz et al., 2015).

The problem of increasing the actual safety of vehicles is primary importance in modern scientific and technical, periodical, patent literature and in Internet sources. Among the researches on this subject, we should note the researches by T.Z. Aralbaev, E.V. Balakina, S.V. Bakhmutov, V.O. Volkov, S.V. Gaysin, A.P. Gusarov, A.S. Gurin, D.A. Zatuschny, G.O. Kotiev, I.V. Lukashov, A.V. Makarov, M.V. Nagaitsev, A.A. Revin, S.A. Rynkevich, A.M. Saikin, V.P. Tarasik, A.N. Turenko, A.V. Uzhva, I.V. Hodes, M. Bansal, L. Bombini, A. Broggi, C. Caraffi, E. Cardarelli, J. Choi, A. Das, T. Graf, D. Kim, G. Kreutzer, J. Lee, P. Medici, M. Meinecke, C. Stefano.

The analysis of modern publications has shown the existing methods and devices of computer support in positioning vehicles to have disadvantages despite significant advances in the methodology of constructing active vehicle safety systems:

- they are not informative and efficient for a group of vehicles in the conditions of visual information shortage;
- they do not perform a coordinated exchange of navigational data between the vehicles in a group that use wireless technologies according to “V2V” principles;
- their hardware and software have a high cost (more than 20 thousand euro) for one vehicle;
- they have closed architectures due to foreign defense orders and for this reason the results of the printed researches are not often open.

Thus, the task of improving computer support system for drivers based on the use of multiport memory devices is relevant.

# 2 METHODS, THEORETICAL APPROACHES AND MATHEMATICAL MODELS

The effectiveness of a computer support system for drivers is determined by its increased actual safety and improved operating modes for mobile objects due to reduced uncertainty for a driver in case of insufficient visual information.

The “effect” in the study is understood as some cumulative result, consisting of the sequence of the following actions: the exact position determination (orientation) of vehicles on the roadway, the choice of a safe speed regime and the trajectory of the movement of a motor vehicle at every moment of time. In other words, it is the maintenance of adequate positions (stable condition) of vehicles on the roadway due to chosen safe modes of driving in the conditions of insufficient visual information and, thus, ensuring its active safety and safety of other road users.

The creation and further operation of computer support systems for drivers to position the car on the roadway in the conditions of insufficient visual information is concerned with the development of appropriate criteria and techniques for assessing their quality and effectiveness.

According to the studies, the criterion was established to meet the following basic requirements:

- to account for the most significant and available parameters in order to calculate both the positioning mode of a vehicle and the hardware and software of the computer support system for a driver;
- to provide the possibility of comparing different types of computer support systems for a driver and determining ways to improve their technical and economic indicators;
- to have a clear physical meaning and ease of calculation when performing engineering calculations with quantitative estimates.

In the researches (Shen and Neyens, 2014; (Roessing et al., 2013; Meguro et al., 2005), the number of criteria of monitoring systems and on-board systems are noted. These criteria allow assessing the quality of the organization of the system that is being developed.

The analysis of the criteria shows that they are useful for evaluating and comparative analysing for on-board vehicle systems of various classes. However, the attempt to apply them at the design stage of computer support systems for drivers showed that they do not include certain features of the decision when choosing the mode of positioning for vehicles, in particular:

- the dynamics of occurring and developing the errors of the satellite navigation system “GLONASS/GPS” when a vehicle has “hot” or “cold” starts;
- the performance of each subsystem of the computer support system for the driver, depending on the time limits and the nature of occurring errors;
- the effect of the operation quality of one subsystem of the driver's computer support system on the operation results of the other subsystems;
- the considered criteria cannot determine the qualitative contribution of each subsystem to the overall result of the computer support system for the driver.

Thus, in order to achieve this goal, it is necessary to determine the objective function for assessing the effectiveness of decision-making when choosing the positioning mode of a group of vehicles on the roadway in the conditions of visual information shortage, and also to develop a prototype of a high-performance computer support device for drivers based on the use multiport memory devices.

To illustrate the definition of the objective function and the generalized criterion for assessing the effectiveness of the chosen mode of vehicle positioning, Figure 1 presents a topological scheme for determining the effect of metrological errors of the satellite navigation system, the magnitude of the errors of the 1st and 2nd kind being considered.

The following conventions are adopted: points M1 and M2 are the locations of the antennas the satellite navigation system “GLONASS/GPS” on the front and rear parts of the car; R11, R21 are the radii of metrological errors of the “hot” start of navigation equipment; R12, R22 are the radii of metrological errors in the “cold” start of navigation equipment; α, β are the distribution (spread) zone of probable errors of the 1st and 2nd kind, respectively; LATC is the base of the car.

A black solid line indicates the direction of the car. The red solid lines show the worst positions of vehicles, with the magnitude of errors of the 2nd kind being considered, and the red dotted lines indicate possible directions (trajectories) of moving vehicles, with the worst consequences of the errors of the 2nd kind being taken into account. The red points along the borders of the roadway indicate the coordinates of the digitized borders of the roadway. Similarly, the worst variants for vehicles and the worst possible directions of their movement for errors of the 1st kind are identified.

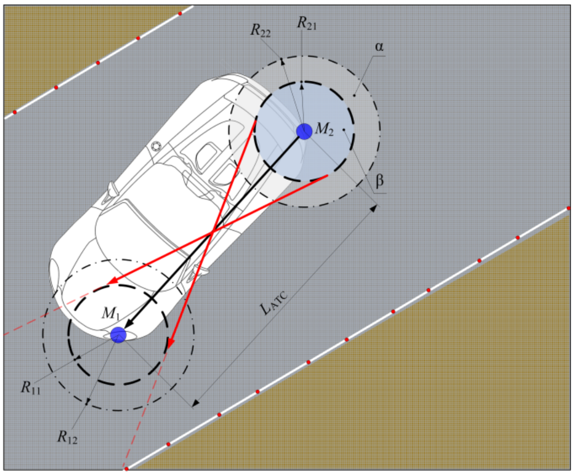


Figure 1: A topological scheme for determining the effect of metrological errors of the satellite navigation system, the magnitude of the errors of the 1st and 2nd kind being considered.

Decision-making for choosing the mode of positioning for vehicles is associated with the corresponding errors of the first kind caused by the “cold start” of navigation equipment, and of the second kind caused by the “hot start” of navigation equipment.

According to Gusarov (2011), the “hot start” is the state of a navigation receiver, which occurs when its power has been turned off for some time, while the data on ephemerides, almanac and time are preserved. This drastically shortens the time period necessary for the first location determination. At the “cold start” navigation signals are searched for unknown data on ephemerides of satellites and the almanac of the system.

When determining the objective function, the navigation equipment, in addition to metrological errors, is known to provide information with a certain degree of discreteness, for example, the discreteness of modern satellite navigation systems “GLONASS/GPS” is 1 ÷ 500 Hz, with the range of metrological errors being 2 ÷ 60 cm for modern inertial satellite navigation systems, operating in the differential correction mode, and the range of metrological errors being 1 ÷ 15 m for widely available 24-channel modern satellite navigation systems “GLONASS/GPS” (Park et al., 2013; Khasanov and Sarajkin, 2016; Khasanov, 2016; Gusarov, 2011; Turenko et al., 2013).

The objective function when choosing the mode for positioning a group of vehicles can be presented in the following way:

$$Z_{PM}=\sum_{j=1}^{M}\left(\lambda\cdot T\cdot\sum_{i=1}^{N}\left[\left(Z_{V,TR}-E_{V,TR}\right)\cdot P_d(i)\right]\rightarrow min\right) \quad (1)$$

$$\Delta\leq\Delta_3,\ D\geq D_3,\ H\geq H_3,\ Z\leq Z_3$$

where: $Z_{PM}$ (positioning mode) is the cost of maintenance and repair of vehicles, determined by the positioning mode; $M$ is the number of vehicles in a group; $\lambda$ is the discreteness of obtaining navigation information; $T$ is the time necessary to obtain navigation information; $N$ is the number of categories (gradations) of the conditions for insufficient visual information (for example, the visibility being up to 50 m, 50 ÷ 100 m, 100 ÷ 200 m, 200 ÷ 300, 300 ÷ 400 m, > 400 m); $Z_{V,TR}$ is the total costs caused by an incorrectly chosen positioning mode and determined by the speed and trajectory of vehicles; $E_{V,TR}$ is the overall economic effect of a correctly chosen positioning mode for a vehicle; $P_d(i)$ is the probability of a driver's mistake occurring while driving the vehicle in the $i$-th category of insufficient visual conditions that led to slipping or driving the vehicles from the existing roadway borders; $\Delta$, $\Delta_3$ are the actual and required metrological error of navigation equipment; $D$, $D_3$ are the actual and required reliability of results; $H$, $H_3$ are the performance of the computer support system for a driver, with the actual and specified ones being considered, respectively; $Z$, $Z_3$ are the costs for the hardware and software of the computer support system for a driver, with the actual and specified ones being considered, respectively.

$$Z_{V,TR}=[(z_{V\alpha}+z_{TR\alpha})\cdot\alpha+(z_{V\beta}+z_{TR\beta})\cdot\beta] \quad (2)$$

where $z_{V\alpha}$, $z_{V\beta}$ are the costs (negative effects) caused by an incorrectly chosen speed mode, with the errors of the 1st and 2nd kind, respectively, being made; $z_{TR\alpha}$, $z_{TR\beta}$ are the costs caused by the incorrect determined current location (orientation) of vehicles on the roadway and (or) caused by the incorrect choice of the vehicle trajectory in conditions of insufficient visual information, with the errors of the 1st and 2nd kind, respectively, being considered.

$$E_{V,TR}=[(e_{V\alpha}+e_{TR\alpha})\cdot(1-\alpha)]+[(e_{V\beta}+e_{TR\beta})\cdot(1-\beta)] \quad (3)$$

$$\begin{aligned}P_d(i)=&\delta\cdot(1-P_{FNE})\cdot(1-P_{CSSD})\cdot(1-P_U)+\\&+P_{FNE}\cdot(1-\delta)\cdot(1-P_{CSSD})\cdot(1-P_U)+\\&+P_{CSSD}\cdot(1-\delta)\cdot(1-P_{FNE})\cdot(1-P_U)+\\&+P_U\cdot(1-\delta)\cdot(1-P_{FNE})\cdot(1-P_{CSSD})+\\&+\delta\cdot P_{FNE}\cdot P_{CSSD}\cdot P_U\end{aligned} \quad (4)$$

$P_d(i)$ is determined by the value of the insufficient visual information parameter $\delta_{IVI}$, probable failures of navigation equipment $P_{FNE}$ and computer support system devices $P_{CSSD}$, and the value of the relative accident rate on the investigated part of the roadway $P_U$.

The relative accident rate $P_U$ shows the number of road accidents in relation to the mileage of vehicles or to the number of vehicle passages.

The value of insufficient visual information $\delta_{IVI}$ is determined by the ratio of the visible roadway part to the total area of the roadway that the transport process subject must see from the observation point (h=1.2 m).

According to Cheng et al. (2015), the relative accident rate is used to assess the degree of accident rate within some sections of the roadway or road network.

The relative accident rate $P_U$ shows the number of road accidents in relation to the mileage of vehicles or to the number of vehicle passages.

In the first case, the coefficient $P_U$ characterizes the degree of accidents on long and homogeneous parts of roads along geometric elements (Cheng et al., 2015):

$$P_U=z/(T\cdot\lambda_{TI}\cdot L) \quad (5)$$

where $z$ is the number of accidents for a period of time $T$; $\lambda_{TI}$ is the average annual traffic intensity (the average one for the period of time $T$), aut./day; $L$ is the length of the roadway section, km.

In the 2nd case the coefficient $P_U$ characterizes the degree of accidents on long and homogeneous parts of roads within short sections (intersections and junctions, small bridges, overpasses) (Cheng et al., 2015):

$$P_U=z/(T\cdot\lambda_{TI}) \quad (6)$$

## 3 RESULTS AND DISCUSSIONS

The studies established that the effectiveness of the chosen mode of positioning vehicles in the conditions of insufficient visual information largely depends on the reliability of the navigation methods and means used. Thus, the use of the criterion in (1) – (6) made it possible to take into account:

- the specific character of operating means the satellite navigation system "GLONASS/GPS", with their discreteness and inaccuracy being taken into account;
- the efficiency of each subsystem of the computer support system for the driver, depending on the time limits and the nature of the violations of the rules for the safe operation of vehicles in the conditions of insufficient visual information;
- the influence of the operation quality of one subsystem on the results of the other operating subsystems, with their contribution to the overall result of the computer support system for the driver.

As sources of information about the Driver-Car-Road system, the following types of data are taken into account: the prior data received as a result of registration, collection and processing the information from mobile road laboratories; the posterior data obtained as a result of exchanging the information between road users and road infrastructure elements via wireless communication channels in the operation of motor vehicles; the operational data obtained as a result of registration, collection and processing of the data from sensors and devices located directly in the vehicle.

The analysed factors influencing the efficiency of solving the problem of choosing a high-speed mode, with (1) – (6) being taken into account, proved that to cope with it a complex information support system is necessary, including subsystems for collecting and recording data on the state of road situations, identifying the surface condition of the roadway, the choice of optimal values for the Driver-Car-Road system operational parameters, visualizing and exchanging the information received between road users. To solve this problem, an integrated simulation model is developed as a complex ergatic system Driver-Car-Road, supplemented with modern hardware and software means for selecting and optimizing high-speed modes for vehicles.

As the choice of the trajectory and speed of the car is significantly influenced by the characteristics of the roadway, some field studies (Khasanov and Sarajkin, 2016; Khasanov, 2016; Gusarov, 2011; Turenko et al., 2013) of the quality of roadways of the route "Orenburg-Isyangulovo" and "Orenburg-Orsk" along two routes P-314 and P-336 were carried out. 30 % of road sections are found to be unsatisfactory; 15 % of the road length have no road signs regulating high-speed modes for vehicles.

The second variant is characterized by: the condition of 55 % of road sections is excellent; 10 % of the road have no road signs regulating high-speed modes for vehicles; 2 especially dangerous areas are identified, as they have no any warning information for road users.

Figure 2 presents a block diagram of a stratified cellular model for a roadway, as an extended object in space, with the values of cells (facets) determining some specific category and level of road safety.

In this case, the road is viewed as an extended object in the space, the boundaries of which are digitized by the satellite navigation system "GLONASS/GPS" with the required degree of discreteness and accuracy.

The road is represented as a set of roadway sections, the number of which is $k$. The section of the road prototype $C_i$ with the length $l_i$ and the width $s_i$ is a collection of two-dimensional matrices in the form of independent layers, the number of which is $z$.

In each of the 7 layers of $C_i$, the information is kept about the specific form of the transport and operational condition (TOC) of the roadway: the longitudinal $\alpha$ and transverse slope $\beta$, the flatness $r$, wheel tracking $\rho$, the roughness $\gamma$ and the adhesion coefficient $\varphi$, the location $K_\delta$, the area $S_\delta$ and the depth of potholes $h_\delta$.

The points $x_1,y_1$ – $x_j,y_j$ denote the navigation coordinates of the digitized boundaries of the roadway; $l_{11}$ – $l_{13}$ indicate distances between the navigation coordinates and up to the described the TOC of the roadway with a specific value of $v_{ij}$; $h_{11}$ is the height of the triangle to the described TOC and (or) the damage of the roadway.

Each cell from a two-dimensional matrix (layer) is associated according to its address with certain values of the TOC of the roadway: $\alpha$, $\beta$, $r$, $\rho$, $\gamma$, $\varphi$, $K_\delta$, $S_\delta$ and $h_\delta$. The values of the cells (facets) of the TOC of the roadway determine the specific category and level of road safety. On the totality of the TOC values of the roadway, the computer support system for the driver determines the safe high-speed mode $V_{safe}$ and recommends the trajectory $TR_{rec}$ for the vehicle.

The input of the choosing (determinating) subsystem model $V_{safe}$ is the set S = {$\alpha$, $\beta$, $r$, $\rho$, $\gamma$, $\varphi$, $K_\delta$, $S_\delta$, $h_\delta$} of the registered values of the parameters of the DVRE (driver-vehicle-road-environment) system, the output of the model is the critical $v_{cr}$ and safe $v_{safe}$ speeds of the car to be calculated on the basis of the mathematical model by I.V.Hodes. In this case, the computer support system of the driver is considered as a hardware-software converter of the parameters $S$ in the speed parameter $V_{safe}$.

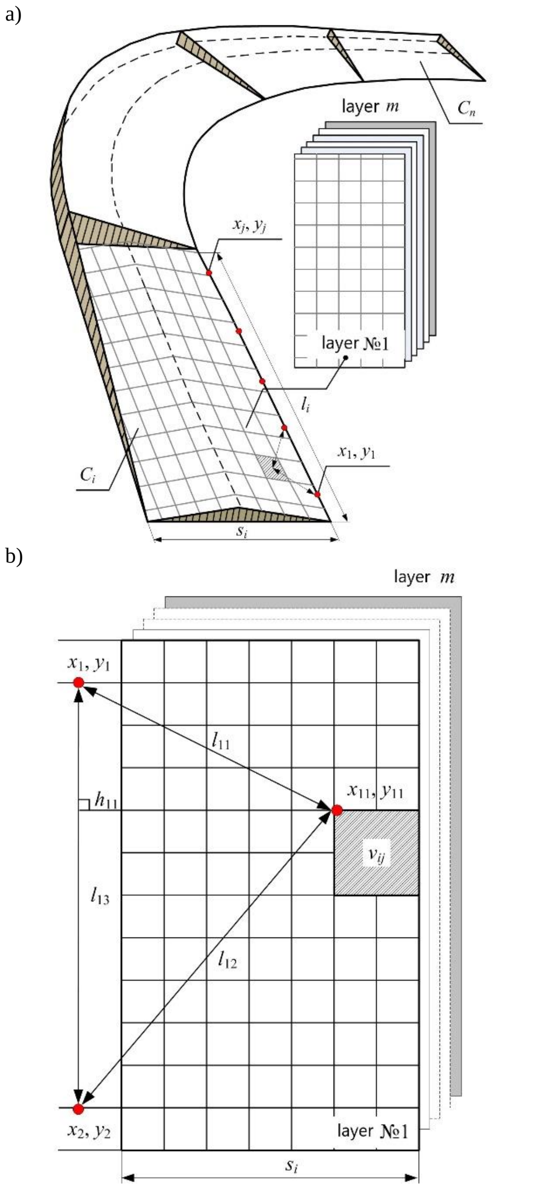


Figure 2: Block diagram of a stratified cellular model for a roadway a) a set of sections of the roadway and layers of TOC roadway; b) the addressing scheme of cells of the matrix fragment.

Addressing of cells in the matrix is carried out in the following way:

1. The digitized section of the roadway is divided into sectors. The discreteness of the subdivision of the road section into sectors is determined by the error value of the satellite navigation system "GLONASS/GPS". For example, if the distance between the neighboring coordinates $x_1y_1$ и $x_2y_2$ of the digitized roadway border is $l_1$=540 cm, and the navigation equipment error $\Delta_{SNS}$ = 60 cm, then the number of rows $m$ in the matrix will correspond to $]l_1/\Delta_{SNS}[$ = 9. For the width of segment of the road cover $s_1$=700 cm, the number of columns $n$ in the matrix will be equal to $]s_1/\Delta_{SNS}[$ = 11, where the functional in the reverse brackets means the whole part of the ratio.

2. To have access to an arbitrary cell of the matrix, it is necessary to specify the coordinates of the two nearest points $x_iy_i$ and $x_{i+1}y_{i+1}$, as well as the distances $l_{11}$ and $l_{12}$. The developed simulation model in the automatic mode according to Heron formula determines the address (index) of the row and column for the corresponding layer. In situations, if any of the layers does not require such a detailed subdivision into sectors, any other necessary dimension is specified.

Thus, it is possible to store and match with cartograms the defects and values of the TOC of the roadway when using dynamic arrays. The use of dynamic arrays as an approach when developing a software design. firstly. makes it possible to change automatically their dimensionality for accumulating the information in the process of collecting. recording and processing data on the geometric and operational parameters of the roadway. Secondly, the use of dynamic arrays can reduce the amount of memory resources consumed in the computer support system of the driver. since unused address ranges and pages (layers) can be automatically freed from the system's RAM.

Thus this program approach makes the work with information more flexible. since it does not require a preliminary determining the dimensions of the stored arrays, the roadway data and the route of movement of the mobile object.

The stratified cellular model of the roadway is implemented in the programming environment "Borland Delphi 7" in the form of a multi-page (multi-layered) dynamic array and is used in the developed simulation model of vehicle controlling, with the errors in navigational data being taken into account.

The effectiveness of the chosen mode of positioning vehicles in the conditions of insufficient visual information depends largely on the reliability of navigation methods and means used. The use of the criterion in (1) – (6) makes it possible to consider the specific character of operating satellite navigation systems "GLONASS/GPS", with their discreteness and inaccuracy being considered (Khasanov, 2016; Cheng et al., 2015).

In determining the objective function navigation equipment is considered to provide information with certain discreteness in addition to metrological errors, for example, the discreteness of modern means of satellite navigation "GLONASS/GPS" is 1÷500 Hz, while the range of metrological error is 2÷60 cm for modern inertial satellite navigation systems operating in the differential correction mode, and in the range 1÷15 m for widely available 24-channel satellite navigation devices.

In Figure 3 the functional diagram for the device is presented.

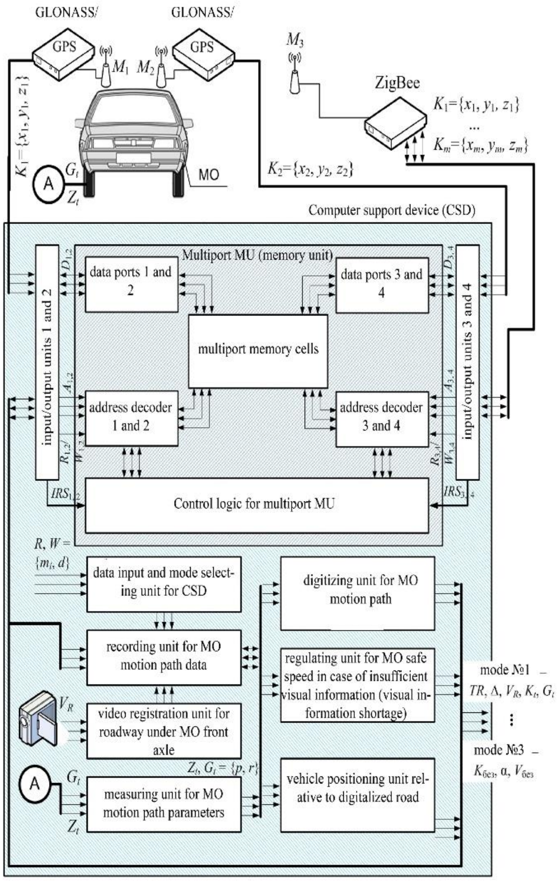


Figure 3: Functional diagram of a device for computer support system for drivers for positioning a group of vehicles.

The requirements for high-speed performance of computer support systems for drivers to position a group of vehicles caused the development of this system in the form of a specialized hardware platform that uses the principles of organization and architecture of multi-port memory devices, modern relational database management systems, "V2V" and EIIP approaches (Turenko et al., 2013) to the group members.

Due to the use of multiport memory devices, the design principles for database management systems, multi-page (n-dimensional) organization of dynamic arrays, wireless ZigBee-modems for data exchange between vehicles ("V2V") a single virtual information space for group members is organized. When the computer support system for drivers functions inside multi-port memory devices, the same copies of the dynamic arrays (images) $Q_t$ are stored. When the structure or content changes at the time moments $t$, the modified image $Q_{t'}$ becomes equally updated for all members of the complex group (Shen and Neyens, 2014).

The presented prototype of the platform can be realized on the basis of the following elements and means of computer technology: multiport memory devices based on VRAM, WRAM and MDRAM technologies, ZigBee-modems "ETRX2-PA", computer driver support systems based on mobile computers of the type (Khasanov and Sarajkin, 2016), (Broggi et al., 2012), (Cheng et al., 2011), (Chen et al., 2015), (Schätz et al., 2015) GLONASS/GPS-modules of the "SIM68EVB KIT" type.

# 4 CONCLUSIONS

The purpose of the research was to increase the efficiency of the information provided to the subjects of the transport process to ensure a safe mode of positioning a group of vehicles on the roadway. Thus, we have suggested the approach to ensuring vehicles' active safety and safety of other road users by the maintenance of adequate positions (stable condition) of vehicles on the roadway due to chosen safe modes of driving in the conditions of insufficient visual information.

The methods and principles of the theories of active vehicle safety, control and optimization, the theory of pattern recognition and the theory of designing computer systems were used.

The objective function is to assess the effectiveness of decision-making when choosing the positioning mode for a group of vehicles on the roadway in the conditions of visual information shortage, with an experimental model (a prototype) of a high-performance computer support device for drivers based on the use of multiport memory units being also developed.

We have developed an emulator program that, using navigation stands, simulates the operation of a multiport memory device.

The results obtained can be recommended for creation of computer support systems for drivers, as well as in the management of vehicles in the conditions of insufficient visual information.

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