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A generalized model of an adaptive information-control system of a car with multi-sensor channels of information interaction

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ABSTRACT

The analysis of existing technologies for the development and implementation of vehicle control systems based on the automation of their functionality in accordance with the standard of the Society of Automotive Engineers J3016 2018 and proposals of the US National Highway Traffic Safety Administration is performed. The classification of the functionality of the on-board information-control system of vehicles according to the type of Advanced Driver Assistance Systems is carried out. On the basis of the conducted analysis the variant of structure of adaptive information-controlled system of the car with multisensory channels of information interaction is offered. Approaches to the elimination of a priori uncertainty regarding the information about the input multisensory information array in the adaptive information system with external and internal standards are proposed. Based on the methods of direct and inverse modeling, an approach to solving the class of problems of system identification is proposed, when the researcher has input and output signals and the transmission characteristics of the system are unknown. On the basis of direct and inverse methods of solving the system identification problems, structures of formation of direct and inverse estimation of the distortion operator are developed. This matrix distortion operator of the input multisensory information array in the system under study is a priori unknown. The analytical dependences of the formation of direct and inverse estimation of the distortion operator of the input multisensory information array in the controlled system with the adaptive principle of information processing in the conditions of a priori uncertainty are substantiated. In this study, the structure of an adaptive robotic complex with an information-controlled vehicle control system is proposed. This structure is invariant to external and internal destabilizing influences.

Keywords: Information-control system; automobile; adaptive system; a priori uncertainty; image; lidar; radar; stereo camera; information array

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1. INTRODUCTION

To ensure high-quality (safe) use of the car in manned and unmanned modes, its use allows the use of various levels of automation of car control processes based on the use of its information-control system. This is especially true of the unmanned or autonomous mode of vehicle movement.

According to experts in the development of unmanned vehicles (UV), the onboard vision system (OVS) should include three types of sensors: a camera (stereo camera), lidar, and radar [1]. Most of the created UV prototypes have just such a set of sensors, and their tests confirm the expert opinion: only a combination of three types of sensors provides a sufficiently reliable idea of the surrounding space for autonomous movement. The use of cameras allows solving the problems of classifying objects and keeping the UV in the occupied traffic lane, the radar has advantages in terms of the detection range of objects and in terms of performance in bad weather conditions [2], lidars combine high accuracy indetermining distances to objects with high resolution.

Thus, the integration of sensors into a single system makes it possible to use the advantages of each of them in solving various problems of autonomous movement [3].

The solution of the problem of combining sensors into a single information-controlsystem in the scientific world is solved by various developers by automating the processes of obtaining primary information, processing it and developing a management decision [3]. At the same time, in the case of a manned mode of operation of the car, the managerial decision based on the information processed in the information-control system of the car remains with the driver. In an unmanned or autonomous mode, the management decision is made by the information-control system of the car.

Depending on the level of automation of the totality of car control functions, the very process of formation and processing of primary information about the environment and directly about the car as a technical device becomes more complicated in order to develop options for its behavior in unmanned operation (motion) mode.

The bases of existing approaches to the development of OVS of modern cars are technologies similar to Advanced Driver Assistance Systems (ADAS) [4]. To ensure the correct operation of the ADAS system, input data from a wide variety of sensors, information systems and software algorithms are used. These include: Light Detection and Ranging (LiDAR). Radar, digital cameras, ultrasonic sensors, navigation systems, mapping services, telematics systems, vision systems, and others.

The latest ADAS systems also actively use connected car technologies: vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) systems, which allow vehicles and roadside infrastructure to exchange data in real time.

Such systems are based on technologies that implement a number of functionalities:

1. The collection and processing of data is based on:

–sensor technology (sensors and sensors) by type of optical cameras, lidars, radars, ultrasonic sensors, etc.;

–technology of cartographic and navigation systems with technological solutions of the form: GPS/GLONASS (GLObalNAvigation Satellite System) receivers, SLAM algorithms, HD 3D mapping services, etc.;

–modular connection technologies with technological solutions of the form: telematic terminals, V2V-, V2I-, V2X-modules, SIM cards, etc.;

2. Data analysis and decision making is based on:

– software algorithm mization technology with technological solutions of the type: vision algorithms, vehicle operating systems, etc.

– processor technologies with technological solutions of the form: ECU/MCU controllers, etc.;

3. Execution and control is based on:

– technology of execution units (drives) with technological solutions of the form: drive systems, execution algorithms, etc.

2. LITERATURE REVIEW

Currently, most of the leading developers of ADAS systems use an integrated approach, using the combined data of three main types of sensors at once: radars, lidars and cameras. This ensures that ADAS systems are provided with data in the required range, resolution, and accuracy. In addition to the above sensors, modern ADAS systems use data from satellite navigation systems, and highly automated and fully autonomous systems also use High Definition Maps, HD Maps, which automakers and manufacturers have been actively working on in recent year's technological giants.

In addition, the use of the above technologies in conjunction with Connected Car modules allows you to send and receive all types of data in order to improve safety, optimize city traffic and save fuel. The active development of 5G technologies and multi-profile SIM cards as part of V2X communication systems will significantly increase the level of safety for drivers, passengers and pedestrians reduce fuel consumption and travel time.

Currently, in terms of developing special software for cars equipped with ADAS systems, a lot of attention is paid to data transmission channels and the development of special platforms that provide data collection for connected cars.

The most common and developed ADAS systems include the following solutions: Adaptive Cruise Control (ACC); Adaptive Front Lights (AFL); Driver Monitoring Systems (DMS); Night Vision System (NVS); Intelligent Park Assist (IPA); Pedestrian Detection System (PDS;Traffic Jam Assist (TJA); Collision Avoidance Systems (CAS; Cross Traffic Alert (CTA); Road Sign Recognition (RSR); Lane Departure Warning (LDW); Automatic Emergency Braking (AEB); Blind Spot Detection (BSD).

To ensure correct operation of the ADAS system, input data from several sources is used, including LiDAR, Radar, external cameras, imaging systems, ultrasound and computer vision.

New ADAS systems can also use real-time data from external vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2X) systems (eg, mobile telephony or Wi-Fi).

Fig. 1 schematically shows the key technological components of modern systems such as ADAS [4].

Even though this driving automation only works under certain conditions (highway driving), it is sufficient for the ACC to be assigned the first level of automation.

Thus, according to the standard of the community of automotive engineers (Society of Automotive Engineers – SAE) SAE J3016 2018 [5] and the proposals of the National Highway Traffic Safety Administration (NHTSA) [6] systems of 1-3 levels of automation are Systems like ADAS, which may allow autonomous driving under certain conditions, however, require constant driver supervision and a willingness to take on the task of dynamic vehicle control.

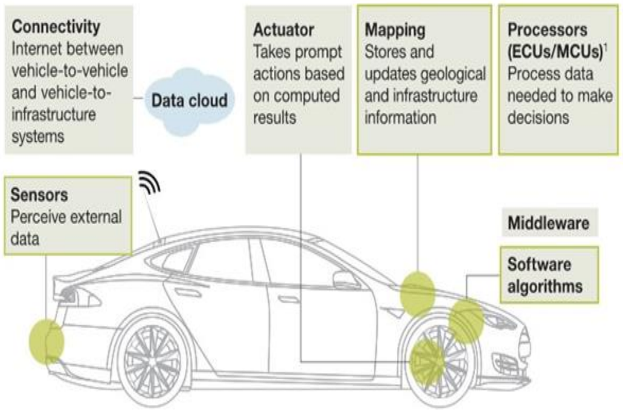

*Fig. 1.***Main typical components of ADAS systems**

***Source:* compiled by the author**

Thus, the main distinguishing characteristic of the third level systems is the time allotted by the system to the driver to take control of the dynamic control if necessary.

With ADAS systems, levels 4-5 allow the vehicle to be controlled by an automatic control system (provided that the driver fully controls it and, if necessary, intervenes in the control process) and even if the driver intervenes in the control process. ADAS systems of the 6th level imply full automation, that is, the complete control of the vehicle is carried out by the automatic control system. [7]. If the ADAS system can perform fully autonomous control of the vehicle, but only within limited areas, then this system can be classified into the upper (4-6) levels of automation, depending on the applied automation level classification standard. [7].

Thus, systems such as ADAS (Advanced Driver Assistance Systems) can be defined as a combination of intelligent systems built into a car that are aimed at ensuring road safety, automating and improving driving comfort, as well as increasing the throughput of road networks [7].

Advanced Driver Assistance Systems is just a generic term, which usually means a whole set of individual technological solutions – small autonomous systems that can be divided into the following groups:

– information and communication systems: rain sensors, tire pressure monitoring systems, etc.

– driving environment recognition systems: car night vision systems, traffic sign recognition systems, etc.

– driver assistance systems: lane change assistance systems, hill start assistance systems, etc.

– safety systems (active and passive): collision avoidance systems, pedestrian protection systems, etc.

– vehicle control systems: adaptive cruise control, lane keeping systems, etc.

Thus, in general terms, the ADAS system is [8], a set of various subsystems for automating the processes of driving a car, which can be represented in general terms (Fig. 2).

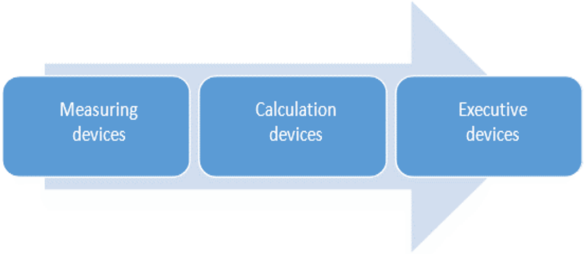

*Fig. 2.***The structure of the control system of an unmanned vehicle**

***Source:* compiled by the author**

As you can see from Fig. 2, functionally, the control system of an unmanned vehicle can be divided into two parts:

– the first part is responsible for the collection and formation of a digital information array, in order to develop a control action.

– the second part is functionally responsible for the transfer of the control action to the actuators.

This statement can be represented in the form of a functional diagram of the on-board vehicle control system (Fig. 3).

In this functional diagram, the key structural and functional component is the control device that receives information from information-measuring devices with its subsequent processing and development of a control action.

As a rule, the process of processing information coming from information-measuring devices ultimately comes down to the formation, on the one hand, of a high-quality picture of environmental objects, road marking elements, road signs, road infrastructure objects, road users, etc.

On the other hand, assessing the parameters of the state of the car as a whole its systems and mechanisms in particular.

Thus, to solve the problem of autonomous driving, starting from the fourth level of automation, the key task is the task of generating and processing an input multi-sensor information array with a given degree of quality under a priori uncertainty about information about the input multi-sensor information array.

3. RESEARCH METHODOLOGY

The purpose of the work is to develop a structural model of an adaptive information-control system of a car with multi-sensor channels of information interaction, as a subsystem of a control device in a model version of the design of an adaptive mobile robotic complex.

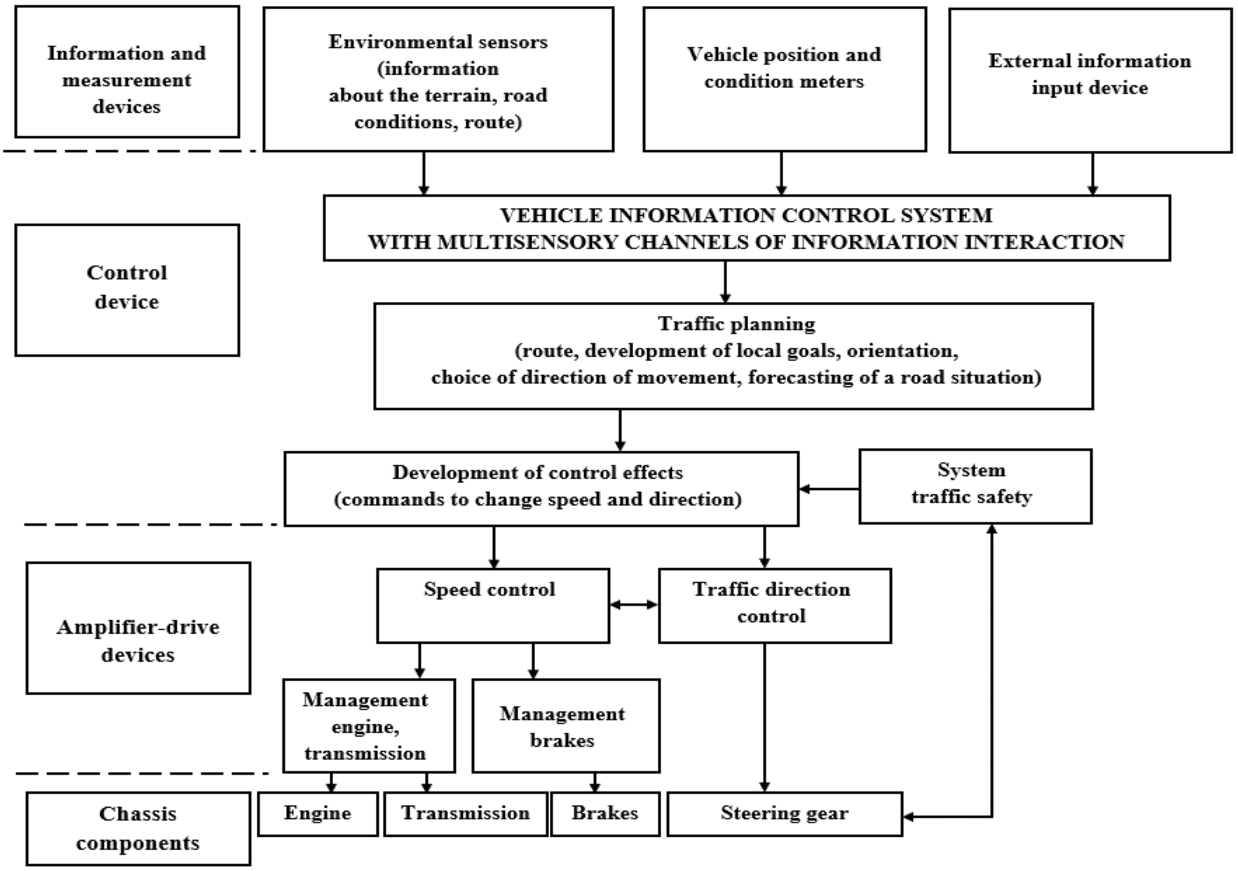

*Fig. 3.***Functional diagram of the onboard control system**

***Source:* compiled by the author**

An adaptive information-and management system of a car with multi-sensor channels of information interaction in the general case should provide a solution to a number of subtasks:

1) perception (registration) of primary information – the original image;

2) formation of a situation model based on primary visual information for further processing (analogue picture model, digital model, etc.);

3) search for objects;

4) classification of objects;

5) determining the location of objects in the working area;

6) determination of the orientation of objects in space or on a plane;

7) measurement of the characteristic parameters of an object or a set of objects (number of objects, geometric dimensions, area, color, etc.).

The task of forming and processing an input multi-sensor information digital array assumes the presence of a priori information about all the constituent components of the process of its processing:

1) information about the input image;

2) characteristics of the transfer function of the imaging system;

3) the observed image.

As a rule, information about the observed image is available to the developer, that is, Y is available in the formation of an array of samples of the observed image:

$$Y(m,1) = H(m,n) \cdot X(n,1) + Z(m,1), \quad (1)$$

and the transfer characteristic of the imaging system and the input image are unknown, that is, H and X are not available in the operator equation (2).

Formation of an array of samples of the restored image:

$$\hat{X}(n,1) = W(n,m) \cdot Y(m,1). \quad (2)$$

Elimination of a priori uncertainty about information about the input image is possible by supplying a test image to the input of the system, for example X_o.

In this case, it remains to solve the problem of determining the transfer characteristic of the system.

One of the ways to solve this problem is the possibility of forming an estimate $\hat{H}$ of a priori unknown distortion operator.

The formation of the evaluation matrix of the deformation operator belongs to the class of problems of system identification, when we have input and output signals at our disposal, and the transfer function of the system is unknown.

As is known, the problem of system identification can be solved by inverse or direct modeling.

For the variant of the adaptive information-control system of a car with multi-sensor channels of information interaction with an external standard, the elimination of a priori uncertainty is possible by forming an estimate of the system's impulse response matrix using the inverse modeling method.

The structure of the system for estimating the matrix of the deformation operator by the inverse modeling method is shown in Fig. 4.

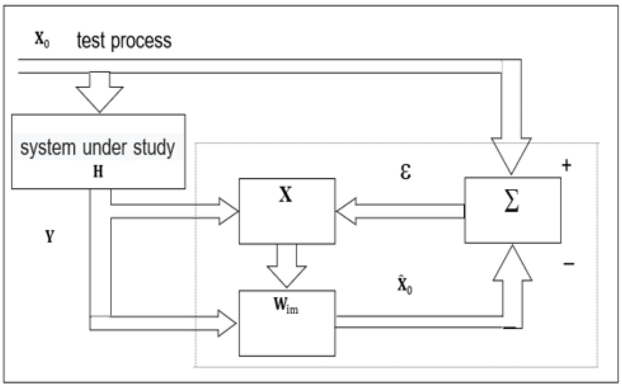

Fig 4. **Estimation of the distortion operator matrix by inverse modeling**
Source: **compiled by the author**

Here, the estimate $\hat{X}_o$ of the unknown test process X_o is formed in the subspace Y of the processes observed at the output of the system, which is investigated in accordance with the principle of orthogonal projections [8, 9]. A graphical interpretation of the feedback evaluation process is shown in Fig. 5.

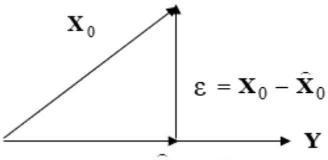

Fig. 5. **Formation of the inverse estimate $\hat{Y}$ of the observed image Y in accordance with the orthogonal projection theorem**
Source: **compiled by the author**

Let us define an expression for estimating the matrix of the distortion operator based on the orthogonal projection theorem from the observed image

$$\left(X_0 - \hat{X}_0\right)Y^T = 0. \quad (3)$$

In this case, the estimate of the original image can be described as

$$\hat{X}_0 = W_{\text{im}}Y. \quad (4)$$

Here the restoration operator is generated by inverse modeling

$$W_{\text{im}} = (X_0Y^T)(YY^T)^{-1} = \{\text{при }\ Y = HX_0\} =$$

$$(X_0X_0^T)HH^{-1}(X_0X_0^T)^{-1}H^{-1} = \hat{H}^{-1}. \quad (5)$$

The disadvantage of this method is the need to invert the matrix of observed processes$(YY^T)^{-1}$,which, with an unknown transfer characteristic of the distortion operator $H$of the system under study, will be degenerate.In this case, a solution to system (2) may not exist.

For a variant of an adaptive information-control system of a car with multi-sensor channels of information interaction with an internal standard, the elimination of a priori uncertainty is possible by forming an estimate of the system's impulse response matrix by the direct modeling method – the direct method.

The method of direct modeling is based on the possibility of determining the direct evaluation matrix of the distortion operator. In this case, there is no need for an inversion procedure in the process of forming the evaluation matrix. This is an advantage of the considered method over the inverse modeling method.

The difference between the implementation of the direct modeling method and the inverse modeling method lies in the place of inclusion of the system H under study at the output of the structure for forming its assessment (Fig. 6).

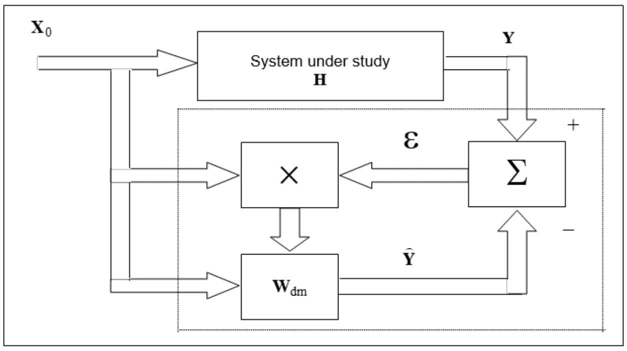

Fig. 6. **Estimation of the distortion operator matrix by direct modeling**
Source: **compiled by the author**

The direct modeling method allows one to form an estimate $\hat{Y}$ of the observed image Y in the subspace of test signals X_0 in accordance with the orthogonal projection theorem [8, 9].

Graphical interpretation of the direct modeling method is shown in Fig. 7.

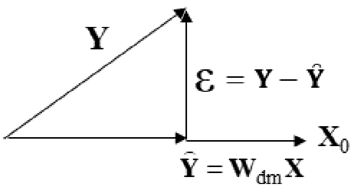

Fig. 7. **Formation of a direct estimate $\hat{Y}$ of the observed image$Y$ in accordance with the orthogonal projection theorem**
***Source:* compiled by the author**

In this case, the matrix of test images $(X_0X_0^T)^{-1}$ is subject to inversion, which can be given a diagonal form in advance.

The absence of the need to invert the matrix of observed images $(YY^T)^{-1}$ in the direct modeling method avoids the situation when it is necessary to invert the ill-conditioned matrix $(YY^T)^{-1}$. In this case, the direct evaluation matrix $\hat{H}$ of the deformation operator is rather simply formed.

Let us write an equation for estimating the matrix of the deformation operator based on the orthogonal projection theorem through the observed image

$$\left(Y-\hat{Y}\right)X_0^T = 0. \qquad (6)$$

Here, the estimate of the observed image has the form

$$\hat{Y} = W_{\mathrm{dm}}X_0, \qquad (7)$$

and the restoration operator is formed by direct modeling

$$W_{\mathrm{dm}} = (YX_0^T)(X_0X_0^T)^{-1} = \hat{H}, \qquad (8)$$

where $Y = HX_0 = H(X_0X_0^T)(X_0X_0^T)^{-1}$.

In the formed direct estimate W_{dm} of the deformation operator, measures can be taken to improve its computational stability.

In this case, a solution to system (2) will always exist, and the accuracy of the solution will depend on the accuracy of the direct estimate.

Thus, based on the approach proposed above to solving the problem of system identification, in an adaptive information-controlsystem of a car with multi-sensor channels of information interaction, three situations of its solution are possible [3,12], [13,14], [15,16], [17,18].

4. EXPERIMENTALRESULTS

Considering a car with the fourth and higher levels of automation, it can be argued that in this case the car can be represented as a robotic technical complex (RTC) operating under conditions of destabilizing factors. The presence of these factors creates a priori uncertainty about the input information array in the adaptive information-controlsystem of a car with multi-sensor channels of information interaction. At the same time, this system is a structural and functional element of the RTC, as a vehicle with a high level of automation.

The methods proposed above for eliminating a priori uncertainty and the possible situations proposed above for solving the problem of identifying systems are subject to the global efficiency criterion [10].

$$J_G \equiv J_0 = \underbrace{extr}_{\omega\in\Omega} J_0\{G, W, X, \xi(t), F_\Xi\,[X, \omega(U), W_{c\Xi}(U), C_\Xi(U)]\}.. \qquad (9)$$

The operator form (9) reflects the hierarchicalcore of the adaptive RTC model with a control channel, for which the algorithms for processing information and hardware and software for their implementation are understood. The block configuration of this model is approved by modular elements, as they are recognized by the global efficiency criterion (goal function). For the logic of the combined model, it is best positioned with the scheme, which is shown in Fig. 8.

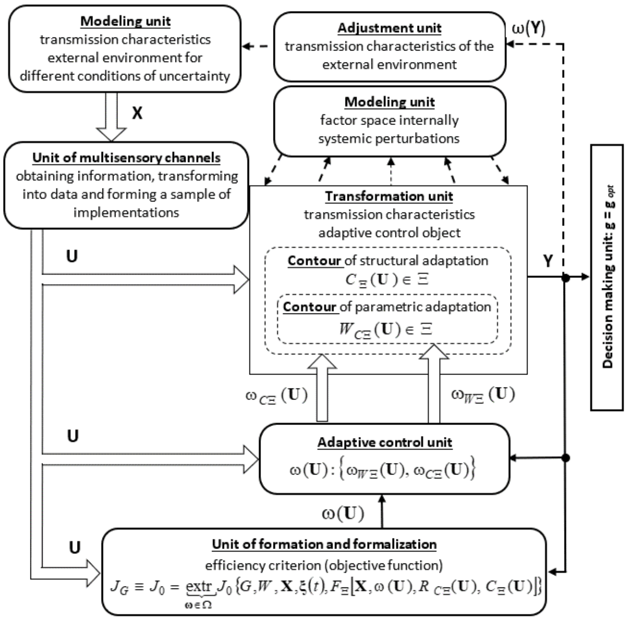

Fig.8. **Block diagram of the model of the adaptive robotic complex**
***Source:* compiled by the author**

In the presented block diagram, adaptation, as a specific process of situation management, is modeled in several aspects of practical implementation.

First, situation management is seen as a purposeful process of environmental impact. In this aspect, the adaptation is presented as a means: achieving a given target function (the link is represented by a solid line). This definition is postulated on the understanding that adaptation is adequate to optimization in conditions of external and internal systemic uncertainties. Moreover, for the interval of observation $T \to \infty$ and the invariance of the properties of the object Ξ and the environment, there is an equality of $J_G = \tilde{J}_G$ and to solve the problem of adaptation it is permissible to use optimization methods. Unacceptable time costs can be reduced by reducing the observation base $U(t)$. However, this will reduce the efficiency of each iteration step, as the $\tilde{J}_G$ estimate becomes very rough.

Decreased efficiency of adaptation is compensated by its efficiency: compensation for adverse changes in the environment that violate the target conditions (the link is shown by a dotted line). This statement is based on the formal differences between adaptation and compensation procedures for information sources for the control device. In the compensation process, the source information for the $\omega(U)$ control synthesis is the state X of the medium, and in the adaptation process, the $\omega(U)$ control rule is synthesized based on the Y state information. In contrast to compensation, in adaptation algorithms the problem of functional optimization (9) is solved by “noisy” implementations and unknown structure of functional. This procedural property of adaptation made it possible to choose a formal apparatus for describing the criterion of efficiency $J_G$in its relationship with the definition of the function of adaptive control $\omega(U)$ and the development of requirements for this function.

Secondly, the adaptation factor is modeled as an archeological process $\omega(U) \in \Omega$of improving the performance of the ground-based RTC in the optimal state independently from the impacts of any external and internal alarms. With what physical design of the ground-based RTC imposes on the control process the power of $\omega(U)$: $\{\omega_{W\Xi}(U), \omega_{C\Xi}(U)\}$
Decomposition of the $\omega(U)$ control factor on the structural $\omega_{C\Xi}(U)$ and parametric $\omega_W(U)$ processes allows more efficient implementation of the task of adapting the RTC, no matter how foldable. For such a point, the gap changes in the course of adaptation are manually set up for help, as the parametric vector $W_{C\Xi} = W_{C\Xi}(U)$ of the robotization object Ξ is parametric adaptation, and the second structure $C_\Xi = C_\Xi(U)$ is structural adaptation [11].Moreover, on the upper level of the archeological structure of the RTC, the structure C_Ξ is adapted, and on the lower level, the parameters of the $W_{C\Xi}$ center structure are adapted.

In the given model variant of the ground-based RTC, adaptation is organized in the form of a double-loop control loop (Fig. 9). The skin contour works in different clock modes: the rate of parametric adaptation is significantly higher than the rate of structural. Indeed, the whole cycle of parametric adaptation falls on the skin of the structural changes of the object, otherwise the effectiveness of the implemented structure will not appear. The choice of the optimal structure of the parametric vector $\{C_{\Xi opt}, W_{\Xi opt}\}$ extremizes the criterion indicator of efficiency J_G regardless of the situation.

Thirdly, the factor of adaptive control seems to be an algorithmic process of functioning of a ground-based RTC in the “real” minds of the medium, if the information sounds like a hundred percent of the model of technological interaction. In this way, the optimization problem (9) diverges along the path of a parametric vector $W(U) = W_{C\Xi}(U)$ and the structure of the robotic object Ξ behind the results of warnings $U \equiv D_X X$. Here - $D_X = D_{X(m \times k)}$rectangular$(m \times k)$– dimensional matrix of transfer functions of a system of independent multisensor. Conversion of the measured values X of the medium into the form Uallows us to formulate the criterion of efficiency J_G (set the objective function) in terms of the parameters of the electromagnetic fields, which are related to the measured values, but not identical to them.

Summarizing the above, it should be noted the key importance of this model for the synthesis of the control process $\omega(U)$, both at the stage of optimal design and during adaptation. Indeed, one problem (9) is solved, but with different source information. With optimal design, the $J_G(\bullet)$functional should be calculated, and in adaptation processes it is possible to limit oneself to estimating $\tilde{J}_G(\bullet) = J_0(\bullet)$instantaneous values. This fact simplifies the model version of the adaptive control system of terrestrial RTC.

The subject variant of the ground RTC design is represented by a model configuration of two main parts - the executive system and the control system.

Depending on the complexity of the problem to be solved, the level of uncertainty of the external environment and the given degree of autonomy, each of these systems may be influenced by different control loops. Fig. 9 shows a variant of the model of two-circuit control of the configuration of terrestrial adaptive RTC systems.

The executive system is designed for the delivery of special technological equipment and direct execution of tasks.

CONCLUSIONS

The subject configuration of the executive system is formed by the transport system, as a vehicle of the ground RTC, consists of a chassis, hull and power plant.

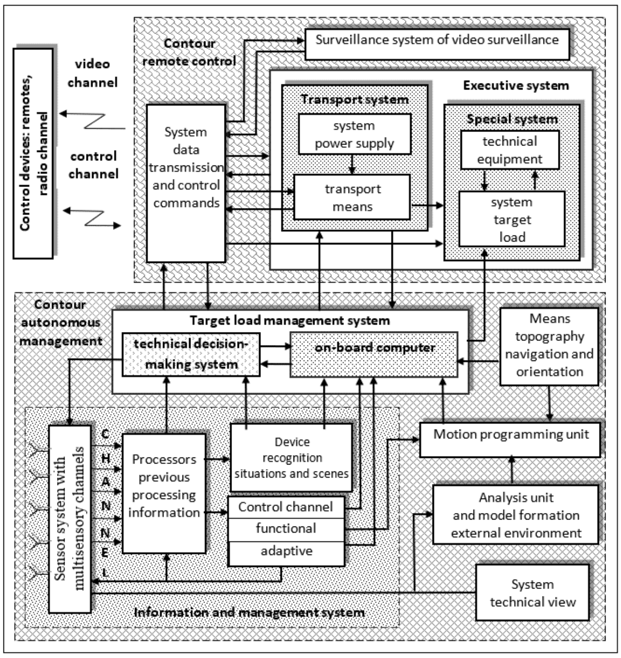

*Fig. 9.***Model design of adaptive robotic complex**
***Source:* compiled by the author**

The versatility of the vehicle design and the adaptability of the ground RTC engine ensure its confident movement in difficult operating conditions. Adaptive drivers of terrestrial RTC have the ability to change their parameters and structures independently or on the command of the control system based on current information on traffic conditions and achieve optimal condition in the initial uncertainty and variability of the situation.

The special system by the design consists of system of target loading and the necessary technological equipment which set is defined by a kind of the solved problem and purpose of ground RTC. In particular, a set of sensors and means of primary information processing in reconnaissance, manipulators and a set of interchangeable tools during technological tasks.

The ground RTC control system ensures the implementation of the specified technological process of interaction of the object with the environment. To do this, the RTC control system is designed so that it can:

– optimize the operation of algorithms for the operation of terrestrial RTC in conditions of situational (informational) uncertainty;

– guarantee the software movement of actuators and technological equipment of the RTC ground, as well as functional and adaptive control of the chassis and power supply system during the interaction of the RTC transport system with the operating environment;

– develop control actions on the drives of the vehicle, power plant and technological equipment of the ground RTC.

The model configuration of the control system presents:

– information-control system, which by its design combines the equipment of multisensory channels for obtaining primary information, processors for pre-processing information, device for recognizing scenes and situations, channels of functional and adaptive control;

– target load management system, which is based on technical decision-making system and central on-board computer, as well as separate modules of technical vision system, unit analysis and modeling of external and internal environment, as well as traffic programming;

– data transmission system and control commands, which is supplemented by mobile control panels, a set of transceiver equipment, a survey system of external video surveillance and more.

The research results make it possible to solve the problem of adaptive processing of an input **multisensory information array** with a given degree of accuracy under conditions of a **priori uncertainty**.

The problem of eliminating a priori uncertainty regarding the input information array is proposed to be solved on the basis of both direct and inverse modeling methods.

This approach made it possible to develop a model version of the design of an adaptive robotic complex based on an adaptive information-controlled system with multi-sensor channels of information interaction.

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Узагальнена модель адаптивної інформаційно-керованої системи автомобіля з різносенсорними каналамиінформаційної взаємодії

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АНОТАЦІЯ

Проведено аналіз існуючих технологій розробки та впровадження систем керування транспортними засобами на основі автоматизації їх функціональності відповідно до стандарту SocietyofAutomotiveEngineers J3016 та пропозицій Національного управління безпеки дорожнього руху США. Проведено класифікацію функціональності бортової інформаційно-керуючої системи транспортних засобів за типом AdvancedDriverAssistanceSystems. На основі проведеного аналізу запропоновано варіант структури адаптивної інформаційно-керованої системи автомобіля з мультисенсорними каналами інформаційної взаємодії. Запропоновано підходи до усунення апріорної невизначеності щодо інформації про вхідний мультисенсорний інформаційний масив в адаптивну інформаційну систему із зовнішніми та внутрішніми стандартами. На основі методів прямого та зворотного моделювання запропоновано підхід до вирішення класу задач ідентифікації системи, коли дослідник має вхідні та вихідні сигнали, а характеристики передачі системи невідомі. На основі прямих та обернених методів розв'язування задач ідентифікації системи розроблено структури формування прямої та оберненої оцінки оператора спотворення. Цей оператор матричного спотворення вхідного мультисенсорного інформаційного масиву в досліджуваній системі апріорі невідомий. Обґрунтовано аналітичні залежності формування прямої та оберненої оцінки оператора спотворення вхідного багатосенсорного інформаційного масиву в керованій системі з адаптивним принципом обробки інформації в умовах апріорної невизначеності. У даному дослідженні запропоновано структуру адаптивного робототехнічного комплексу з інформаційно-керованою системою керування транспортним засобом. Ця структура інваріантна до зовнішніх і внутрішніх дестабілізуючих впливів.

Ключові слова: інформаційно-керована система; автомобіль; адаптивна система; апріорна невизначеність; зображення; лідар; радар; стереокамера; інформаційний масив

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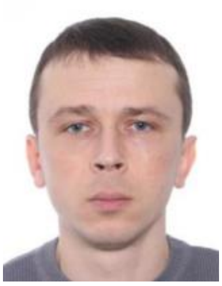

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