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Creation concept of objective control systems for traffic safety of vehicles

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Creation concept of objective control systems for traffic safety of vehicles

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Abstract. Traffic safety is one of the most important problems for modern society. The relevance of research aimed at creating effective means for monitoring the vehicle technical condition and driver condition is determined by the importance of improving traffic safety. The study aims to propose the scientific substantiation of the creation concept of objective control systems for traffic safety of vehicles. To conduct the study system analysis methods and modern control theory were used. The safe driving task is formulated as collision prevention with moving and stationary obstacles. A structured set of collisions contains all typical collisions and overturns caused by technical malfunctions, pavement condition and driving errors. The system creation concept assumes both the measurement and recording of the state vector, its dynamic boundaries and warning signals demonstration to the driver about approaching dangerous boundaries or exceeding them. Modern foreign and domestic objective control automotive systems were compared. System acquires intellectual properties by using mathematical models and algorithms for indirect measurements performed with a minimal quantity of primary information sensors. The research novelty consists in the scientific substantiation of building automobile systems for objective control based on virtual information sensors providing the solution of the dynamic stabilization problem in its most fully algorithmically resolved form.

1. Introduction

The road safety problem affects the vital interests of almost all members in modern society and it is characterized by a global level of significance.

To solve this problem, which is in the field of legislative and executive authorities view, various state and public organizations are constantly working. Leading foreign automakers are carrying out large-scale research in the field of active and passive safety. Some foreign manufacturers equip produced cars with standard systems of objective control and collision parameters registration during an accident [1]. Tachographs [2], DVRs [3] and other monitoring systems [4] have become widespread mean of checking vehicle operating conditions. For an objective assessment of the accidents conditions the usage of "black boxes" is predicted [5, 6, 7], they will automatically register the accident site [8] and call emergency services. Sets of parameters that should be recorded in order to obtain an adequate incident picture as well as the construction principles of the system are open for discussion.

The purpose of this study is scientific substantiation of construction concept for vehicle traffic safety objective control systems.

To determine the motion parameters vector a structured typical collisions set is used, which makes it possible to decompose the general collision avoidance problem into a group of particular problems and formulate the state variables dynamic stabilization problem [9].

In case of state variables dynamic stabilization problem it is proposed to use indirect measurements based on mathematical models and algorithms for solving ill-posed problems.

A comparative analysis is carried out to compare the intellectual level of information-measuring systems within three generations. The results of sensor properties and intelligent systems analysis show the objective advantages of virtual information sensors usage.

2. Problem statement

Automobile objective control systems (OCS) of vehicle traffic safety are intended as for analysis of vehicle movement parameters and driver actions in cases of an accident and for decision making informational support for the driver in the process of accident-free operation.

The collision avoidance problem is reduced to the problem of vehicle state variables dynamic stabilization in the form:

$$x_{i\,\mathrm{b}}^{L}(X,U,t) \le x_i(t) \le x_{i\,\mathrm{b}}^{H}(X,U,t), 1 \le i \le n \text{ at } U \in U_{per}, \text{ where} \quad (1)$$

$x_i(t)$, $1 \le i \le n$ – the i-th component of the state vector X;

$x_{i\,b}^{H}$ и $x_{i\,b}^{L}$ – higher and lower boundaries of the state vector X i-th component;
U – the control actions vector, including traction, brakes, steering wheel and gearbox;
U_{per} – the permissible range of control actions.

The components x_i of the state vector X and their boundaries are determined from the conditions for preventing typical collisions. The output x_i out of dynamic boundaries means the occurrence of prerequisites for at least one of the typical collisions in a structured set.

It should be noted that object state vector dynamic stabilization problem is one of the most complex control problem. Its solution complexity is caused both by the incomplete observability of the object and by the uncertainty of some dynamic boundaries. For the practical solution of such problems, operator participation in the control is required, who will complete the unobserved components of the state vector and estimate their dynamic boundaries.

The results of this problem solution are largely determined by the individual qualities of operators, the level of their training, accumulated experience, intuition and other hard-to-formalize properties.

3. Research results

Various schemes can be used to solve the problem of monitoring object state variables. The first generation of monitoring systems (Figure 1) arose in the in the 30s-40s of the XX century. They assumed the measurement of the state coordinates X_1 ... X_4 with the help of specialized information sensors S_1 … S_n, converting the measured physical quantities into the electrical signals parameters $y_i = f_i(x_i)$ with the subsequent inverse transform $\hat{x}_i = f_i^{-1}(\hat{y}_i)$ in the information display devices (IDD).

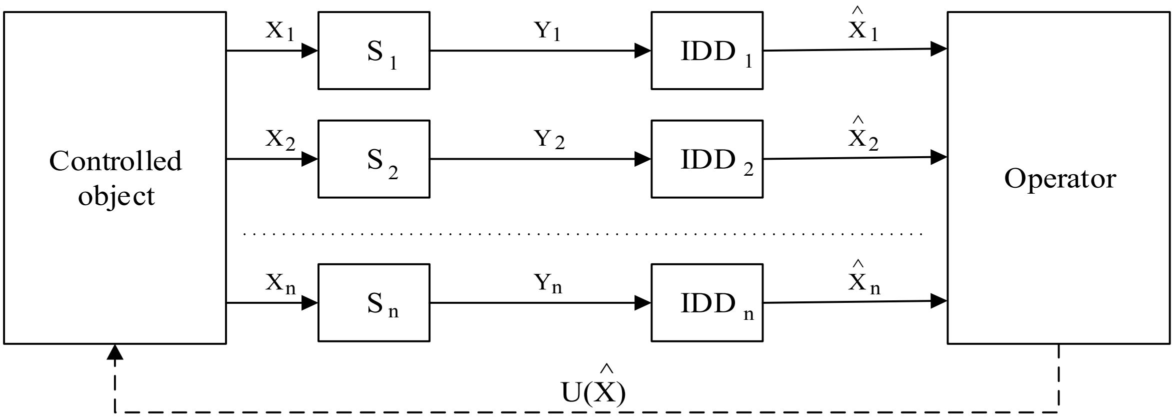

Figure 1. Scheme of the 1st generation system for object state monitoring.

First generation of monitoring systems had several shortcomings in particular the rigid requirements to the stability of direct and inverse transformations and the boundaries stationarity fixed on the IDD scales.

The second generation of monitoring systems (Figure 2) appeared in the 60s of the XX century. They implied the usage of a microcontroller unit (MCU) with software reverse transformation and the possibility of using dynamic boundaries. The disadvantage of such monitoring systems is a significant number of primary information sensors and communication cables, which worsen the majority of system indicators.

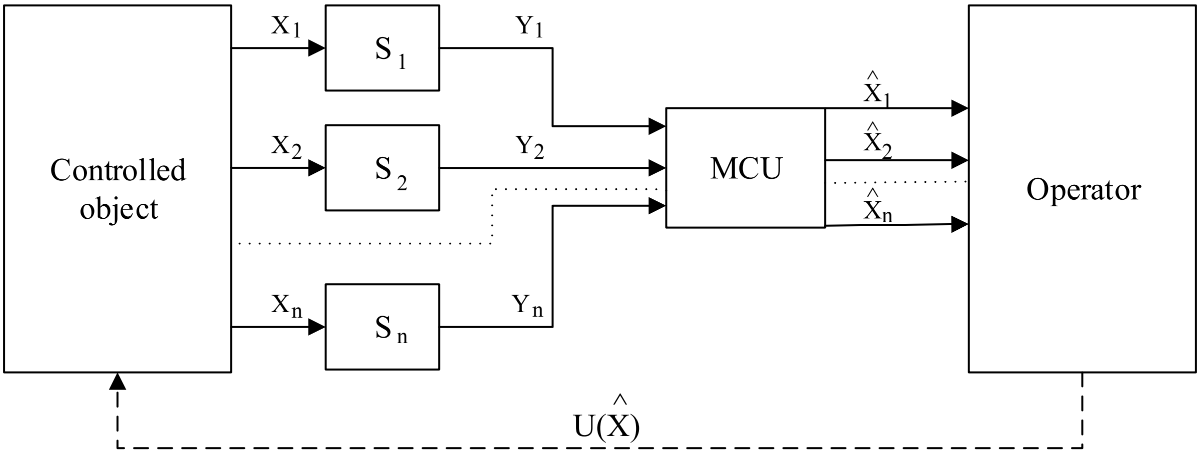

Figure 2. Scheme of the 2nd generation system for object state monitoring.

The third generation of monitoring systems (Figure 3) appeared at the beginning of the XXI century, it assumes the replacement of physical information sensors by virtual ones. Minimum configuration of technical means is used for their work, which is sufficient for indirect measurements of the state coordinates and their dynamic boundaries.

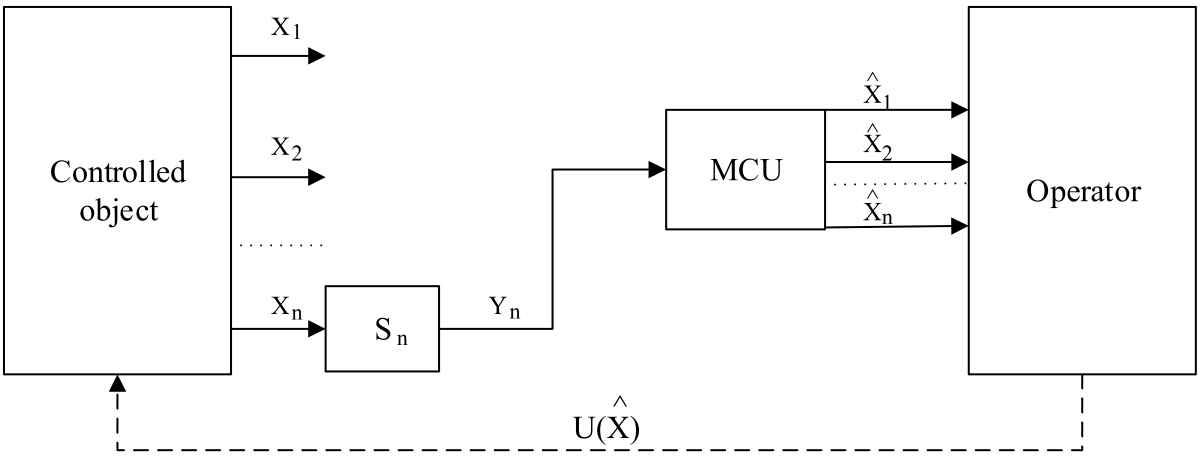

Figure 3. Scheme of the 3rd generation system for object state monitoring.

The intellectual level of the monitoring systems estimated by the ratio of the functions number to the number of required technical means. We found that for the first generation of monitoring systems the assessment of the intellectual level did not exceed 0.5, for the second generation it is around 1.0, and for the third generation it is $\gg 1$.

The conceptual core of the 1st and 2nd generation systems are physical sensors of information, which allows considering these systems as sensor systems. The conceptual core of the third generation systems is shifted to the field of mathematical support, which makes it possible to consider that they are intellectual systems.

Comparative characteristics of sensor and intelligent systems of objective control are given in Table 1.

Table 1. Characteristics of sensor and intelligent objective control systems.

№	Objective control system characteristics	Tachograph	Videorecorder	EDR	ERA "GLONASS"	Developed objective control systems
1	Registration of traffic rules violation	No	No	No	No	Provided
2	Warning about dangerous vehicle states	No	Sound warning about lane departure	No	No	Provided
3	Determination of vehicle location	No	Limited by the conditions of radio visibility	Limited by the conditions of radio visibility	Limited by the conditions of radio visibility	Provided for various conditions
4	Driver condition monitoring	No	No	No	No	Provided
5	Car control state monitoring	No	No	Provided	No	Provided
6	Wheels, suspension and steering condition monitoring	No	No	No	No	Provided
7	Monitoring of the vehicle position on the lane	No	Provided	No	No	Provided
8	Monitoring of the dangerous approach to the obstacle on the lane	No	Provided	No	No	Provided
9	Road pavement condition monitoring	No	No	No	No	Provided

Comparison of properties and characteristics of well-known foreign, domestic and developed systems shows that the main advantages inherent in intelligent systems are manifested in the consumer indicators and characterized by the stability of properties.

The predicted characteristics of the objective control system being developed are superior to those of known systems, some functions of this system are not available in known systems.

The video cameras usage together with the software image processing is necessary to determine distances to the nearest obstacle on the lane in the front and back hemispheres [10].

By processing images of video cameras, it is supposed to determine the speed of obstacles movement and the degree of controlled vehicle deviation from the center of the lane.

In this case, the problem of accident causes recording as well as vehicle state variables dynamic stabilization to which the collision avoidance problem reduces, solved both in real time and based on the results of an objective analysis of the driver's actions in the accident, acquires the property of solvability and determinism of state coordinates and their dynamic boundaries.

It should also be noted that the current traffic rules and penal system of their violations also reduces to an approximate solution to the simplified dynamic stabilization problem for the observed variable state (speed, position on the lane, technical malfunctions, crossing of road marking, turns, stops and parking, etc.).

The simplification of the dynamic stabilization problem in accordance with the algorithm determined by the traffic rules is the blurring of recommendations on the choice of safe speed, distances, decelerations, etc. Penalties for the detected violations are episodic, different from the time integration of penalty functions, characterizing the time during which the vehicle stays in dangerous state, when prerequisites for certain typical collisions remain.

Conceptual difficulties arises when the legislator tries to determine the term "dangerous driving".

The states variables exceed their dynamic boundaries in the time interval mean the existence of prerequisites for collisions and, accordingly, for accidents.

The identification of such intervals and certain variables corresponding to the type of possible collision is carried out by the OCS automatically and allows to evaluate the quality of control based on the results of the driver actions.

At present, none of the known designs of the OCS allows solving the "dangerous driving" identification problem.

In addition, the developed OCS basic design with the basic composition of technical means demonstrates state variables and their dynamic boundaries, as well as indicates their excess in real time for the driver. In comparison with foreign counterparts, it provides information support for decision-making by the driver to ensure driving safety.

4. Conclusion

The results analysis of the conducted studies allows us to formulate the following conclusions.

The trivial solution of the OCS creation problem is reduced to equipping the object with numerous sensors of physical variables that form the conceptual core of traditional sensor monitoring systems.

This direction, developed by leading foreign companies, inevitably leads to the deterioration of almost all system indicators, including the total cost, the cost of operation, installation, maintenance, consumed energy, influence on adjacent systems, fault tolerance, etc. and requires highly qualified service, possible only in the branded centers.

A non-trivial solution of the OCS creation problem with the usage of new technologies is consist in the utilizing of indirect measurements based on knowledge of the object in the form of formalized properties descriptions that form the conceptual core of intelligent systems.

It should be noted that many of the indirect measurements problems are initially incorrect and for the solution they need to be redefined by the properties of the object.

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