ABSTRACT

of the dissertation for the degree of «Doctor of Philosophy» (Ph.D.) in the educational program 8D07101 – «Automation and Control»

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INTELLIGENT VIDEO SURVEILLANCE SYSTEM FOR SAFETY SUPPORT

The relevance of the research. Video surveillance systems are widely used in the modern world. The tasks solved with the help of such systems affect many aspects of social life and are extremely relevant. The development of intelligent video surveillance systems has become a new challenge for supporting safety in various fields. The relevance of improving the safety of the population at work and in everyday life is obvious today. A special place is occupied by activities associated with increased danger in the case of monotonous, routine work, when a person ceases to adequately control the situation due to fatigue or distraction, for example, when guarding objects in front of security camera monitors, when the driver of a vehicle is driving for a long time, etc. The use of modern digital technologies in this field is a promising area of research. The results of the work are aimed at improving the safety of people engaged in monotonous activities in real time using neural networks. The study is intended for operational control of the employee's condition at jobs associated with increased danger (object security, vehicle driver, etc.), which is an urgent area of research.

The Republic of Kazakhstan has statistics on road accidents caused by various causes, but information on fatigue or drowsiness has been displayed in official sources only since 2023 and amounts to 34 registered cases, 4 accidents were detected in four months of 2024 according to the Committee on Legal Statistics and Special Records of the Prosecutor General's Office of the Republic of Kazakhstan. Moreover, it should be noted that these are only officially registered cases.

This dissertation research corresponds to the strategic directions of the concept of digital transformation, the development of the information and communication technologies and cybersecurity industry for 2023-2029. The research not only supports the global goals of digitalization and automation of processes, but also solves specific tasks related to security, cyber defense and sustainable development.

The relevance of the chosen direction to date is also confirmed by the words of President of Kazakhstan Kassym-Jomart Tokayev at an expanded government meeting on February 7, 2024 in Astana that digitalization of various industries and the introduction of artificial intelligence (AI) technologies will help to qualitatively change the situation in the economy of Kazakhstan. Moreover, AI, according to the president, can become «the driving force of economic progress and innovation in the country». The topic of the dissertation research corresponds to the priority direction of the development of science in the Republic of Kazakhstan - information, communication and space technologies, which since 2023 has been called advanced manufacturing, digital and space technologies.

The main idea of the work is to develop an affordable, reliable system for improving the safety of people engaged in monotonous activities in real time, and not creating obvious inconveniences for a person and not distracting from their main activities. The equipment used to assemble an automated installation should be inexpensive and freely available for the average resident of the Republic of Kazakhstan. In this dissertation, the work of a car driver is chosen as the main research area.

The object of the research is video surveillance control systems.

The subject of the research is an intelligent video surveillance system to ensure safety.

The research goal: develop software and hardware for an intelligent video surveillance system based on methods and algorithms for operational control of an employee's condition at work associated with increased danger.

To achieve this goal, the following research objectives were identified:

- to explore the problems and directions of development of modern automated driver support systems;
- to study existing models and methods for assessing the role of the human factor in ensuring safety;
- to develop a methodology for assessing the driver's condition based on an adapted method;
- to develop an adapted method based on video oculography;
- implement simulation of driver condition monitoring based on a theoretical and empirical approach, on a classical approach and using convolutional neural networks;
- to develop a block diagram of the software and hardware of an intelligent video surveillance system;
- to design an experimental installation of an automated video tracking system for a car driver using the proposed methods;
- to conduct an experimental study of the operability of the software and hardware of the system.

The main research methods. General scientific methods of cognition are used to solve the problems considered, as well as special research methods (mathematical modeling, field experiment: testing scanning techniques on model objects). Principles of automation of management of system and intellectual analysis.

Scientific statements submitted for protection:

1) an adapted method for analyzing eye movement based on video oculography and an adaptive algorithm in which the parameters for detecting eye movement are determined taking into account the characteristics of the processed data;

2) a video surveillance system for the human condition based on an original model combining different types of parameters, taking into account the fuzzy nature of the data, into a convolutional neural network;

3) the obtained results and conclusions of modeling and testing a new intelligent video surveillance system for ensuring safety using a convolutional neural network, taking into account the fuzzy nature of test and real data.

Scientific novelty of the work:

1) A new adapted method for analyzing eye movement based on video oculography and an adaptive algorithm has been developed, in which detection parameters are

determined taking into account the characteristics of the processed data. In addition to fixations and saccades, the algorithm also highlights glide paths and makes it possible to use combined data processing using several algorithms, depending on the conditions of image acquisition and the equipment used.

2) A video surveillance system for the human condition was first proposed, based on an original model combining different types of parameters, taking into account the fuzzy nature of the data, into a convolutional neural network.

3) The obtained results and conclusions of modeling and testing a new intelligent video surveillance system for ensuring safety using a convolutional neural network, taking into account the fuzzy nature of test and real data, which has an advantage in accuracy of approximately 95% of the correct definition of situations compared to existing analogues.

The appropriate application of the methodology of system analysis, general scientific methods of cognition and mathematical modeling, as well as the principles of automation and control, the theory of fuzzy sets and neural networks, including the implementation of the results obtained, are the basis for the **reliability and validity** of the formulated scientific statements, conclusions, results and recommendations.

Scientific and practical significance of the dissertation work.

The developed intelligent video surveillance system is a software and hardware installation that has passed production tests, which monitors the human condition while driving in order to increase safety, notifies about attenuation using light and sound signals, analyzes and predicts drowsiness and falling asleep at the wheel of a vehicle using a neural network.

The results of the work, such as the developed intelligent video surveillance system, a hardware and software installation for monitoring the human condition during routine monotonous activities and others, can be widely used on vehicles by drivers traveling long distances, as well as in an urban environment during long trips or with high fatigue, installation can also be easy It is adapted for the work of object tracking operators, security guards who carry out surveillance for a long time.

The software system received the author's certificate No. 38413 dated August 15, 2023. «Intelligent system for monitoring the condition of the car driver» (Appendix A).

The results of the dissertation work were put into the educational process of D. Serikbayev East Kazakhstan Technical University in the educational program for the preparation of doctoral and undergraduates «Automation and Control» for the disciplines «Fuzzy algorithms and control» and «Software for industrial controllers» (the act of implementation dated May 25, 2022 is given in appendix B).

Production tests of the assembled installation for monitoring the driver's condition to prevent dangerous situations, located at 102 Abaya Street, Semey city in the Vostok-Leader Driving School PC, were carried out. The tests were carried out on a specially equipped circuit simulating various road conditions, including straight sections, turns, various types of pavements, etc. The tests carried out have shown the operability of the installation. Testing period: March 2024.

The personal contribution of the author of the dissertation research consists in the independent formulation of the problem, the identification of the purpose and objectives of the research, the search and justification of opportunities and ways to solve

them, as well as the scientific and practical results obtained during the research, the analysis and generalization of the final conclusions are made personally by the author of the dissertation.

Approbation of the work. The main results of the dissertation work were discussed and reported at international conferences:

VI International Scientific and Technical Conference of students, undergraduates and young scientists «Creativity of young people for innovative development of Kazakhstan», (Ust-Kamenogorsk, Kazakhstan, 2020);

The traditional International Scientific and Practical Conference of Students, the XII conference dedicated to the 30th anniversary of Independence of the Republic of Kazakhstan: materials of the international student scientific practice. conf., March 19, 2021 /– Semey, 2021.-Volume II - 319 p.

16th International Symposium on Applied Informatics and Related Areas AIS 2021, Obuda University, Szekesfehervar, Hungary, pp. 88-92

XIV International Scientific and Practical Conference «Theoretical and science bases of actual tasks», April 12-15, 2022, Lisbon, Portugal

XV International Scientific and Practical Conference «Multidisciplinary academic notes. Science research and practice», April 19-22, 2022, Madrid, Spain

AIS 2022 17th International Symposium on Applied Informatics and Related Areas PROCEEDINGS Obuda University, Szekesfehervar, Hungary, p. 98.

Publications. 5 papers have been published on the topic of the dissertation, of which: 2 articles in journals reviewed by Scopus, 1 with a quartile on engineering and interdisciplinary works Q2 and a percentile 75, and 1 article in a journal with a quartile Q4 and a percentile 13; 3 articles in journals recommended by the Committee for Quality Assurance in the Field of the Ministry of Education of the Republic Kazakhstan, 6 in conferences of the near and far abroad and the Republic of Kazakhstan.

The structure and scope of the dissertation. The study consists of an introduction, three main sections, a conclusion, a list of used sources from 119 titles on 109 pages, including 2 tables, 69 figures, 5 appendices.

The first section of the dissertation presents the results of the analysis of automated driver support systems, which are aimed at improving road safety by minimizing the influence of the human factor. The description of the human factor as one of the key causes of accidents on the roads is presented. Modern problems and prospects for the development of automated driver support systems are described. The systems that monitor fatigue, concentration level and physical condition of the driver using sensors and data processing algorithms are considered.

The second section of the dissertation presents methods, algorithms and models used to develop automated driver support systems with an emphasis on monitoring his condition. A method for assessing the driver's condition is described, developed on the basis of an adapted method for specific tasks of monitoring the condition of drivers. The development of an adapted method using video oculography is presented, a technology that uses video to track the movement of the driver's eyes, which allows you to assess the concentration, fatigue and level of attention of the driver in real time. It also describes the process of developing an adaptive algorithm that is able to adapt to changes in the

driver's condition, adjusting its work depending on the dynamics of behavior and external factors. The results of modeling driver condition monitoring based on a theoretical and empirical approach and using convolutional neural networks (CNN) are also presented, which allows for higher accuracy in analyzing visual information and predicting driver behavior.

The third section describes the design process of an experimental installation of an intelligent video surveillance system for monitoring the driver's condition, including the development of software and hardware, as well as their testing. The structure of the system, including video surveillance cameras, sensors and computing devices, is considered.

At the conclusion of the dissertation work, the main results are shown, conclusions on dissertation research are drawn, thus the scientific novelty and practical significance of the study are confirmed.