ABSTARCT

of PhD thesis on "The methodology for reducing the impact of the human factor on flight safety" submitted for the degree of Doctor of Philosophy (PhD) on speciality - Aviation Engineering and Technology (6D071400) by Raziyam Kurvanzhanovna Anayatova

Relevance of the study.

It is generally recognized that safety of transport is one of the most urgent problems, and more than 80% occurs under the influence of the human factor.

The concept of "human factor" in civil aviation is extremely multifaceted and complex, and is associated with the problem of accidents, since it is the speed and correctness of human decision-making that determines people's life and health.

How acute this problem is in the aviation industry of the Republic of Kazakhstan can be judged at least from the sources on the analysis of flight safety, where it is indicated that the reasons in more than 90% of cases of aviation accidents were incorrect, including violations by the crews of the established rules for performing flights, in-flight decisions and poor-quality actions in the operation of aviation equipment, insufficient training of aviation specialists (pilots and air traffic controllers) in English, errors in piloting techniques, etc.

The analysis of works devoted to the present topic of research has revealed the existence of several solutions to the above problem by applying new methods of psychodiagnostics and training, increasing the responsibility of the person himself, his psychophysiological, psychological and behavioural capabilities.

However, the proposed solutions are not effective enough, since only professional training and compliance with some medical indicators are taken into account when admitting aviation personnel to the operation and maintenance of aviation equipment. At the same time, there is no external adequate assessment of moral and psychological qualities in the absence of perfect techniques for recognising emotional states.

The formulated problem and established conclusions formed the basis for theoretical research on the evaluation of statistical information of aviation accidents, on summarizing the achievements of the world aviation powers and domestic researchers in reducing the influence of the "human factor", on providing a highly efficient flight safety management system based on the application of artificial intelligence.

As a result, it has been found that a possible reduction of a human factor influence on flight safety can be achieved by applying two approaches. Firstly, by improving not only aviation English, but also plain English for pilots and dispatchers as well as for engineering and technical personnel and flight attendants; Secondly, by applying methods of psycho-emotional state recognition based on digital processing of speech signals and intelligent data analysis.

Thus, based on the current state of the problem, dissertation research aimed at developing a methodology to reduce the impact of the human factor on flight safety and aviation accidents is currently very important and relevant.

The aim of this thesis is to develop theoretical and methodological approaches, scientific and practical recommendations to improve the safety of flying on the basis of reducing the impact of the human factor, by creating and optimizing methods for digital processing and intelligent analysis of speech signals of phrasal verbs in aviation and plain English.

To achieve this goal, the following **tasks** are solved within the framework of the dissertation work:

1. Study of the psychological safety of workplace on production plant.

2. Research and analysis of the impact of the human factor (HF) on flight safety (FS), determination of human errors in aircraft maintenance and development of a safety system at aircraft enterprises based on the assessment and analysis of the risks of psychological safety of workplace.

3. Investigation of the possibility of assessing the psycho-emotional state (PES) of aviation personnel using fixed phraseological units of aviation and plain English.

4. Study of the processes and phenomena underlying the mechanism of speech formation. Study of the structure of a speech signal in the time and frequency domains. Analysis of the peculiarities of acoustic perception waves by the human hearing organs from the position of the theory of signals and systems.

5. Development of an integrated approach to intelligent automatic speaker-independent recognition of a person's emotional state by a speech signal when using aviation English.

6. Formation of a representative corpus of speech signals for seven archetypic types of PES in English, characterized by a variety of utterances used, the number of speakers presented, and the variability of the degree of PES manifestation.

7. Development of the structure and substantiation of the main stages of the preliminary digital processing of speech signals process (preprocessing) for the selection of informative features in automatic recognition of speaker's emotional state tasks.

8. Search and determination of the most informative signs of speech signals that can provide the maximum information increase in the emotional state classifying tasks of a person by voice.

9. Development and experimental study of intelligent algorithms for the classification of speech signals for automatic detection of PES without the need to recognize the semantic load of the analyzed statements.

10. Effectiveness evaluation of the developed algorithms and methods for intelligent analysis of speech signals in comparison with existing solutions for speaker-independent recognition of PES by a voice.

11. Development of a methodology that includes the rules for the formation of fixed phraseology, an integral technique and algorithm for reducing the impact of HF on flight safety based on aviation personnel psycho-emotional state recognition by a speech signal.

Research methods

To solve the problems posed in the dissertation research there were widely used such methods as analytical research and mathematical statistics, signals and systems theory, digital signal processing, spectral short-term, as well as correlation and probability-analysis method. Методы исследования

To build a mathematical model classifier, we used intelligent methods of pattern recognition based on machine learning algorithms, an apparatus for synthesizing deep convolutional neural networks, tools for computer and mathematical modeling, linear algebra, and a set of optimization methods. In the experimental part of the work there were actively used mathematical calculations automating means and results visualizing tools based on the Python 3 language programming.

The methodology was developed using the expertise and advice of leading civil aviation experts.

The subject of research focuses on PES recognition technologies to improve flight safety.

The object of the research is speech signals for the assessment of psycho-emotional state with issuing expert opinions.

Scientific novelty. The most significant new scientific results contained in the thesis are:

1. Justification of applicability of the approach to reducing the impact of PF on flight safety on the basis of recognizing PES of aviation personnel on the steady phraseological phrases of aviation English, which differs from the known ones in that it allows objectively, by informative parameters, to determine the levels of stress and fatigue, recognize depressed states, prevent fatigue.

2. A general process and methods of sequential digital pre-processing of speech signals have been developed and justified for the classification of emotional state of the speaker based on said signals.

3. Important informative features are proposed, as well as a method for extracting and presenting them for automatic classification of PES by voice signals using data mining methods.

4. A general approach to solving the problem of automatic classification of human PES on the basis of voice signals is proposed by the methods of intelligent information analysis.

5. A mathematical model of the PES classifier based on speech signal has been developed, which is based on the use of complex information from two deep convolutional neural networks trained on various informative features.

6. A comprehensive methodology is proposed for increasing flight safety by taking expert corrective actions based on emotional condition of aviation personnel assessments as pilots, dispatchers, engineers and flight attendants.

Practical relevance.

The practical significance of the work consists in the possibility of applying the results obtained in the study to build automatic systems for the aviation industry, allowing to perform recognition of the emotional state of a person by a speech signal.

This includes determining the level of stress and fatigue, recognizing depressive states, and keeping from tiredness.

The results of the presented study allow us to develop new effective decision support systems for human personnel, aimed at reducing the risk of errors and lowering attention.

The preprocessing structure proposed in the paper allows to effectively implement in practice the process of digital processing of speech signals for the subsequent application of intelligent methods of information processing.

The comprehensive approach to intelligent automatic PES recognition by speech signal presented in the thesis research can be applied in other spheres of human activities related to the operation of complex technical systems with man-machine interfaces.

The proposed intelligent system for the recognition of PES of aviation personnel, allows, among other things, to provide noise-resistant recognition of speech signals of complex form, to build up databases, to give various quantitative and qualitative characteristics.

Relationship with government programs

In the Address of the President of the Republic of Kazakhstan - the Nation Leader Nursultan Nazarbayev to the people of Kazakhstan "The Strategy "Kazakhstan-2050": the new political course of the established state" (Astana, Akorda, 2012) a special role is allocated to the development of transport and logistics potential. In this regard, this dissertation work is fully consistent with the formulated requirements for the modern direction of air transport development.

In the Message of the Head of the State "Constructive public dialogue is the basis of stability and prosperity of Kazakhstan" Astana, Akorda, 2019, to the people of Kazakhstan the President of the Republic of Kazakhstan Kassym-Zhomart Tokayev drew the attention of the executive power to the full and high-quality implementation of Infrastructure Development State Program "Nurly Zhol" for 2020 - 2025 years, approved by Government Decree of the Republic of Kazakhstan dated December 31, 2019 No. 1055. This strategic project states that effective modernization will affect the entire transport infrastructure.

State program "Digital Kazakhstan", approved by the Decree of Kazakhstan Government No. 827 dated December 12, 2017, implies accelerating the pace of economy development of the Republic of Kazakhstan and improving the quality of population life through the use of digital technologies in the medium term, as well as creating conditions for the transition of Kazakhstan economy to a fundamentally new trajectory of development, ensuring the creation of the digital economy of the future in the long term.

The proposed methodology for reducing the impact of HF on air safety and the intelligent voice PES recognition method are consistent with the aviation aviation concept for air safety and to meet the needs of the economy of the Republic of Kazakhstan, Individuals and entities in aviation services.

Scientific research presented in the dissertation work was carried out within the framework of grant financing of MES RK on the topic "AP08857126 -

Development of a complex of interactive training programs on technological processes of aircraft repair".

Thesis provisions to be defended:

1. A comprehensive approach to intelligent automatic recognition of PES by a speech signal to reduce the impact of HF on flight safety.

2. The process of speech signal preprocessing at the stage of extraction of informative features for automatic classification of human emotional state.

3. The method of using informative features and the form of their representation to build a model of multi-class classifier in the task of PES recognition by speech signal.

4. A mathematical model of a multiclass classifier for determining the emotional state of a speaker by his speech signal based on synthesized deep convolutional neural networks trained on various types of informative features.

5. Methods for reducing the impact of HF on flight safety based on the recognition of the emotional state of aviation personnel using steady phraseology of aviation English.

The approbation of results.

The results of the thesis research have been implemented in the training process of the Civil Aviation Academy and in the "Sunkar Air" LLP industry to improve flight safety, as well as taken into account in the development of the Strategic Development Plan of the company until 2025, which aims to improve the profiling technology based on artificial intelligence in the aviation security system.

The main results of the thesis are reported and discussed at: the XIV-International Scientific and Technical Conference "Dynamics of Systems, Mechanisms and Machines" (Omsk, Russia, 2020); VII-International Scientific and Practical Conference "Science and Education in the Modern World: Challenges of the 21st Century" (Nur-Sultan, Kazakhstan, 2020); International Scientific Conference "V International Scientific-Practical Conference "Integration of the Scientific Community to the Global Challenge so four Time" (Tokyo, Japan, 2020); IV-International scientific-practical conference "Scientific and technical aspects of innovative development of the transport complex" (Donetsk, Ukraine, 2018); International scientific-theoretical conference of students and young scientists "Rukhani zhangyru-the choice of the President, supported by the society" and the World Cosmonautics Day (Almaty, Kazakhstan, 2018); International scientific-theoretical conference of students and young scientists of the Civil Aviation Academy (Almaty, Kazakhstan, 2017); International conference "1st international pre-service teachers conference "Teaching and learning English in transition to tri-lingual education: research, challenges and success" (Shymkent, Kazakhstan, 2018); III International Scientific and Practical Youth Conference "Creative potential of youth in solving aerospace problems" (Baku, Azerbaijan, 2018).

Publications.

The main results of the dissertation research are reflected in 24 scientific papers, including 8 articles published in the editions recommended by the Committee for Quality Assurance in the Sphere of Education and Science of Ministry of Education and Science of the Republic of Kazakhstan, 3 articles are in

the international scientific journals indexed in the Scopus database, 8 papers reflected in the proceedings of international scientific conferences, 5 - in international and national scientific peer-reviewed journals, including specialized in the field of aviation technology and engineering.

The author's personal contribution.

The author independently obtained the main results of theoretical and experimental studies. In published scientific works as part of the team of co-authors, the applicant is the main contributor in receiving, summarizing and analysing the achieved results.

The structure of the thesis.

The dissertation has a classical structure: the introductory part, main part (four chapters), a conclusion, the list of cited references and applications. The work is presented on 120 pages of computer text, includes 36 figures, 10 tables and 130 titles of bibliographic sources.

The main research findings.

The thesis study provides a theoretical basis and proposes a solution to the current scientific problem of reducing the influence of the human factor (HF) on the safety of air transport system based on the application of artificial intelligence. As a result of statistical analysis of accidents and incidents the professional group of aviation personnel, insufficient level of knowledge of aviation or plain English, as well as their improper actions, is defined HF, which affect the flight safety. These are pilots, dispatchers, engineering staff and flight attendants.

According to the results of the study, it was found that there are certain characteristics of the behavior of aviation personnel, which are reflected in the speech signal.

A new approach to solving the problem of reducing the number of accidents and incidents by determining the psycho-emotional states (PES) of aviation personnel on the basis of speech signal recognition, as this characteristic is individual, easy to measure, and hardware and software implementation of analysis and processing has low cost and is applicable to a wide range of tasks.

Machine learning theory methods have been found to be an effective intellectual technology for automatically classifying PES by speech, as they allow the detection of hidden patterns in data, including some uncertainty. In order to create a representative set of educational data, an emotionally colored speech box was created for the seven classes in aviation and plain English, characterized by a diversity of narrators of both sexes spoken in a set of phrases, emotional color.

A new discrete model of speech formation is proposed for the selection of informative features in the preprocessing structure. The special procedures of digital signal processing for prefiltering and pause removal are proposed. This allowed establishing the features of the objects for training the mathematical model of the classifier, as they contain information about emotional coloration of speech.

The architecture of the deep-convolutional neural network (DCNN) and the algorithm of its training on selected informative attributes, allowing obtaining high

results of classification of PES of aviation personnel for seven classes of objects only by acoustic data of the studied samples were defined. To improve PES classification parameters, a method is proposed that combines the results of classification from two DCNN trained on different types of informative attributes as mel-spectrograms and mel-frequency cepstral coefficients. The result is an average of the probabilities that the test sample belongs to each of the seven PES classes, equal to 0.9007 in the deferred test sub-sample, which confirms the superiority of the proposed method of quality metrics over existing models.

The scientific-theoretical foundations of phraseology formation in radio communication for pilots and controllers, as well as standard phrases for engineering and technical personnel and flight attendants were proposed. This subsequently allowed proposing a new methodology to reduce the HF impact on flight safety on the basis of PES recognition by speech signal for aviation personnel by seven archetypal classes, including the following elements: rules of formation of fixed phraseological units and phrases, integral methodology and algorithm, intelligent system with the issuance of recommendations to experts.

An intelligent system has been developed that allows for additional noise-resistant recognition of speech signals of complex form, building up an information feature database, the ability to provide various quantitative and qualitative (linguistic) characteristics, intelligent scheduling etc.