

ABSTRACT

Thesis on the topic: "**Improvement of methods and means of processing speech signals based on the bionic method for voice control systems in emergency situations**" submitted for the degree of Doctor of Philosophy (PhD) in the specialty "6D071600 – Instrumentation engineering"

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Relevance of the work. Ensuring human communication with the information system is one of the highest priorities in the field of information technology. Currently, the use of voice control as an interaction interface has gained wide popularity in information-measuring and control systems (IMCS), especially in areas where the presence of a person is associated with a risk to his life and the use of robotic mechanisms is justified. Voice control is based on speech recognition technology, which is the processing of speech signals by filtering and suppressing noise, segmentation into informative sections in order to determine informative parameters reflecting the unique properties of speech.

The aim of the work is to improve the characteristics of dual-purpose voice control systems based on the bionic method for use in normal conditions and emergency situations.

Research objectives:

1. Critical analysis of the conditions for the use of dual-purpose voice control systems and existing methods and means of speech recognition and voice control.

2. Development of a new methodology for the construction of dual-purpose voice control systems, which makes it possible to increase the reliability of functioning on the basis of the bionic method.

3. Development of criteria and method of zoning to determine the zones of the territorial technosphere.

4. Development of a new technique for preprocessing speech commands, differing:

- the allocation of signal/pause segments in the speech signal with the determination of the boundaries and information parameters of phonemes in the flow of meaningful speech and the determination of the average duration of the sound;

- an improved algorithm for filtering non-stationary background noise based on the Hilbert-Huang transform and analysis of noise and energy characteristics of empirical modes (EM) to determine the mode containing the fundamental tone.

5. Development of a new technique for neural network analysis (NNA) of speech commands.

6. Development of a voice control system for robotic mechanisms.

Research methods. Methods of bionics, the theory of artificial neural networks, the theory of digital signal processing, and the theory of measurements are used to solve the tasks in the work.

The reliability of the results obtained is due to the consistency and completeness of the initial assumptions, the correct use of analytical and computational methods, the comparability of the results of theoretical research with experimental data and the practical implementation of the proposed methodology for analyzing speech commands as part of the voice control system layout.

The scientific novelty of the research consists in the following:

1. For the first time, an approach to the construction of a dual-purpose voice control system based on the bionic method in a complex signal-interference environment is proposed, which makes it possible to more reliably recognize the control commands of robotic mechanisms.

2. A new speech recognition algorithm has been developed, which differs duplication in the formation of a speech command and providing a more reliable functioning of the voice control system (at least 99%) compared to known algorithms.

3. A new method of zoning of the territorial technosphere according to the criterion of public health risk has been developed, characterized by the use of:

- heterogeneous group of unmanned aircraft to identify factors of negative impact on the objects of the territorial technosphere under normal conditions and minimize the consequences in emergency situations;

- geoinformation system for creating a dynamic map of the territorial technosphere and visual representation of the ecological situation on it.

4. A new technique for preprocessing speech commands has been developed, characterized by an improved algorithm for filtering non-stationary background noise based on the Hilbert-Huang transform and analysis of noise and energy characteristics of empirical modes to determine the mode containing the basic tone.

5. The structure of the LSTM neural network and the technique of neural network analysis of speech commands have been adapted, which, according to the results of an experimental study of a speech command, ensure the reliability of speech command recognition by 5% higher than that of known methods of speech signal analysis.

6. The structure of a dual-purpose voice control system based on the bionic method is proposed and justified, which implements new methods of analyzing speech signals and provides reliable (at least 99%) recognition of speech commands in a complex signal-interference environment.

The practical significance of the study is that:

1. The proposed methods of processing speech signals can be used in the construction of new voice control systems. The results of the dissertation research were partially implemented in the voice control system of mobile robot layouts. The results of the approbation at the Department of "Robotics and technical tools of automation" of Satbayev University indicate an increase in the reliability of the voice control system.

2. A new method of zoning the territorial technosphere based on the use of a heterogeneous group of unmanned aircraft and a geoinformation system identifies areas of the territorial technosphere with different intensity of phenomena and provides a tool for operational planning, organization and work on the territory of the technosphere.

3. The results of the dissertation research are used in the educational process of the Department of Robotics and Automation Equipment of Satbayev University.

Implementation and implementation of the results of the work. The prototype of the voice control system developed with the participation of the author of the work is used in the educational process of the Department of "Robotics and technical tools of automation" of Satbayev University and MedRemZavod Holding LLP has adopted the bionic method of creating voice control systems for controlling robotic actuators in the production process and design and research works.

The following are submitted for defense:

1. The proposed methods of processing speech signals can be used in the construction of new voice control systems. The results of the dissertation research were partially implemented in the voice control system of mobile robot layouts. The results of the approbation at the Department of "Robotics and technical tools of automation" of Satbayev University indicate an increase in the reliability of the voice control system.

2. A new method of zoning the territorial technosphere based on the use of a heterogeneous group of unmanned aircraft and a geoinformation system identifies areas of the territorial technosphere with different intensity of phenomena and provides a tool for operational planning, organization and work on the territory of the technosphere.

3. The results of the dissertation research are used in the educational process of the Department of Robotics and Automation Equipment of Satbayev University.

Personal contribution of the author. The main results submitted for defense were obtained by the author personally. The results published jointly with other authors belong to the authors in equal shares. The results of other authors, which are used in the presentation, contain links to relevant sources.

Approbation of research results.. The main results of the work were presented at 4 international and scientific and technical conferences and symposiums, including the International Scientific and Practical Conference "Satpayev Readings-2017" (Almaty 2017), the XVIII International Conference of Young Specialists on "Micro/Nanotechnology and Electronic Devices", EDM 2017, (Novosibirsk 2017); the XXI International Conference of Young Specialists on "Micro/Nanotechnology and Electronic Devices", EDM 2020, (Novosibirsk 2020); Ural Symposium "Biomedical Engineering, Radio Electronics and Information Technologies" (Yekaterinburg 2021).

Publications. The main provisions of the work are presented in 10 publications, including 1 article in the journal included in the Scopus database (percentile 26%), 3 articles in international conferences included in the Scopus database, 1 article in publications recommended by the Committee for Control in the Field of education and Science of the Ministry of Education and Science of the RK, 2 articles in journals included in the RSCI, 2 patents of the Russian Federation for invention, 1 article in other publications.

Structure and scope of work. The work consists of an introduction, three chapters, a conclusion, a list of references and nine appendices. The total volume of the work is 109 pages, the work contains 52 figures, 10 tables, a list of references, including 122 titles.