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В сборник вошли тезисы докладов и сообщений на английском, немецком и русском языках, сделанные на V Межвузовской конференции аспирантов, соискателей и молодых ученых «Наука, технологии и бизнес», состоявшейся 18–19 апреля 2023 г. Обсуждаются вопросы, связанные с научными исследованиями, проектно-конструкторскими и методическими разработками, экспериментальными работами в области биомедицинских и машиностроительных технологий, радиоэлектроники и лазерной техники, специального машиностроения, робототехники и автоматики, информатики, систем управления, инженерного бизнеса и менеджмента, а также прикладной лингвистики.

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**Электроника
и лазерная техника**

**Electronics
and Laser Technology**

УДК 535.14

Метод оценки эффективности мер защиты от атаки лазерного повреждения компонентов волоконно-оптических систем квантового распределения ключей

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Представлен новый метод оценки мер защиты от атак лазерного повреждения. Этот метод поможет разработчикам сделать систему квантового распределения ключей более безопасной. С помощью этого метода была исследована устойчивость волоконно-оптических аттенюаторов для использования их в волоконно-оптических системах квантового распределения ключей. Проведен анализ разработок контрмер от атаки лазерного повреждения разных компаний в области систем квантового распределения ключей.

Ключевые слова: система квантового распределения ключей, атаки, квантовое распределение ключей, лазерное повреждение, криптография

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Method for Evaluating the Effectiveness of Protection Measures against Laser Damage Attack of Fiber-Optical Quantum Key Distribution Systems

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This paper presents a new method for evaluating measures of protection against a laser damage attack to make the quantum key distribution system more secure for the developers. The resistance to laser damage attack of fiber optic attenuators in the quantum key distribution fiber-optic systems using this method is investigated. The authors have analysed countermeasure developments against laser damage attacks of various companies operating in the area of the quantum key distribution systems.

Keywords: quantum key distribution system, attack, quantum key distribution, laser damage, cryptography

Introduction

The quantum key distribution (QKD) system provides a fast and secure exchange of information between legitimate users guaranteed by the laws of quantum mechanics. However, designing QKD systems developers face physical imperfections of the equipment used, which can be exploited by an eavesdropper to compromise the security of the secret key. Currently, there are many studies that describe vulnerabilities of QKD systems and eavesdropper impact on them [1, 2].

Using powerful laser radiation an eavesdropper can create a vulnerability in QKD systems by changing the characteristics of optical components in their favor [3, 4]. This method of hacking is called a laser damage attack, which can lead to compromising the secret key.

Commercial QKD systems currently use pulsed coherent laser sources, the radiation of which is attenuated by fiber-optic attenuators to a quasi-single-photon state for further transmission over the quantum channel. The mean number of photons in the pulse corresponds to the protocol's safe value and is pre-calibrated. In the transmitter the fiber-optic attenuator is the last component before entering the quantum channel but for an eavesdropper it is the first component that can be attacked by powerful laser radiation. Under the action of laser radiation the attenuator changes its properties, and as a result, its attenuation coefficient decreases.

Therefore, in order to develop protection approaches a method for evaluating the effectiveness of protection measures against laser damage attacks on fiber-optic quantum key distribution systems has been developed.

Experimental setup and method

We have developed a method for evaluating the effectiveness of protection measures to assist in the development of QKD systems. Such an approach is a significant element of the research since only by evaluating the practical outcome of experiments QKD systems can

be created. We have simulated the change in the probability of two photons appearing in a pulse due to the changes in attenuation (P) and a mean photon number (MPN). The simulation plot is shown in Fig. 1a. This study will help developers identify the changing attenuation that could compromise the security of their system. By taking a slice of the MPN used in the QKD protocol, the threshold for the attenuation change can be determined, as shown in Fig. 1b. The plot shows an MPN equal to 0.5, which is the most common value in commercial QKD systems.

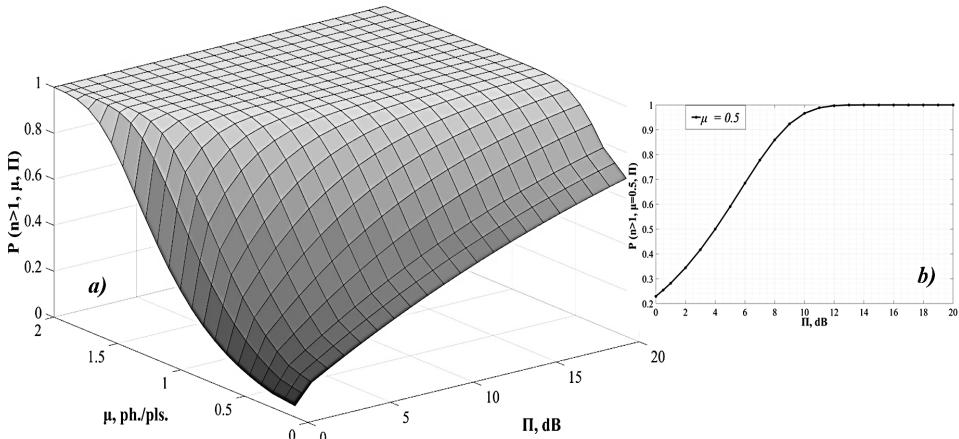


Fig. 1. The effect of the changing attenuation (Π) and the mean number of photons on the probability of the appearance of two photons in a pulse (a) and the effect of the changing attenuation (Π) on the probability of the appearance of two photons in a pulse at $\mu = 0.5$ (b)

We performed a series of tests aimed at testing the effectiveness of protection measures against laser attacks. Four types of widely available attenuators in telecommunications had been selected as objects of investigation. In these tests a laser damage attack was simulated, and measurements and analysis of the obtained results were performed.

Using the experimental setup shown in Fig. 2 we measure the attenuation of attenuators using the following principle: continuous laser radiation with a power of up to 5.5 W at a wavelength of 1561 nm (λ_1) is directed through a circulator to the device under test (DUT). As a result the absorption of the attenuator could increase, which in turn leads to the distortion of the single-photon state. To monitor the changes in DUT absorption in the experimental setup another continuous wave laser is installed at a wavelength of 1547.315 nm (λ_2). A powerful 90/10 splitter was used to control the laser power λ_2 (10 %) and the transmission of power to the DUT (90 %). The high-power circulator is used not only to deliver high-power continuous radiation to the DUT but also to transmit the power of the λ_2 laser to the measurement system after the DUT. The spectral filter is tuned to the λ_2 wavelength to cut off the radiation reflected from the powerful continuous λ_1 laser. Using this experimental setup the changing attenuation can be calculated as shown in Equation:

$$P_{i_i} = 10 \log \left(\frac{P_{m.PM1} - P_{m.ref}}{P_{m.st.PM1}} \right),$$

where $P_{m.st.PM1}$ is the value of the average power at the receiver $PM1$ before exposure to the powerful laser radiation on the component, W; $P_{m.ref}$ is the value of the average power

reflected from the sample, W; $P_{m,PMI}$ is the value of the average power at the receiver PM1 during the exposure to the powerful laser radiation on the component, W.

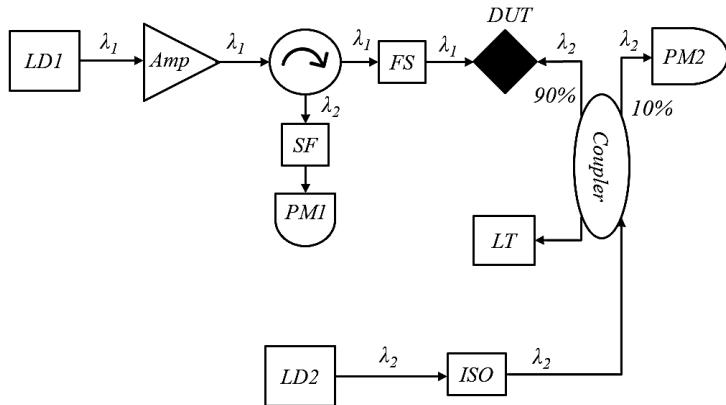


Fig. 2. The experimental setup, in which LD1 is 1 laser diode, Amp is Er-doped fiber amplifier, Circ is a fiber-optic circulator; FS is a fiber spool; Coupler is a 90/10 fiber optical coupler; PM1, PM2 are power meters; SF is a spectral filter; Att is an attenuator; ISO is a high-power fiber optical isolator; DUT is the device under test; LD2 is 2 laser diode; LT is a fiber optical light trap

Experimental results

We selected attenuators widely used in telecommunications including fixed attenuators in the form of a socket and a barrel to be tested. We have found that in some types of attenuators an eavesdropper could compromise the entire secret key.

The first type of the attenuator tested is a socket-type attenuator, which is most widely used in QKD systems and fiber-optic telecommunications.

Four samples of 10 dB attenuation have been tested in this research. The graph shown in Fig. 3 demonstrates that all four samples show a decrease in their attenuation. An eavesdropper could exploit this and the security of the optical communication system would be at risk.

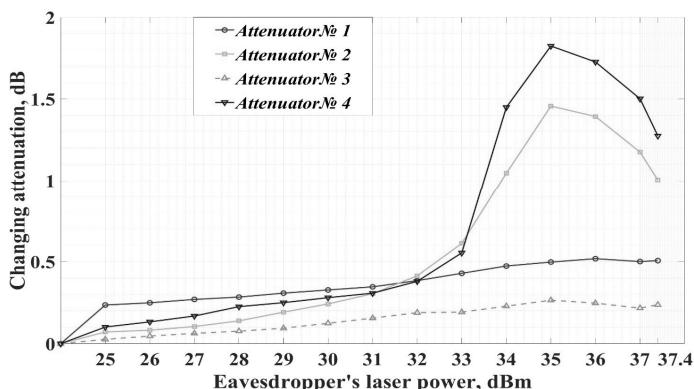


Fig. 3. The dependence of the changing attenuation (Π) on the eavesdropper's laser power

This may be due to the fact that the 10 dB attenuation rosette-type attenuator contains a metallic ring that can dissipate some of the heat from the connectors. Additionally, during the heating process of the metallic ring, thermal expansion may occur, which can lead to an increase in the internal diameter of the ring. As a result the attenuator decreases its attenuation coefficient.

In this study rosette-type attenuators with a 20 dB attenuation have been also tested using the method developed. As can be seen from the graphs shown in Fig. 4 this attenuator is resistant to the laser damage attack as during the testing process the attenuator only increased its attenuation. However, it should be noted that it is possible for the attenuator to decrease absorption when exposed to higher power.

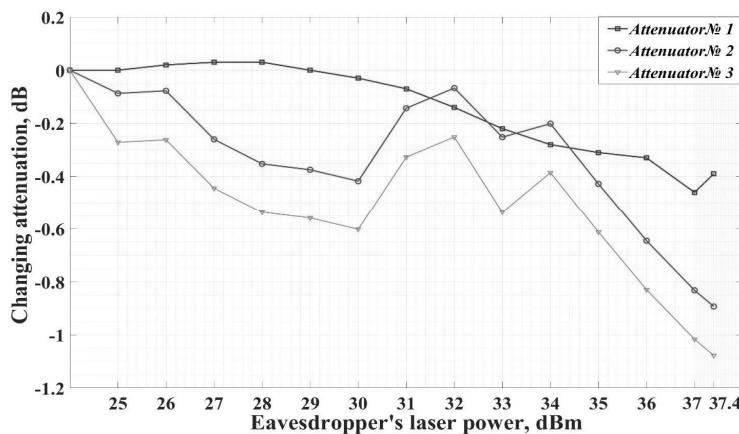


Fig. 4. The dependence of the changing attenuation (Π) on the eavesdropper's laser power

This can be explained by the fact that an optical contact is used to create the required attenuation in it. However, if the optical contact is unevenly heated, it can easily be destroyed. An increase in absorption can be observed on the graphs because the attenuator samples are heated. In addition, since the manufacturing technology of this attenuator involves decentration as a result of heating, diaphragmization will occur due to the change in the optical aperture of optical fibers.

The next type of attenuator investigated is a barrel-shaped attenuator with a 20 dB absorption.

Five samples of a 20 dB attenuator have been tested in this study. As shown on the graph in Fig. 5 all five samples exhibited changes in their attenuation. Four samples decrease their attenuation, which could be exploited by an attacker and compromise the security of such QKD system. Additionally, one sample experienced an irreversible increase in its attenuation when subjected to a power of 5.5 W, which could disrupt the communication between the transmitter and the receiver.

It is assumed that the attenuation change occurs due to the thermo-optical effect resulting from the heating of the attenuator under the influence of powerful laser radiation. In other words, the special absorbing filter in it became transparent when heated. During the experimental studies the attenuator samples are heated up to a maximum temperature of 135 °C.

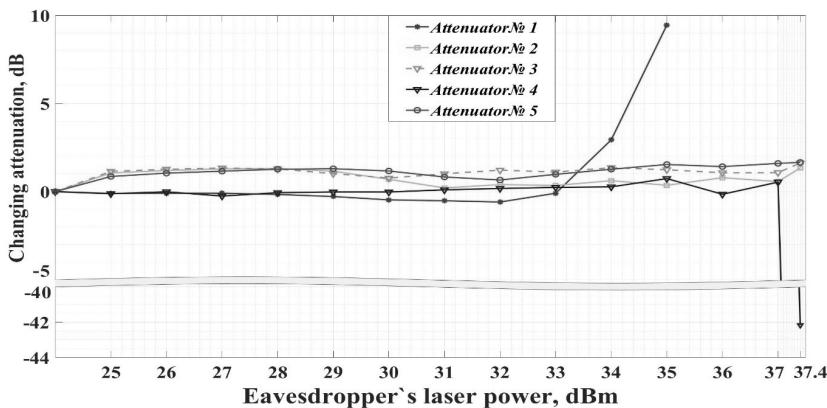


Fig. 5. The dependence of the changing attenuation (Π) on the eavesdropper's laser power

The results of this experimental study lead to the conclusion that a barrel-shaped attenuator with a 20 dB absorption cannot be used in quantum key distribution systems as it jeopardizes the security of such a system.

Conclusion

In conclusion, it can be noted that the quantum key distribution (QKD) system is considered one of the most secure methods for exchanging information between legitimate users. However, QKD system developers face physical imperfections in the equipment used, which can be exploited by an eavesdropper to compromise the security of the secret key. In particular, an eavesdropper may use the laser damage attack to modify the characteristics of the optical components of the QKD system. To evaluate the effectiveness of protection measures against such attacks on fiber-based QKD systems a unique method has been developed. The experimental tests have shown that in some types of attenuators an eavesdropper can compromise the entire secret key. Therefore, it is necessary to further strengthen the measures to protect QKD systems from such attacks.

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Перспективные кристаллы для преобразования частоты лазерного излучения в средний инфракрасный диапазон

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Исследованы перспективные кристаллы, которые можно использовать для преобразования частоты лазерного излучения в средний инфракрасный диапазон. Рассмотренные кристаллы проанализированы по различным критериям таким, как диапазон прозрачности, нелинейность, порог оптического повреждения и теплопроводность. Эти данные могут быть использованы для дальнейших исследований, основанных на применении среднего ИК-диапазона для выбора кристалла-преобразователя с требуемыми характеристиками.

Ключевые слова: средний инфракрасный диапазон, преобразование частоты, перспективные нелинейные кристаллы, халькогениды, нелинейные свойства

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Advanced Crystals for Converting Laser Radiation Frequency to a Mid-Infrared Range

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The paper reviews advanced crystals that can be used to convert the frequency of laser radiation to the mid-infrared range. The reviewed crystals are analyzed according to various criteria, such as a transparency region, nonlinearity, optical damage threshold, and thermal conductivity. This data can be used for further research based on the mid-infrared range for choosing a converter crystal with the required features.

Keywords: mid-infrared range, frequency conversion, advanced nonlinear crystals, chalcogenides, nonlinear properties

Introduction

The modern science and technology are developing rapidly. This leads to the need to search for new nonlinear optical materials to solve new problems. At present, many crystalline media are of interest for practical applications in the fields of nonlinear optics, quantum electronics, acoustic-optics, etc. In particular, it is impossible to imagine our life without lasers. Various types of optical frequency converters make it possible to convert the frequency of laser radiation into both short-wave and long-wave ranges. They also help us with frequency-tunable radiation. Thus, one of the most important areas of nonlinear optics is the search and study of promising nonlinear crystals for frequency conversion of solid-state lasers. Nonlinear optical devices that convert the radiation of the near infrared (IR) range of a solid-state laser ($1 \mu\text{m}$) directly into the mid-IR range are noteworthy. For example, the $8\dots14 \mu\text{m}$ range corresponding to one of the atmospheric transparency windows is used for lidars or countermeasure systems. Besides, coherent sources in the spectral range of strong absorption by water ($6\dots7 \mu\text{m}$) can be used in medical (surgical) applications. More generally, tunable mid-IR laser sources can be useful for spectroscopy or the detection of hazardous gases. Thus, mid-IR sources can be applied in many areas [1].

In modern optics, there are many nonlinear optical crystals. In recent decades, several non-linear oxide crystals have been grown. They largely meet the practical requirements in the UV and visible regions, such as KTiOPO_4 (KTP), LiNbO_3 , $\beta\text{-BaB}_2\text{O}_4$ (BBO) and LiB_3O_5 (LBO). Non-linear oxide-based compounds belonging to the ferroelectric crystal family are commercially available, but their IR transparency does not exceed 5 microns and therefore cannot be used for longer wavelength SIR applications. To generate the mid-infrared range, crystalline materials that have a quadratic non-linearity with a transparency range extending far into the infrared region of the spectrum are required. With regard to IR nonlinear optics crystals, the most used crystals are of the ABC_2 chalcopyrite structure type, including AgGaQ_2 ($\text{Q} = \text{S}, \text{Se}$) and ZnGeP_2 . However,

the use of highly non-linear phosphide crystals is limited to a relatively narrow transmission range due to their narrow band gap. This lead either to losses at the pump wavelength in the near IR range (1...2) μm due to one- and two-photon absorption in ZnGeP₂ and CdSiP₂, or to losses due to absorption at the idler wavelength of the mid-IR range of more than 6.5 μm in CdSiP₂ [2]. Gallium arsenide (GaAs) has also become useful for mid-infrared applications, since quasi-phase matching can be obtained in orientationally patterned GaAs. In addition, various oxide-free nonlinear optical IR crystals of selenides and sulfides with high second-order nonlinearity and transparency in a wide spectral range from the visible to the mid-IR range can be used for frequency conversion. These materials have the least two-photon absorption limitations at sharp focusing. Selenide and sulfide crystals have a wider band gap and a wider transmission range. These are lithium-based chalcogenide crystals such as LiGaS₂, LiGaSe₂, LiInS₂, LiInSe₂, and barium-based crystals such as BaGa₄S₇ and BaGa₄Se₇.

The AgGaS₂ (AGS) crystal and its non-linear optical properties have been studied since the early 1970s. They can be used for frequency conversion in the SIR range. In the article [3] authors report that the optical transparency of the crystal is in the range from 0.47 to 13 microns. The effective non-linear coefficient at a wavelength of 10,6 μm is 11...13 pm/V. Laser induced damage threshold (LIDT) at 1.064 μm is 0.2 J/cm². Nikoghosyan in his work indicates [4] that the thermal conductivity for AgGaS₂ is 1.4...1.5 W/(m · K).

Silver selenogallate (AgGaSe₂, AGSe) is an optically negative uniaxial crystal with a transparency range of about 0.7...18 μm . The effective non-linear coefficient at a wavelength of 10.6 μm is 38...41 pm/V. Laser induced damage threshold (LIDT) at 1.064 μm is 1.5 J/cm² [5]. The thermal conductivity for AgGaSe₂ is 1...1.1 W/(m·K) [4]. Unfortunately, this crystal, which is very promising in terms of nonlinear optical and technological parameters, does not have synchronism when pumped with radiation of about 1 μm .

GaSe is negative uniaxial with a wide transparency range of 0.62...18 μm . The features of this crystal are a high optical damage threshold of 3.5 J/cm² and a high coefficient of effective nonlinearity (54 pm/V) [3]. The thermal conductivity for GaSe is 2...16.2 W/(m · K) [4]. However, the main problem of GaSe is the layered structure and strong cleavage, tendency to chip along a plane perpendicular to (001), as well as weak (van der Waals) bonds and, as a result, plasticity of the material (Mohs hardness ≈ 0). Due to the brittle nature of GaSe, antireflection coatings cannot be applied.

In recent years, there has been increasing interest in the use of lithium-containing ternary chalcogenides belonging to the LiBC₂ family with B=In, Ga; C=S, Se, Te for nonlinear optics and semiconductor radiation detection. The property patterns of these compounds were systematized and analyzed in 1987. All members of this family, except for tellurides, crystallize in an orthorhombic wurtzite-type structure (space group Pna2₁). The typical spectral range covered by an optical parametric oscillator (OPO) based on LiBC₂ extends from 1.5 to 12 μm at 820 nm pumping, but recently Japanese researchers have also covered the terahertz range up to 700 μm [6].

The first crystals of this family (LiInS₂ and LiInSe₂) were obtained in 1973. The transparency range of LiInS₂ (LIS) and LiInSe₂ (LISe) crystals is 0.41...12 μm and 0.47...13.3 μm respectively. The effective non-linear coefficient is 7.5 pm/V and 12.5 pm/V. LIDT is 6 J/cm² for LIS and 5 J/cm² for LISe. The thermal conductivity is 6.2...7.6 W/(m·K) for LIS and 4.7...5.5 W/(m·K) for LISe [7–10].

The first LiGaSe₂ (LGSe) crystal was grown in 1981, while LiGaS₂ (LGS) was demonstrated much later. The transparency range of LGS and LGSe crystals is 0.32...

11.6 μm and 0.37...13.2 μm respectively. The effective non-linear coefficient is 5.8 pm/V and 10 pm/V. LIDT is 3.3 J/cm² for LGS and 0.4 J/cm² for LGSe. The thermal conductivity is 6...8 W/(m·K) and 4.7...6 W/(m·K) [2, 11].

Recently, studies related to the appearance of new barium-containing sulfides and selenides, which have not only a wide transparency region, but also high quadratic nonlinearity and radiation resistance, have become widespread. A recent example is the BaGa₄S₇ (BGS) crystal. In 2009, it was found to be a material with an IR non-linear optical effect close to that of LiGaS₂. The transparency range of BGS is 0.35...13.7 μm . The effective non-linear coefficient 6 pm/V. LIDT is 6 J/cm². The thermal conductivity is 1.45...1.68 W/(m·K) [12].

In 2010, a new BaGa₄Se₇ (BGSe) crystal was synthesized [13], which has promising properties for nonlinear optics in the mid-infrared range, which is confirmed by recently launched large-scale studies of the BGSe crystal as a nonlinear optical converter, showing good prospects for its application. The transparency range of BGSe is 0.47...18 μm . The effective non-linear coefficient 15 pm/V. LIDT is 2.8 J/cm². The thermal conductivity is 0.56...0.7 W/(m·K) [1, 12].

Researchers, engineers and other professionals in various fields use solid-state infrared laser sources for various purposes. The crystalline media used in these lasers have various disadvantages. Because of this, researchers need to select a proper crystal to create an IR laser radiation source. Therefore, they need to know the characteristics of certain promising IR crystals. However, this takes a long time. Thus, the main characteristics of crystals for the mid-infrared range will be defined in this article.

Materials and method

In this paper, we analyze the main properties of crystals in order to use them as frequency converters of laser radiation from the near infrared to the mid-infrared range. One of the main characteristics of a nonlinear crystal is the transparency range. The wider this range is the greater is the possibility of using the crystal. Besides, the material must have a high value of non-linearity. It allows us to increase the conversion efficiency. Laser resistance and thermal conductivity are also important characteristics. The high threshold of optical damage allows the crystal to be pumped with more powerful radiation, and the high thermal conductivity prevents the crystal from heating. Thus, such crystals properties as the transparency region, nonlinearity, optical damage threshold, and thermal conductivity are selected from the reviewed papers.

We have reviewed articles dealing with non-oxide crystals for the mid-infrared range. For this, some articles, in which the authors investigate or use the crystals we are interested in, were selected from the Research Gate electronic library according to certain criteria. The first criterion is reliability. Here we checked the credibility of the source and the citation of the authors of the study. The second criterion is utility. From this point of view, we considered the applicability of information about promising crystals in our research. Thus, we have selected 13 sources for research promising mid-IR crystals in order to bring together and structure the research on non-oxide crystals that are used in the mid-IR range. We have defined the main characteristics of the selected crystals necessary for frequency conversion. In addition, we have compared the reviewed crystals. Thus, a brief review of the literature in the area under research, as well as the selection and structuring of the main characteristics of crystals can be useful for further research.

Results

The results of the research are presented in Table.

Important characteristics of advanced nonlinear crystals to converting laser radiation to the mid-infrared range

Material	AGS	AGSe	GaSe	LIS	LISe	LGS	LGSe	BGS	BGSe
Transparency range, μm	0.47–13	0.7–18	0.62–18	0.41–12	0.47–13.3	0.32–11.6	0.37–13.2	0.35–13.7	0.47–18
Nonlinear coefficient, pm/V	11–13	38–41	54	7.5	12.5	5.8	10	6	15
LIDT, J/cm^2	0.2	1.5	3.5	6	5	3.3	0.4	6	2.8
Thermal conductivity, $\text{W}/(\text{m}\cdot\text{K})$	1.4–1.5	1–1.1	2–16.2	6.2–7.6	4.7–5.5	6–8	4.7–6	145–1.68	0.56–0.7
Peculiarities	–	Not pumped by 1 μm	Brittle nature	–	–	–	–	–	–

We can see that selenide and sulfide crystals have a wide transmission range. AGSe, GaSe, and BGSe crystals are especially distinguished due to the wide transparency region in the far IR range among the selected crystals. However, for AGSe and GaSe crystals, the transparency range starts at about 0.7 μm . The nonlinear coefficient is the highest for GaSe (54 pm/V) and AGSe (38...41 pm/V), it is many times less for other crystals. The laser-induced damage threshold is the highest for LIS and BGS (6 J/cm^2), the lowest for AGS (0.2 J/cm^2) and LGSe (0.4 J/cm^2). Lithium-containing crystals are distinguished by good thermal conductivity, low thermal conductivity is observed in the BGSe crystal (0.56...0.7 $\text{W}/(\text{m}\cdot\text{K})$). AGSe and GaSe crystals have limitations in use. The first of them cannot be pumped by radiation with a wavelength of 1 μm and the second of them has a layered structure. Thus, it is possible to obtain optical properties only by cleaving crystals perpendicular to the optical axis (001). In general, we can see that all crystals have differences.

Discussions and Conclusion

Crystals, which have good non-linear characteristics at first glance, have limitations in their application. With low thermal conductivity of the crystal, it is desirable to connect additional cooling to remove heat. Also, the use of crystals with low thermal conductivity or optical breakdown threshold leads to a limitation in output power or the complexity of buck converters. AGS, AGSe, BGS, and BGSe crystals include their limitations. Also, the GaSe crystal, at first glance an excellent candidate for frequency conversion to the mid and far infrared ranges, has a limitation in the form of a layered structure, which will determine the manufacture of optical elements only by cleaving the crystals perpendicular to the optical axis (001). Therefore, when designing and conducting experiments, it is necessary to take into account its features and select a crystal for the task.

Among non-oxide nonlinear optical crystals transparent at wavelengths greater than 5 μm , rhombic ternary lithium-containing chalcogenides LiGaS₂, LiGaSe₂, LiInS₂, and LiInSe₂ are unique crystals with the widest band gap and a transmission range 0.4...12 μm . These crystals also have a high fracture threshold, but their nonlinearity is relatively low.

Despite the fact that the nonlinearity coefficient of LiGaS₂ and LiInS₂ is lower than that of LiGaSe₂ and LiInSe₂, the optical breakdown threshold of the LiGaS₂ crystal under nanosecond pumping is much higher. Compared to the commonly used non-linear AgGaS₂ and AgGaSe₂ crystals, LiBC₂ orthorhombic compounds exhibit nearly isotropic thermal expansion behavior with three to five times higher thermal conductivity, high optical damage thresholds, and low intensity dependent absorption. These features make LiBC₂ crystals promising for direct high power downconversion from near IR, especially at 1064 nm, to deep mid IR.

In general, we can see that all crystals have their own characteristics, which we should take into account when using them. The key properties of these materials necessary for frequency conversion are highlighted, and their comparison is clearly presented. These findings can be used for further research based on obtaining the mid-infrared range when choosing a converter crystal, taking into account its features.

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Фундаментальная математика и физика

**Fundamental
Mathematics
and Physics**

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Зарядовая накачка баллистического анода позитронным пучком

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Рассмотрены вопросы о возможности создания электростатического заряда с помощью позитронных пучков. В частности, рассмотрены вопросы выбора материала баллистического анода, зависимость величины электрического поля от типа материала мишени, физические принципы и процессы создания ионов внутри толстого слоя материала. Сделаны выводы о возможности дальнейшего развития технологии накачки заряда с помощью позитронных пучков.

Ключевые слова: зарядовая накачка, позитроны, ионы, баллистический анод, электрическое поле, вольфрамовая мишень

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Charge Pumping of a Ballistic Anode by a Positron Beam

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In this essay, the possibility of creating an electric charge by charge pumping into a metal, ballistic anode is considered. Our goal was to prove the possibility of creating an electrostatic charge on a ballistic anode by charge pumping. Charge pumping was

performed by irradiating the target with a positron beam. And another goal was to determine the most suitable material for creating an electric charge in this way. It has been established that the rate of change in the charge value of a tar-get charged with a positron beam is practically independent of the target material. The possibility of creating an electric charge using the charge pumping method was determined. The study, is not completed. The main result will be the dependence of the energy of the positron beam on the target charge, which will give us the understanding how the charge is pumped. However, the results obtained already prove the possibility of creating accelerators with such a charging system.

Keywords: charge pumping, positrons, ions, ballistic anode, electric field, tungsten target

Introduce

To study the charge pumping method, a model of a modern ion accelerator it is proposed. It uses the electric charge to accelerate the ions. Charge and ions are created by a beam of positrons. Accelerator consists of four technical holes, a ballistic anode, a vacuum chamber and auxiliary devices.

To solve the charge pumping problem, we bombard the target with a positron beam. By theory, positrons penetrating into the target annihilate on the electrons of the target atoms, and create ions [1–10]. However, there are two factors limiting this process. The first is the energy of the positron beam. If this energy is very low, then the Coulon field of the target will deflect the beam away from the target. The second is the desorption energy [6].

For the numerical experiment, we use software program GEANT4 with the FTFP_BERT physical list. The hadronic part of this physics list consists of elastic, inelastic, capture and fission processes. Each process is built from a set of cross section sets and interaction models which provide the detailed physics implementation.

Purpose

The purpose of this study is to obtain experimental data on the charge pumping of a ballistic anode by a positron beam.

Method

The work submitted for consideration is a structured study that considers the possibility of creating an ion accelerator based on the charge pumping method. To achieve this goal, a number of tasks are solved, such as: analysis of previous works in the fields of knowledge directly or indirectly related to the topic of the presented work:

- Synthesis from the data obtained during the analysis of a certain generalized position or point of view using an incomplete induction method of cognition.
- Carrying out a numerical experiment.
- Analysis and processing of the data obtained from the experiment, bringing them into a single hypothesis.
- Summing up the work in the form of deductive conclusions.

Relevance and novelty

Novelty and relevance are as follows: linear high-current accelerators of medium-energy ions are widely used at present. The scope of their application lies in the area from

scientific research to solving practical problems such as: transmutation of radioactive waste, thermonuclear fusion, powerful laboratory sources of fast neutrons, etc.

However, their use is associated with a number of technical and economic problems. Examples of these problems are: low acceleration rates and large resonator sizes. And the price of one such accelerator ranges from one to three billion dollars, which greatly limits their applications. These problems can be solved by designing accelerators using new physical approaches.

In connection with the above problems, it was proposed to develop an accelerator using a quasi-electrostatic acceleration method. In it, the ions experience acceleration in the potential difference created by the walls of the accelerator itself and the charged ballistic anode. The ballistic anode is charged by means of an incident cylindrical positron beam [2].

Practical part

Model of a modern ion accelerator uses the electric charge to accelerate the ions. Charge and ions are created by a beam of positrons. It consists of four technical holes, a ballistic anode, a vacuum chamber and auxiliary devices.

To solve the charge pumping problem, we bombard the target with a positron beam. By theory, positrons penetrating into the target annihilate on the electrons of the target atoms, and create ions [9]. However, there are two factors limiting this process. The first is the energy of the positron beam. If this energy is very low, then the Coulomb field of the target will deflect the beam away from the target [4, 10]. The second is the desorption energy:

$$E_D = n^{(-3)} e^{(-3)} (\Lambda + U_i - n\varphi - kT \ln t / \tau_0)^2$$

For the numerical experiment, we use GEANT4 with the FTFP_BERT physical list. The hadronic part of this physics list consists of elastic, inelastic, capture and fission processes [5–7]. Each process is built from a set of cross section sets and interaction models which provide the detailed physics implementation.

First of all, creating a technology for producing ions by positron beams, it is necessary to determine the target material, and the dependence of positrons energy on the charge of the target.

On the Table we see the results of charging a tungsten target with a 10 MeV positron beam. In this experiment, we changed the target material and obtained the dependence of the charge on the material at a fixed energy of the positron beam. As it was found, the charging rate does not depend on the material, therefore, we use only tungsten targets, since they have a high desorption energy.

Results of charging

Element	Evaporation heat input, eV	Ionization energy, eV	Work function, eV	Energy barrier, eV	Desorption voltage, MV/cm
W	8,67	7,98	4,35	12,30	1052
Cu	3,52	7,72	4,55	6,69	312

The second part of the simulation shows the possibility of charge pumping by a positron beam. For this, a spherical tungsten target was created, which was irradiated with positrons. The energy of positrons was calculated so that their path length would not exceed

the target diameter [8]. As a result, we received data in the form of a list of secondary particles inside the target. This list included electrons and photons, but most of it was occupied by ions. When we sum up the charges of all ions, it is possible to obtain the charge of the target and confirm the theory.

Conclusion

In conclusion, it can be said we have achieved some results in our study, but it is not completed. As the main result will be the dependence of the energy of the positron beam on the target charge, which will give us an understanding how the charge is pumped. However, the results obtained already prove the possibility of creating accelerators with such a charging system.

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Методология обнаружения и удаления аномальных значений в статистических исследованиях

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Изложены фундаментальные вопросы из теории надежности для проектирования различных технических систем, методы сбора и обработки данных о надежности аппаратуры по результатам эксплуатации и специальных испытаний на надежность. Разработаны методы, математические модели и проведен анализ структуры аппаратуры на этапе проектирования и при изготовлении. Проводятся эксперименты для определения аномального выброса. Представлены методики оценки ресурса технических объектов, среди которых важное место занимают методики, основанные на использовании контрольных карт.

Ключевые слова: статистика методики, методики, аномальность, выброс, обработка, контрольная карта

Введение

Стадии проектирования, начиная с разработки технического задания и кончая выпуском технической документации опытного производства, являются ключевыми в общей проблеме обеспечения надежности высокотехнологического изделия. Важной работой, регламентирующей взаимоотношения всех участников разработки продукции, является обоснование программы обеспечения надежности (ПОН) изделия в целом, его составных частей и элементов, а также выработка и согласование порядка подтверждения требований по надежности на всех стадиях создания [1–4]. С этой целью используют модели ПОН, типовые ПОН и модели (процедуры) подтверждения надежности. После выбора основных проектных, схемных и конструкторско-технологических решений перед окончательным оформлением проекта службой надежности предприятия совместно с подразделениями-разработчиками осуществляется оценка (экспертиза) результатов проектирования с позиций обеспечения надежности и корректировка принятых решений [5–8]. Подход к проблеме исследования далеко отстоящих значений наблюдений зависит от поставленных целей.

Возникает необходимость рассмотреть вероятное смещение оценки и ее дисперсию надлежащим образом, опираясь на использование критерия для выбросов. Если после применения этого критерия выборочные данные должны быть использованы для проверки гипотезы относительно некоторого параметра совокупности, то для исследователя представляется важным не только сам критерий для выявления выбросов, но также и мощность других критериев для проверки гипотезы.

Критерии для выбросов применяют, преследуя одну из следующих целей:

- выровнять наблюдения перед анализом (отбрасывание выбросов);
- убедиться, что аномальные значения присутствуют, что указывает на необходимость пересмотра процедуры получения данных;
- выделить наблюдения, которые могут представлять особый интерес именно из-за их экстремальности.

В этой статье кратко рассмотрены критерии первого типа.

В случае классического подхода к решению задачи обнаружения аномальных точек необходимо предположить, что выборочные наблюдения производятся над случайной, нормально распределенной величиной, образовать соответствующую статистику для обнаружения выбросов, чувствительную к резким отклонениям такого рода, найти ее распределение при нулевой гипотезе, утверждающей, что все наблюдения принадлежат одной и той же нормально распределенной совокупности, и затем отвергнуть гипотезу, если окажется маловероятным, чтобы вычисления статистика появилась в случайной выборке. Теория и практические методы отбрасывания выбросов разработаны слабо [2], т. е. отбрасывание аномальных значений на чисто статистической основе было и остается весьма опасной процедурой. Само их присутствие может являться доказательством того, что исследуемая совокупность в действительности отличается от предполагаемой.

Обнаружение и исключение аномальных значений

Рассмотрим критерий, предложенный в работе [2]. Пусть дана некоторая выборка наблюдений x_1, x_2, \dots, x_n ($n \geq 3$), которая по предположению является случайной выборкой для случайной величины X , распределенной по нормальному закону с параметрами μ_x и σ_x^2 . Вычислим разности $Y_i = x_i - \bar{X}$ ($i = 1, 2, \dots, n$, где $\bar{X} = \sum_{i=1}^n X_i / n$). Если одно из значений x_i выделить, то выборочное среднее для оставшихся наблюдений будет равно

$$\sum_{\substack{i=1 \\ j \neq i}}^n \frac{x_j}{v} = \bar{X}, \quad v = n - 1. \quad (1)$$

Если выделить несколько значений x_1, x_2, \dots, x_r , то выборочное среднее будет равно

$$\bar{X} = \frac{Y_1 + Y_2 + \dots + Y_r}{n - r}. \quad (2)$$

При использовании индекса M для обозначения наблюдения, которому соответствует максимальная разность $Y_M = x_M - \bar{X}$, правило, предложенное в работе [2], состоит в следующем (для случая, когда дисперсия σ_x^2 неизвестна): при заданном значении с наблюдение x_M отбрасывается, если $|Y_M| > cS_X$. В противном случае наблюдение x_M оставляется. Для выборок большого объема, если наблюдение x_M отброшено, оставшаяся выборка рассматривается как вновь полученная и для нее анализ можно продолжить. Каждый раз величина σ_x оценивается по наблюдениям, оставшимся после отбрасывания x_M . Величина c может изменяться с изменением объема выборки и ее можно выразить неявно через t :

$$\left[\frac{nc^2(v - v_0 - 1)}{v(v + v_0 - nc^2/v)} \right]^{1/2} \approx i_{1-\alpha/2}^{v+v_0-1}, \quad (3)$$

а также можно использовать приближенное выражение через распределение F в явном виде:

$$c \approx \left(\frac{v}{n} \right)^{1/2} \left(\frac{3F_{1-q}}{1 + \left[\frac{3F_{1-q} - 1}{v + v_0} \right]} \right)^{1/2}, \quad (4)$$

где $v = n - 1$, а v_0 — любое другое число дополнительных степеней свободы, которое связано с оценкой σ_x^2 по выборке объема, не равного n . С помощью выражения (4) можно провести проверку следующим образом. Если никакие значения не были отброшены, умножим допустимое относительное приращение σ_x^2 , «премию», на величину v/n . Обозначим это произведение через q и найдем соответствующую верхнюю процентную точку для отношения дисперсий F_{1-q} при трех и $v + v_0 - 1$ степенях свободы. Вычислим значение c по выражению (4) и применим критерий для x_M .

Использование контрольных карт

Проверку гипотез можно применить весьма простым и практически удобным способом для контроля качества процесса. Контрольные карты представляют собой графические средства анализа, которые нетрудно подготовить и использовать в заводских рабочих условиях.



Рис. 1. Контрольная карта качества процесса

На рис. 1 показана типичная контрольная карта для выборочного среднего значения и указаны верхний и нижний контрольные пределы. До тех пор, пока статистика, обозначенная на этом графике, попадает между этими двумя границами, процесс считается под контролем. Правила принятия решения, используемые для фиксирования этих линий, могут быть основаны на предполагаемом виде распределения (обычно нормальному) для наблюдаемой случайной величины, или они выводятся с помощью непараметрического анализа. Если на графике статистика превысит контрольные пределы, принимается решение, что процесс «вышел из-под (статистического) контроля»; пересечение контрольных границ свидетельствует о ненормальной работе. Даже чрезмерное скопление точек по одну из сторон от центральной линии можно интерпретировать как некоторый сдвиг нормального хода процесса. Контрольные карты можно использовать:

1. Как сигнал о том, что в процессе произошло некоторое изменение, так и в качестве оценки величины изменения, для которого требуется коррекция.

2. Исключительно как сигнал о том, что в процессе произошло некоторое изменение, чтобы оператор осознал, что процесс требует его внимания.

3. Для получения оценок числа случаев в прошлом, когда в процессе возникали изменения, и установления на их основе причин, вызывающих эти изменения.

4. Как меру качества продукции для классификации по периодам.

Из-за способа, с помощью которого на практике устанавливаются контрольные пределы, и в силу недостатка информации о функции распределения вероятности случайной величины обычно стараются избегать точных вероятностных формулировок. Использование контрольных карт для непрерывных производственных процессов не было столь плодотворным. Однако сдвиг уровня и (или) циклические флюктуации в некотором процессе трудно приписать определенным причинам, некоторые из которых могут быть связаны с ненаблюдаемыми переменными или с внешними условиями. Есть некоторые виды контрольных карт, различающиеся между собой статистиками, которые откладываются на графике:

- контрольные карты Шухарта (карты X , R и s);
- карты скользящих геометрических средних (скользящего экспоненциально взвешенного среднего);
- карты накопленных сумм;
- многомерные контрольные карты.

В равной степени полезны и многие другие типы карт; они описаны в работах [5–10]. В таблице указана относительная эффективность обнаружения различных изменений в процессе для четырех типов контрольных карт.

Относительная эффективность обнаружения изменений в процессе

Причина изменения	Контрольные карты			
	Среднее	Размах	Стандартное отклонение	Накопленная сумма
Отклонение с пересечением (грубое)	1	2	—	3
Сдвиг среднего	2	—	3	1
Сдвиг дисперсии	—	1	—	—
Медленная флюктуация (тренд)	2	—	—	1
Быстрая флюктуация (колебание)	—	1	2	—

(1 = наиболее эффективная, 2 = следующая по эффективности, 3 = наименее эффективная, — = неприменима).

При разработке контрольных карт процесса, т. е. при определении положения центральной линии и контрольных пределов, требуется некоторое обдумывание и исследование самого процесса. Допустим, что процесс и точки замеров четко определены, учтено время запаздывания и мертвое время и найден подходящий выборочный метод и выборочный интервал. Тогда нужно исследовать и саму процедуру получения выборки, чтобы точность данных, которые будут использоваться, была известна (и находилась на допустимо низком уровне). Для более тонких проверок

требуются выборки большого объема, однако временной шаг может быть и такой, что выборка будет состоять лишь из одного показания.

Контрольные карты Шухарта

Рассмотрим контрольные карты Шухарта. Контрольные карты Шухарта для \mathbf{V} были одним из первых методов статистического контроля качества [7]. Берется некоторая выборка случайной переменной с нормальным законом распределения со средним значением μ_x и дисперсией σ_x^2 [8]. Здесь показано, что влияние отклонений от нормального закона слабое, и таблицы поправочных коэффициентов, вычисляются и затем откладываются на графике, как показано на рис. 1. Для выбранного значения α (обычно $\alpha = 0.0027$, так что $1 - \alpha = 0.9973$) подсчитывают верхний и нижний контрольные пределы, используя σ_x или ее оценку, и наносят на карту по обе стороны от известного или оцененного значения μ_x . Если выборочное среднее попадает за контрольные пределы, делают вывод, что процесс «вышел из-под контроля». При этом очень важно решить, какое нужно выбрать значение α ; чем уже полоса между контрольными пределами, тем чаще будет неоправданно звучать сигнал «выхода из-под контроля». Также важно решить, какой использовать объем выборки n . Обычно принимают $n = 5$. Вместе с \mathbf{X} часто откладывают на графике вторую статистику, размах выборки R . Арифметическое среднее значение размаха \mathbf{V} можно использовать в качестве оценки выборочной дисперсии, а арифметическое среднее величин \mathbf{X} , \bar{X} может служить оценкой среднего μ_x .

Размах оказывается более удобной для подсчета мерой рассеяния данных, чем стандартное отклонение. Нанесение на контрольную карту наряду с \mathbf{X} размаха выборки позволяет легче заметить аномальное изменение. Размах служит грубой мерой скорости изменения переменной, за которой ведется наблюдение. Его значение может выйти за контрольные пределы на карте размаха и подать сигнал тревоги значительно раньше, чем изменение среднего, которое при этом еще может находиться в заданных контрольных пределах. Если превышение одного из двух контрольных пределов не вызывает особого беспокойства или ущерба, а для другого предела справедливо обратное утверждение, то среднее значение для процесса можно сдвинуть так, чтобы более важный предел находился дальше от среднего значения, а другой предел при этом не учитывать. Если один из пределов оказывается больше физически допустимого предела для процесса, например если некоторое значение в процентах меньше 0 или больше 100, то в таком случае контрольный предел приводят в соответствие с физическим пределом.

Процесс введения поправок на основе контрольных карт

Рассмотрим ситуацию, когда контрольные карты могут с успехом применяться для выявления нежелательных рабочих условий и последующего определения необходимых корректировочных действий. Обсуждение выборочных планов выходит за рамки нашей статьи. При приемочном контроле измеряются некоторые характеристики продукта, согласно некоторому выборочному плану, берется случайная выборка объема n , вычисляются выборочное среднее и выборочное стандартное отклонение и для проверки нулевой гипотезы применяется критерий значимости. С нулевой гипотезой связаны альтернативная гипотеза и ошибки первого и второго

рода. Потребитель, покупающий этот продукт, устанавливает предел, ниже которого продукт считается непригодным к использованию, и именно он определяет альтернативную гипотезу. На рис. 2 изображена кривая оперативной характеристики для типичного выборочного плана.

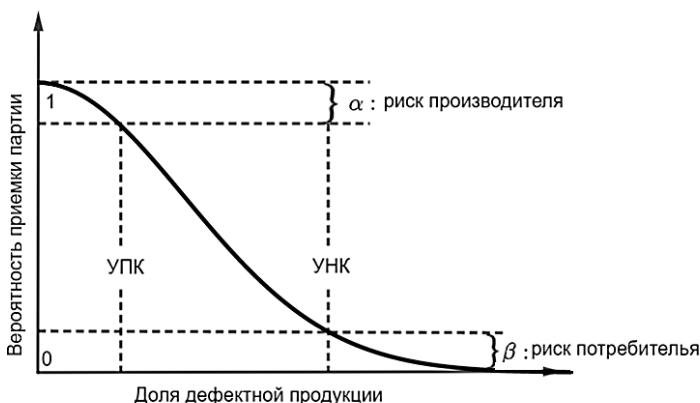


Рис. 2. Кривая оперативной характеристики для выборочного плана

Для производителя нулевая гипотеза H_0 состоит в том, что продукт приемлем, и даже если он производит приемлемый продукт, 100 α % продукции будет считаться неприемлемой, так как по своей природе выборочная статистика процесса стохастична. В этом смысле величина α , называется риском производителя, а связанный с ней уровень доли дефектных изделий — уровнем приемлемого качества (УПК). Если производитель выпускает 100 β % дефектной продукции, которая не зарегистрирована как дефектная из-за стохастической природы выборочной статистики, то вероятность β называется риском потребителя, и альтернативная гипотеза H_1 устанавливает уровень неприемлемого качества (УНК). При составлении контрольной карты приемки приемлемый уровень для процесса (ПУП) определяется по величине α , а неприемлемый уровень (НУП) — по величине β . До тех пор пока контролируемая статистика продукта попадает между ПУП и НУП, считается, что процесс находится под контролем. Заметим, что контрольные пределы зависят от α , β и n .

Заключение

Предложены методы по использованию контрольных объединяющих информацию из прошлых выборок с данными из текущей выборки, что позволяет использовать больший объем информации, причем в результате регистрации наблюдаются меньшие сдвиги уровня процесса. Их недостаток состоит в том, что прошлая информация маскирует возможные малые сдвиги уровня процесса, определяемого лишь новой информацией. Систематизированы и изучены существующие методы по использованию контрольных карт. Выявлены проблемы недостатка информации при расчетах классическими методами, игнорирование таких факторов, как влияние отклонения режима работы или внешних воздействий от номинальных значений, непостоянность интенсивности отказов, нелинейный характер влияния внешних факторов на результат принятия решения. Изучен характер влияния внешних факторов на на-

дежность статистических данных и степень учета данных факторов в существующих методах. Качественные, организационно-технические (конструктивные и программные) требования по надежности, задаваемые в ТЗ для каждой стадии создания элементов в целом, должны выполняться и подтверждаться на соответствующей стадии работ. Для их подтверждения не требуется статистический эксперимент, и в этом их большое преимущество. Значительному сокращению затрат на экспериментальные исследования и вообще созданию высоконадежных изделий на стадиях проектно-конструкторской разработки способствуют создаваемые в отдельных отраслях промышленности проектные нормы надежности — системы количественных и качественных требований и правил, выполнение которых обязательно при разработке изделий различного назначения.

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Methodology of Detection and Removal of Abnormal Values in Statistical Studies

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The article outlines the fundamental issues of the theory of reliability for the design of various technical systems, methods for collecting and processing data on the reliability of equipment based on the results of operation and special tests for reliability. Methods, mathematical models have been developed, and an analysis of the equipment structure at the design stage and during manufacture is carried out. Experiments are being carried out to determine the anomalous release. Methods for assessing the resource of technical objects are presented, among which an important place is occupied by methods based on the use of control charts.

Keywords: statistics, methods, anomaly outlier, processing, control chart

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Экспериментальное исследование образования ячеистой структуры сферически расширяющегося пламени

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Проведено экспериментальное исследование ячеистой структуры сферически расширяющегося водородно-воздушного пламени с концентрацией водорода 10 об. %. Исследование проведено на основе экспериментально полученных теневых изображений. Построены графики зависимости радиуса фронта пламени от угла для каждого момента времени. С использованием дискретного преобразование Фурье получены зависимости изменений амплитуд высших гармоник от времени. В ходе исследования был получен и сформулирован критерий расщепления и образования нового каскада ячеек.

Ключевые слова: неустойчивое горение, ячеистая структура, фронт пламени, неустойчивость

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Experimental Investigation of Cell Generation in an Expanding Spherical Flame Front

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An experimental study of the cell structure of a spherically expanding hydrogen-air flame with a hydrogen concentration of 10 vol.% was carried out. The study is based on experimentally obtained shadow images. Graphs of the flame front radius versus angle for each moment of time have been plotted. Using a discrete Fourier transform, time

dependencies of amplitudes changes in higher harmonics were obtained. In the course of the study, a criterion for splitting and formation of a new cell cascade was obtained and formulated.

Keywords: spherical flame, cell splitting, hydrogen, combustion

Introduction

It is known that the acceleration of a spherically expanding flame is caused by the development of a cellular structure, the main feature of which is an increase in the amplitude of the disturbance and the area of the flame front. The flame area grows faster than the square of the mean (average) radius, thus leading to the flame front acceleration. With spherical flame expansion there is a distortion of inhomogeneities at the flame front. Expanding flames are distinguished by cell wavelengths' increase caused by the expansion of the flame front. In medium-scale flames (10...100 cm) the front structure is determined by two main mechanisms of flame instability: hydrodynamic and diffusive-thermal [1, 2]. At the same time conditions of smooth spherical flame transition to cellular flame have been widely investigated [3, 4]. It has been shown experimentally that unstable flame propagation begins after a certain radius [5].

This paper investigates the cellular structure of a spherically expanding flame and its subsequent analysis at hydrogen content 10 vol. %, based on shadow images of the flame front.

Experimental setup

The experimental setup depicted in Fig. 2 included a spherical transparent latex shell (5 in Fig. 1) with a wall thickness of below 0.1 mm, which was placed in the optical field of the schlieren IAB-451 device (2 in Fig. 1), and then filled up with gas mixture through a gas pipeline and inlet connection (6 in Fig. 1). The diameter of the filled gas shell was 197 mm, the volume of a combustive mixture – 4l. The premixed hydrogen-air mixture was used: air and hydrogen were mixed in a closed cylinder with a volume of 40l in a proportion 10 vol. % of hydrogen in the mixture, with an excessive pressure of 5 atm. Gas partial pressure was measured by a reference pressure gauge with a 0.15 accuracy class, which allowed estimating a 1.5 vol.% mixture measurement error. The mixture was kept in the cylinder for approximately 24 hours to avoid additional instabilities and achieve complete homogeneity of the mixture. Finally, a series of experiments with a pre-prepared mixture was made, so that the measurement error effect of the mixture composition on the shape and dynamics of the flame front was reduced.

Ignition of a hydrogen-air mixture was performed using a spark discharger (7 in Fig. 1), which is a 1.5 mm diameter steel tube with an isolated high-voltage cable inside. A spark gap was placed in the center of the filled latex shell through the gland package in the gas inlet connection. A spark discharge was generated by an impulse high-voltage electric current source. The flame front propagation was visualized by a schlieren technique using an IAB-451 device with a 230 mm field of view diameter. The image sequence of an expanding spherical flame front was registered by a high-speed video camera Phantom VEO710S with a frame rate ranging from 900 to 3000 frames per second, depending on the hydrogen concentration in a hydrogen-air mixture, with the apparent resolution of 1280×800 dots.

The experiment produced a series of shadow images of the flame front, an example is shown in Fig. 2. These shadow images show the global spherical expansion of the cellular flame.

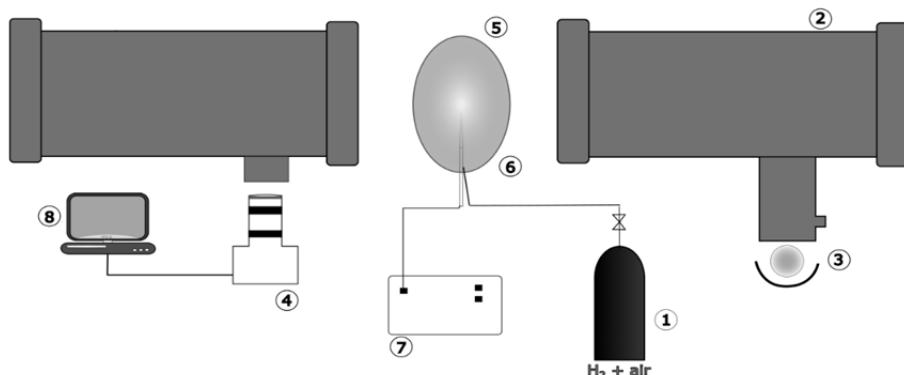


Fig. 1. Experimental setup:

- 1 — gas cylinder; 2 — schlieren IAB-451 device; 3 — light source; 4 — high-speed camera Phantom VEO 710 S; 5 — latex shell; 6 — gas inlet connection with a spark discharger; 7 — power supply of a spark; 8 — computer

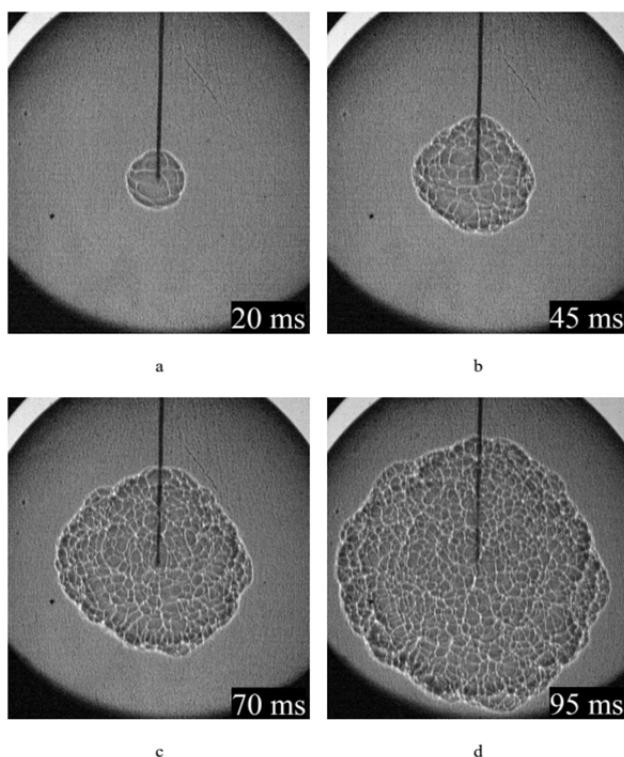


Fig. 2. Schlieren flame front images in the hydrogen-air mixture with the 10 vol.% hydrogen content:
a — 20 ms; b — 45 ms; c — 70 ms; d — 90 ms

Results

In order to determine the flame front in the images and the harmonic amplitudes using the discrete Fourier transform method, a MatLab program was created. The amplitudes were normalized to the critical Darrieus-Landau wavelength and the time from ignition to the expression λ_{DL}/S_L .

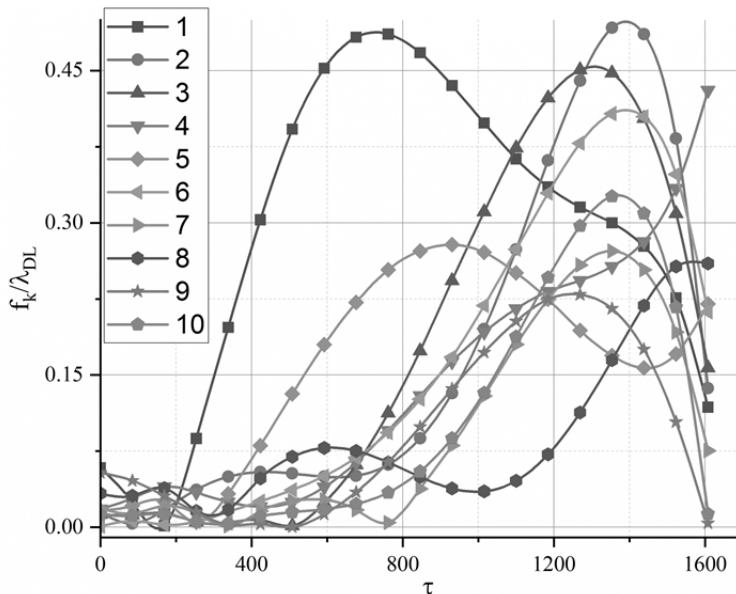


Fig. 3. Graph of the change in amplitude versus time at 10% hydrogen content by harmonic:
1 — 5th; 2 — 6th; 3 — 7th; 4 — 8th; 5 — 9th; 6 — 10th; 7 — 11th; 8 — 12th;
9 — 13th; 10 — 14th

Fig. 3 shows that the disturbance amplitude increases until it reaches a maximum value, then there is a slow decrease. This means that at some point in time, once the critical radius is reached, a cellular structure of the flame front emerges. For example, at the start of the amplitude decrease of the fifth (1 in Fig. 3) harmonic, there is a sharp increase in the amplitude of the tenth (6 in Fig. 3). Also, at cell splitting the velocity of previous harmonic decreases and the subsequent one, on the contrary, increases, which is caused by the influence of Landau's instability mechanism. The cell split for lean mixtures was more noticeable (pronounced) than for the rich, because in the latter, the cell construction and split occurred much slower. In this case, a new cells generation criterion in the unstable flame can be described by the next relationship $\lambda \geq \lambda_{cr}$, where $\lambda_{cr} = \delta_{th} * Ze * \exp(\theta)$.

Conclusions

From the experimental shadow images of the spherical-expanding flame, the dependencies of the flame front radius on the angle at successive points in time are obtained. Using the Fourier transform, the cells amplitudes characterized by a sharp increase and subsequent sharp decrease during the formation of the cellular structure, and with wavelengths corresponding to their harmonics are highlighted. Thus, based on the data

obtained, it is suggested that these dependencies show the splitting of large cells into smaller ones.

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УДК 530.12

О модифицированной гравитации с неминимальной связью скалярного поля и кручения: космологические возмущения и точные решения

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Рассмотрены модели космологической инфляции со скалярными полями на основе телепараллельной гравитации с неминимальной связью скалярного поля и кручения. Представлен класс точных решений уравнений космологической динамики для произвольного вида параметра Хаббла. Показана процедура верификации модели с потенциалом скалярного поля, соответствующего хаотической инфляции с массивным скалярным полем, по наблюдательным ограничениям на значения параметров космологических возмущений.

Ключевые слова: телепараллельная гравитация, кручение, скалярные поля, точные решения.

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On Modified Gravity with Non-Minimal Coupling of Scalar Field and Torsion: Cosmological Perturbations and Exact Solutions

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Cosmological inflation models with scalar field based on teleparallel gravity with non-minimal coupling of scalar field and torsion are considered. Solution type obtained in this paper is justified for any Hubble parameter and scalar field evolution. Also, the model with scalar field potential, relating to chaotic inflation with massive scalar field, is verified by modern restrictions on values of cosmological perturbations parameters.

Keywords: teleparallel gravity, torsion, scalar fields, exact solutions

Introduction

Currently, the cosmological inflation has proven to be the most consistent theory for construction of early universe models based on metric gravity theories. However, some gravity theories alternative to General Relativity (GR) lead to the same cosmological effects [1, 2]. An example of such theory is teleparallel equivalent of general relativity, or teleparallel gravity (TG) [3]. Thus, in the context of Modified Teleparallel Gravity (MTG) theories, it is crucial to analyse how local Lorentz symmetry breaking affects the nature of cosmological perturbations evolution [4].

In this paper we consider exact solutions construction method in cosmological inflation models with non-minimal coupling of torsion and scalar field. Also, we propose generalised solutions, which are justified for arbitrary Hubble parameter and scalar field evolution. Finally, we consider model verification with chaotic inflation potential of scalar field.

Non-minimal coupling of torsion and scalar field: exact solutions and inflationary model verification

For inflationary model analysis and construction we use corresponding action [4] in units

$$S = \int d^4x e[f(T, \phi) + \omega(\phi)X],$$

where $f(T, \phi)$ is arbitrary function of scalar field ϕ and torsion T , $\omega(\phi)$ — kinetic function, $X = -\frac{1}{2}\partial_\mu\phi\partial^\mu\phi$ — kinetic energy of scalar field and $e = \det(e_\mu^\alpha) = \sqrt{-g}$, with Minkowski tangent space metric $\eta_{ab} = \text{diag}(-1, 1, 1, 1)$

In order to describe inflationary dynamics, we use spatially flat Friedmann-Robertson-Walker metric $ds^2 = dt^2 + a^2\delta_{ij}dx^i dx^j$, where $a = a(t)$ is the scale factor. Then we choose corresponding tetrad $e_\mu^\alpha = \text{diag}(1, a, a, a)$ so that spin connection is equal to zero.

In that case, cosmological dynamic equations according to action, can be obtained as follows [4]

$$f(T, \phi) - \omega(\phi)X - 2Tf_{,T} = 0,$$

$$f(T, \phi) + \omega(\phi)X - 2Tf_{,T} - 4Hf_{,T} - 4Hf_{,T} = 0,$$

$$\omega_{,\phi}X - 3\omega(\phi)H\phi - \omega(\phi)\phi + f_{,\phi} = 0.$$

Let us propose exact solutions of equations, which can be written as

$$f(T, \phi) = -K\sqrt{T} - G(\phi)\sqrt{T} - V(\phi),$$

$$\omega(\phi) = -\frac{1}{3}\frac{G_{,\phi}}{V(\phi)}, \quad \dot{\phi} = \frac{\sqrt{6}V(\phi)}{G_{,\phi}},$$

where K is arbitrary constant, $G(\phi)$ defines non-minimal interaction between scalar field and torsion, $f = f(T, \phi)$ sets gravitation theory type.

As it can be seen, proposed solution is justified for any Hubble parameter and scalar field evolution, which corresponds to different inflationary scenario and perturbation parameters as well.

It should be noted that there are 2 types of conditions for inflationary dynamics analysis: $V(\phi) < 0$ and $G_{,\phi} > 0$ or $V(\phi) > 0$ and $G_{,\phi} < 0$ accordingly. The case ω corresponds to phantom scalar field absence [5].

Now we can choose arbitrary $H(t)$ and $\phi(t)$. Let us consider the second type of exact solutions for chaotic inflation with massive scalar field [6]:

$$V(\phi) = V_0\phi^n, \quad H(t) = \frac{m}{t} + \lambda, \quad \phi(t) = e^{\phi_0 t}.$$

where $V_0 = \frac{m^2}{2}$, m is scalar field mass, $m^2 > 0$ in order to avoid tachyonic instability in current cosmological model [7]

Thus, we get other parameters for considered model:

$$G(\phi) = -\frac{\phi^n\sqrt{6}V_0}{n\phi_0}, \quad \omega(\phi) = \frac{\sqrt{6}}{3\phi_0\phi}.$$

$$f(T, \phi) = -K\sqrt{T} + \frac{\phi^n\sqrt{6}V_0}{n\phi_0} - V_0\phi^n.$$

Let us turn to cosmological perturbations parameters, which verification is crucial for estimating viability of cosmological models. Main parameters of cosmological perturbations are tensor-to-scalar ratio r , scalar indices of scalar n_s and tensor n_T perturbations, as well as power spectrum of scalar perturbations \mathcal{P}_S . At the horizon crossing ($k = aH$) in current inflation model with non-minimal coupling of T and ϕ they are defined by the relations: [4]

$$Q_s = \frac{\omega(\phi)X}{H^2} = -\frac{V(\phi)}{H^2G_{,\phi}},$$

$$Q_T = -\frac{1}{2}f_{,T} = \frac{1}{4\sqrt{T}}(K + G(\phi))$$

$$\mathcal{P}_S = \frac{H^2}{8\pi^2 Q_S} = -\frac{H^4 G_{,\phi}}{8\pi^2 V(\phi)}, \quad \mathcal{P}_T = \frac{H^2}{2\pi^2 Q_T} = -\frac{2H^2\sqrt{T}}{\pi^2(K + G(\phi))},$$

$$n_S - 1 = -2\epsilon - \eta + 2\eta_R, \quad n_T = -2\epsilon - \delta_{f,T},$$

$$r = \frac{\mathcal{P}_T}{\mathcal{P}_S} \approx 4\frac{Q_{SK}}{Q_{TK}} = -16\frac{16\sqrt{6}V(\phi)}{G_{,\phi}(K + G_{,\phi})}.$$

The cosmological inflation analysis is carried out in terms of slow-roll parameters, which have the form

$$\begin{aligned}\epsilon &= -\frac{H}{H^2} \quad \delta_{\omega X} = -\frac{\omega X}{2H^2 f_T} \quad \delta_{f,T} = \frac{f_{,T}}{H f_{,T}}, \quad \delta_{f^H} = \frac{f_{,TT} T}{H f_{,T}}, \quad \delta_{fX} = \frac{f_{,T\phi} \phi}{H f_{,T}}, \quad \eta_R \\ &= \delta_{f,T} \left[1 + \frac{\delta_{f,T}}{\delta_{f^H}} \left(1 + \frac{\delta_{fX}}{\delta_{\omega X}} \right) \right].\end{aligned}$$

According to the last cosmological restrictions, cosmological perturbations parameters are constrained as follows [9]:

$$r < 0.032 \quad n_s = 0.9663 \pm 0.004, \quad P_s = 2.1 \cdot 10^{-9}.$$

Let us receive the inverse dependence of average e-fold number during inflation ($N = 60$) versus cosmic time

$$N = \int H(t) dt = -m \ln(t) + \lambda t \Rightarrow t(N) = \exp \left[\frac{1}{m} \left[-m \text{LambertW} \left(\frac{\lambda e^{\frac{m}{N}}}{m} \right) + N \right] \right].$$

where LambertW is ω -Lambert function. By the same token, we receive values of arbitrary constants, which are shown in Table, for $n = 2$ and $n = 4$ accordingly.

Cosmological perturbation parameters and values of arbitrary constants

n	r	n_s	P_s	m	λ	Φ_0	k	V_0
2	0.02	0.9668	$2.1 \cdot 10^{-9}$	5.0	$2.0 \cdot 10^{-4}$	$1.8755 \cdot 10^{-7}$	$3.35 \cdot 10^{-4}$	$2.8880 \cdot 10^{-11}$
2	0.02	0.9663	$2.1 \cdot 10^{-9}$	5.5	$3.1 \cdot 10^{-4}$	$1.9975 \cdot 10^{-7}$	$30 \cdot 10^{-4}$	$2.5699 \cdot 10^{-9}$
4	0.02	0.9663	$2.1 \cdot 10^{-9}$	5.0	$3.1 \cdot 10^{-4}$	$8.4615 \cdot 10^{-7}$	$4.08 \cdot 10^{-4}$	$5.1991 \cdot 10^{-9}$
4	0.02	0.9316	$2.1 \cdot 10^{-9}$	5.0	$2 \cdot 10^{-4}$	$1.8755 \cdot 10^{-7}$	$3.35 \cdot 10^{-4}$	$6.3292 \cdot 10^{-11}$

As we see from table 1, the inflationary model considered corresponds to observational constrains on perturbation parameters. It should be observed that inflation energy scale (here, V_0) was estimated in [11]. Also, the increase in scalar field potential degree leads to power spectrum, which is not justified with cosmological constraints, in contrast to $n = 2$.

Conclusion

We have considered exact solutions construction method in cosmological models with non-minimal coupling of scalar field and torsion, which are the modifications of teleparallel equivalent of general relativity (TEGR).

In addition, we propose exact solutions, which are justified for arbitrary Hubble parameter $H(t)$ and scalar field evolution $\phi(t)$.

Also, we define two types of solutions in terms of scalar field potential $V(\phi)$ and non-minimal interaction function $G(\phi)$. Finally, the model with $V(\phi)$ and $(G_{,\phi}) < 0$ was

considered as an example for chaotic type inflation with massive scalar field. The selected model satisfies observational constraints on values of cosmological perturbations parameters as 95 % C.L.

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Моделирование напряженно-деформированного состояния тонкостенных композитных конструкций с учетом криволинейной анизотропии

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Предложен численный алгоритм решения задачи упругости с учетом криволинейной анизотропии на основе метода конечных элементов и нового предложенного метода, который позволил отвязать криволинейную анизотропию от геометрии исследуемой тонкостенной оболочки. Было проведено моделирование напряженно-деформированного состояния баллона высокого давления, полученного в результате намотки композитными нитями.

Ключевые слова: метод намотки, метод конечных элементов, криволинейная анизотропия, баллон давления

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Modeling the Stress-Strain State of Thin-Walled Composite Structures with Curvilinear Anisotropy

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A numerical algorithm was proposed for solving the elasticity problem taking into account curvilinear anisotropy based on the finite element method and a new proposed method that allowed to untie the curvilinear anisotropy from the geometry of the thin-walled shell under study. A simulation of the stress-strain state of a high-pressure cylinder obtained as a result of winding with composite threads was carried out.

Keywords: winding method, finite element method, pressure cylinder, curvilinear anisotropy

Introduction

In this paper, we considered the simulation of the stress-strain state of a pressure cylinder obtained as a result of winding with composite threads [1–3]. In the proposed model, each winding thread is a cylindrical body with a central line that is a geodesic curve on the middle surface of the pressure cylinder shell, which is the surface of revolution. A numerical method was proposed for modeling these geodesic curves by approximating them with broken lines. The centers of the links of such broken lines were assumed to be the barycenters of the cells of the Voronoi diagram. Inside each cell, the orientation of the anisotropy axes — the local curvilinear orthogonal coordinate system — and the properties of the materials were assumed to be unchanged. This numerical method as part of the finite element method was used to calculate the stress-strain state of winding high-pressure composite cylinders.

Mathematical model of a three-dimensional problem of elasticity of thin-walled structures, taking into account curvilinear anisotropy

Let's consider a three-dimensional elasticity problem in a limited area Ω with a Lipschitz boundary $\partial\Omega = \Sigma_u \cup \Sigma_\sigma$:

$$\nabla \sigma = 0;$$

$$\sigma = {}^4 \mathbb{C}(x) \cdot \varepsilon, \quad \varepsilon = \text{def}(\mathbf{u}) = \frac{1}{2} (\nabla \otimes \mathbf{u} + \nabla \otimes \mathbf{u}^T); \quad (1)$$

$$\mathbf{n} \cdot \sigma|_{\Sigma_\sigma} = S_e, \quad \mathbf{u}|_{\Sigma_u} = u_e,$$

where σ is the stress tensor; ε is the small strain tensor; \mathbf{u} is the displacement vector; ${}^4 \mathbb{C}(x)$ is a symmetric positive definite tensor field modulus of elasticity (fourth rank); ∇ – nabla-operator; \mathbf{n} is the normal vector to the region; S_e, u_e are vectors of external surface forces and displacements [4].

We introduce two coordinate systems:

1. A rectangular Cartesian coordinate system x_i with unit vectors \mathbf{e}_i .
2. A local curvilinear orthogonal system x'_i with unit vectors \mathbf{c}_i corresponding to the principal axes of anisotropy.

The coordinate systems introduced above are interconnected by the transformation matrix $Q(x_k)$:

$$\mathbf{c}_i = Q_{ij} \mathbf{e}^j, x'_i = x'_i(x_i). \quad (2)$$

The elasticity modulus tensor can be represented as follows:

$${}^4\mathbb{C}(x) = C_{ijkl} \mathbf{e}_i \otimes \mathbf{e}_j \otimes \mathbf{e}_k \otimes \mathbf{e}_l = C'_{ijkl} \mathbf{c}_i \otimes \mathbf{c}_j \otimes \mathbf{c}_k \otimes \mathbf{c}_l, \quad (3)$$

where is the relationship between the components of the tensor of elastic moduli:

$$C_{ijkl}(x_m) = C'_{pqrs} \cdot Q_{ip}(x_t) \cdot Q_{jq}(x_t) \cdot Q_{kr}(x_t) \cdot Q_{ls}(x_t). \quad (4)$$

The solution of problem (1) exists under highly restrictive conditions on the smoothness of the elastic modulus tensor ${}^4\mathbb{C}(x)$, vectors of external surface forces and displacements S_e, u_e , so we introduce the definition of a weak solution to the problem [5]. Let $S_e \in [L_2(\Sigma_\sigma)]^3$ and ω is a function from the Sobolev space such $[H^1(\Omega)]^3$ that $Tr_{\Sigma_u}(\omega_i) = u_{ei}$. Then a weak solution of the problem is an element such $\mathbf{u} \in [H^1(\Omega)]^3$ that $\mathbf{u} - \omega \in [H_0^1(\Omega)]^3$ and $\forall \mathbf{w} \in [H_0^1(\Omega)]^3$ the relation is fulfilled – the variational equation in the coordinate system x_i :

$$\int_{\Omega} (Lw)^T C(Lu) dV = \int_{\Sigma_\sigma} w^T S_e d\Sigma, \quad (5)$$

where L is the differentiation operator has the form:

$$[L] = \begin{pmatrix} \frac{\partial}{\partial x_1} & 0 & 0 & 0 & \frac{\partial}{\partial x_3} & \frac{\partial}{\partial x_2} \\ 0 & \frac{\partial}{\partial x_2} & 0 & \frac{\partial}{\partial x_3} & 0 & \frac{\partial}{\partial x_1} \\ 0 & 0 & \frac{\partial}{\partial x_3} & \frac{\partial}{\partial x_2} & \frac{\partial}{\partial x_1} & 0 \end{pmatrix} \quad (6)$$

Problem solving method

The finite element method is used to solve the elasticity problem. As an example, we will use a 10-node tetrahedron with a quadratic approximation of the solution, for which the column of shape functions has the form ($L_i = L_i(M)$ – barycentric coordinates of some point of M the tetrahedron [6]):

$$\varphi = \begin{pmatrix} L_1(2L_1 - 1) \\ L_2(2L_2 - 1) \\ L_3(2L_3 - 1) \\ L_4(2L_4 - 1) \\ 4L_1L_2 \\ 4L_1L_3 \\ 4L_1L_4 \\ 4L_2L_3 \\ 4L_2L_4 \\ 4L_3L_4 \end{pmatrix} \quad (7)$$

The resulting system of linear equations is represented as follows:

$$\sum_{K \in D_n} e_{l(K,n)}^T (GT_K(u_h) - f_k) = 0, n = 1..N, \quad (8)$$

$$G = \int_K B^T C B d\Omega, f_K = \int_{\partial K \cap \Sigma_\sigma} (\varphi \otimes E_3) S_e d\Sigma, B = L(\varphi^T \otimes E_3), \quad (9)$$

where D_n – the set of finite elements containing the degree of freedom with number, $l(K,n)$ – local degree of freedom number in the column $T_K(u_h)$, $T: [H^1(\Omega)]^3 \rightarrow \mathbb{R}^3$ – operator that matches functions from $[H^1(\Omega)]^3$ a column of its values in the nodes of the finite element; $L_i = L_i(M)$ are the barycentric coordinates of some point M tetrahedron.

Finite element approximation Ω_i^h areas Ω_i plunges into the Voronoi diagram [7]:

$$\Omega_i^h \subset \bigcup_{j=1}^{M_i} \Omega_{ij}^h, \Omega_{ij}^h = \{x \in \mathbb{R}^3 : \rho(x, w_j) = \min_{k=1..M_i} \rho(x, w_k)\}, \quad (10)$$

where w_j are the central points of the broken lines approximating the central lines of the winding threads. Where in:

$$Q(x)|_{x \in \Omega_{ij}^h} = (\tau_j \quad \mathbf{c}_j \quad \mathbf{n}_j) = const, \quad (11)$$

$$\mathbf{c}_j = \frac{\mathbf{n}_j \times \tau_j}{|\mathbf{n}_j \times \tau_j|}, \quad (12)$$

where τ_j is the vector of the tangent to the center line of the thread; \mathbf{n}_j is the normal to the center line of the thread (Fig. 1).

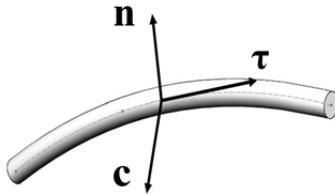


Fig. 1. Local coordinate system

Points w_j with radius vectors ρ_i for a given geodesic are determined by the Taylor formula with correction:

$$\rho_{j+1} = P_\Sigma \circ (\rho_j + \tau_j \Delta s_j + o(\Delta s_j)), \tau_j = t_j \cos(\alpha_j) + b_j \sin(\alpha_j), \quad (13)$$

where t_j, b_j are the vectors of tangents to the meridian and the parallel passing through the given point; α_j is the angle between the meridian and the geodesic passing through the given point; P_Σ is the projection operator on the middle surface.

The geodesic curve is distinguished based on Clairaut's theorem:

$$r_j \sin(\alpha_j) = r_0 \sin(\alpha_0), \quad (14)$$

where r_j is the cylindrical radius of the point w_j , r_0, α_0 – define the starting point and direction of the geodesic.

Results of the calculation of the stress-strain state of a pressure cylinder formed by a composite spiral winding along geodesic lines

The geometry of the pressure cylinder was built (Fig. 2) in the SolidWorks program, consisting of three sub-areas:

1. A shell formed on the basis of a cylinder with a radius $a = 0.15$ m.
2. Shell, based on five interpolating cubic splines of the class C^2 [8] with boundary conditions IV of the type with the following initial data (in meters), which were calculated using the formulas from Vasiliev's handbook [9] for the pole hole $r_0 = 0.065$ m, cylinder radius $a = 0.15$ m and flange radius $b = 0.1$ m:

$$\begin{aligned} r_1 &= 0.0825, r_2 = 0.1, r_3 = 0.12, r_4 = 0.14, r_5 = 0.15, \\ z_0 &= 0.01, z_1 = 0.012767, z_2 = 0.018117, z_4 = 0.050463, z_5 = 0.085345. \end{aligned}$$

3. Flange with radius $b = 0.1$ m.

In the program, ANSYS a finite element mesh was built for the obtained geometry of the pressure cylinder from SolidWorks (Fig. 2).

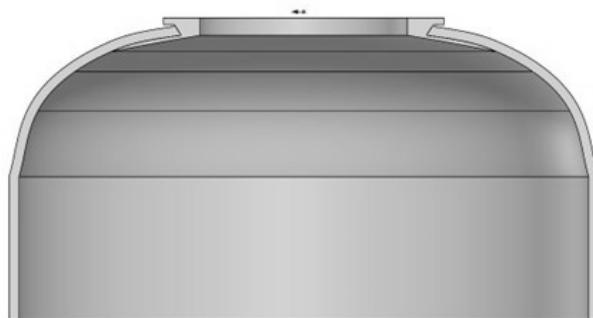


Fig. 2. SolidWorks pressure vessel geometry

In the Maple program, the calculated centers of the links of broken lines approximating the central lines of threads built along geodesic lines were visualized (Fig. 3).

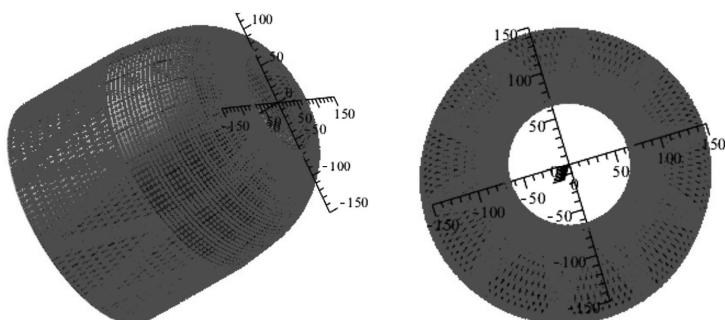


Fig. 3. Centres of links of the polyline approximating the centre lines of the spiral winding yarns plotted from the geodesic lines

The Voronoi diagram showing the belonging of the finite element to the centers of broken links approximating the central lines of helical winding threads built along geodesic lines is shown in Fig. 4.

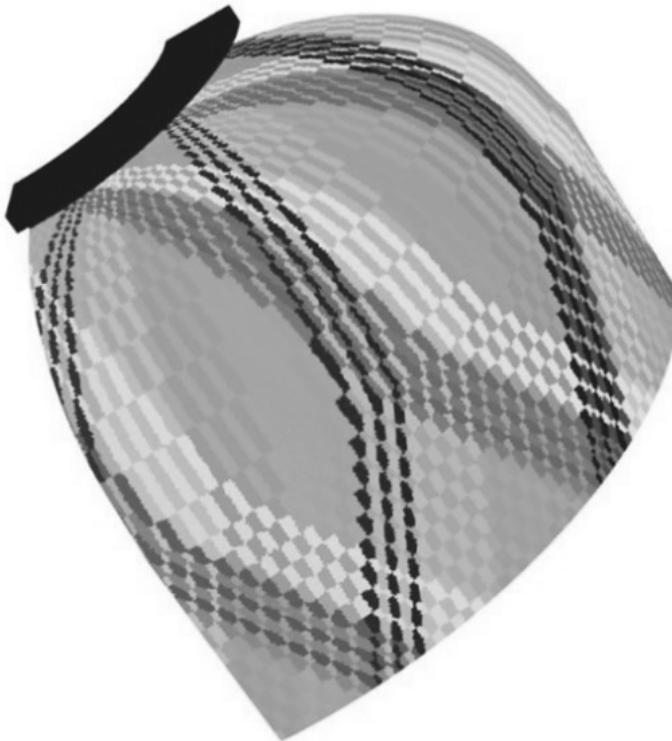


Fig. 4. Voronoi diagram for a pressure balloon formed by spiral winding with composite strands along geodesic lines

The material of threads was chosen, the elastic properties of which are presented in Table.

Elastic properties of the material of the winding threads

E_1 , GPa	216
E_2 , GPa	57
E_3 , GPa	57
G_{12} , GPa	12.41
G_{13} , GPa	12.41
G_{23} , GPa	3.677
ν_{12}	0.21
ν_{13}	0.21
ν_{23}	0.30

The following boundary conditions were set:

- the upper base of the flange has $U_3 = 0$;
- the internal pressure is 50 atm.

The results of calculating the stress-strain state of the studied pressure cylinder using the SMCM software package based on the finite element method using the inverse Cuthill — McKee algorithm [10]: in the Cartesian coordinate system (Fig. 5–8).

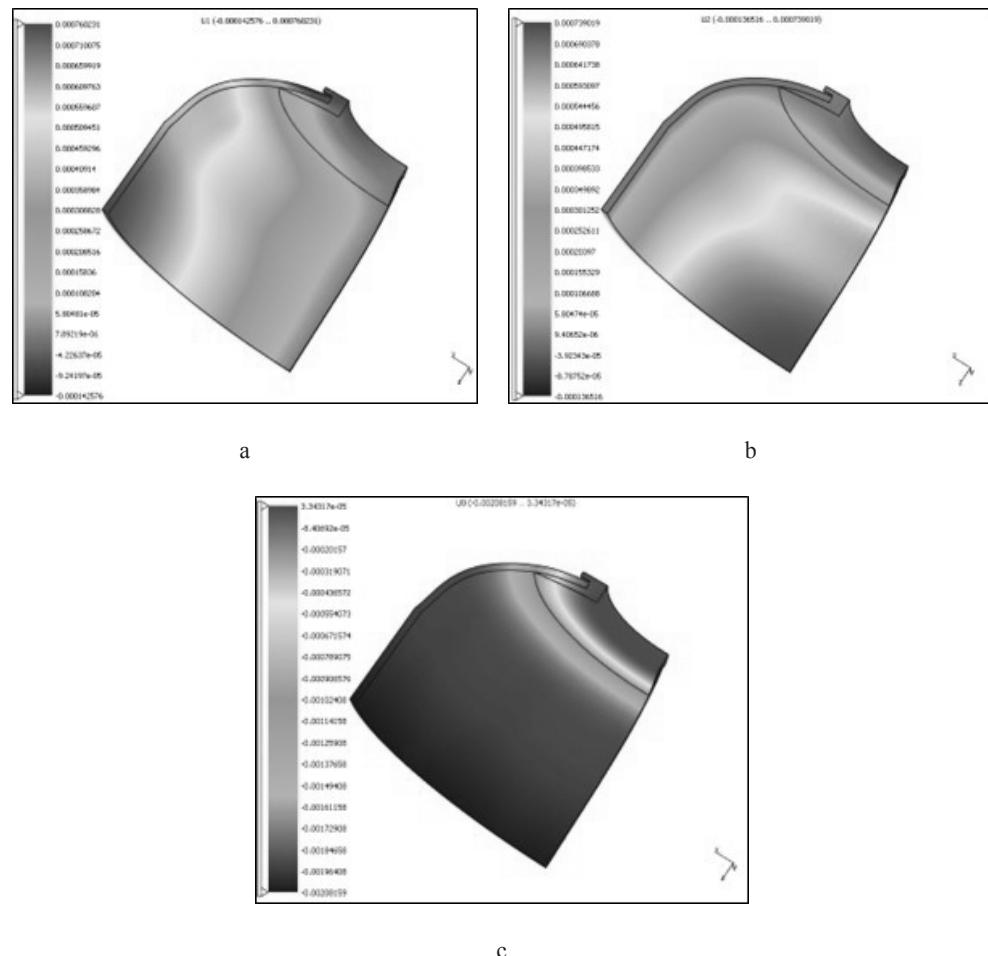


Fig. 5. Displacement field:
a — U_1 , м; b — U_2 , м; c — U_3 , м

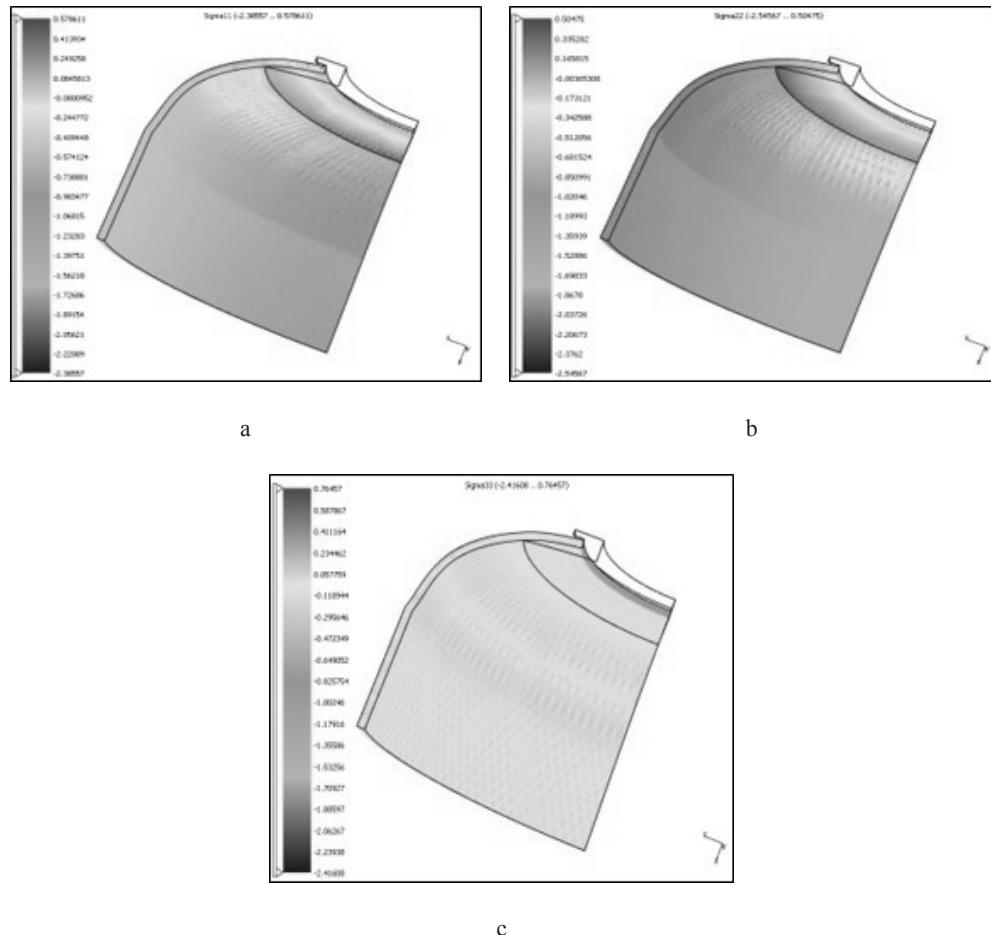


Fig. 6. Stress field:
a — σ_{11} , GPa; b — σ_{22} , GPa; c — σ_{33} , GPa

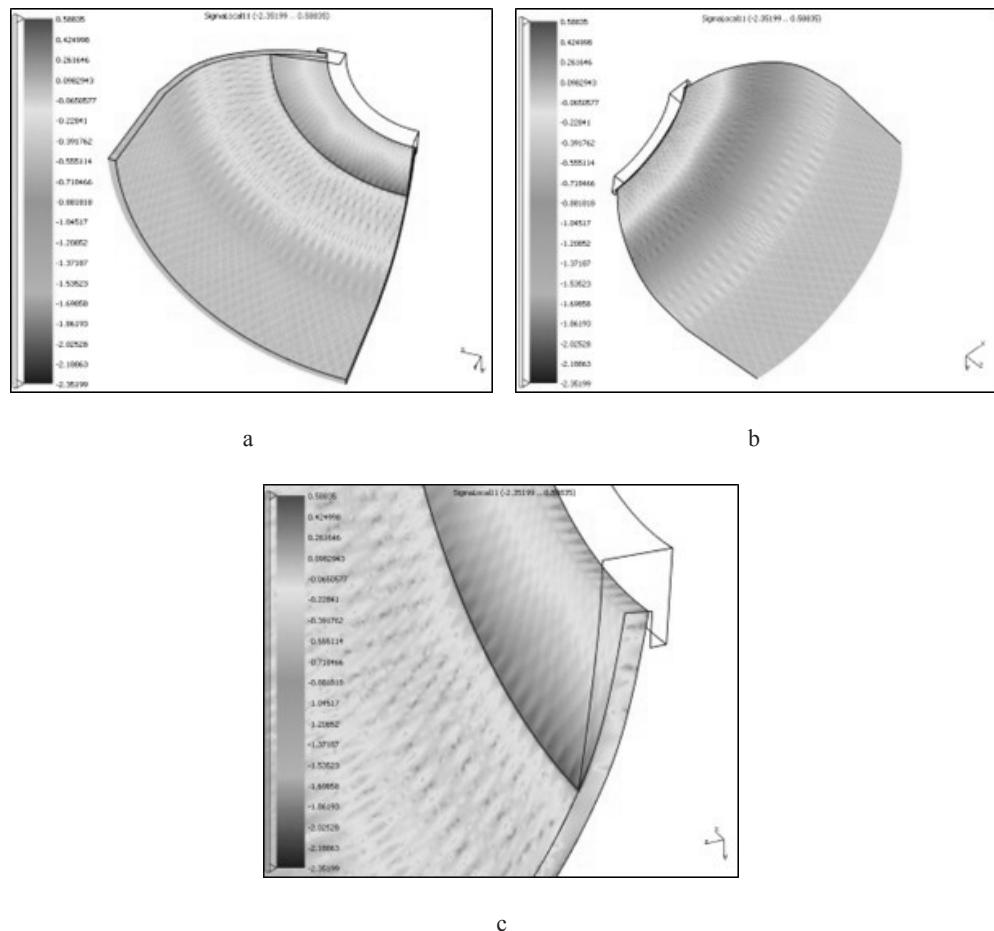


Fig. 7. Stress field, σ_{11}^{loc} , GPa;
 a — inner side of the pressure container; b — outer side of the pressure container;
 c — flange feather

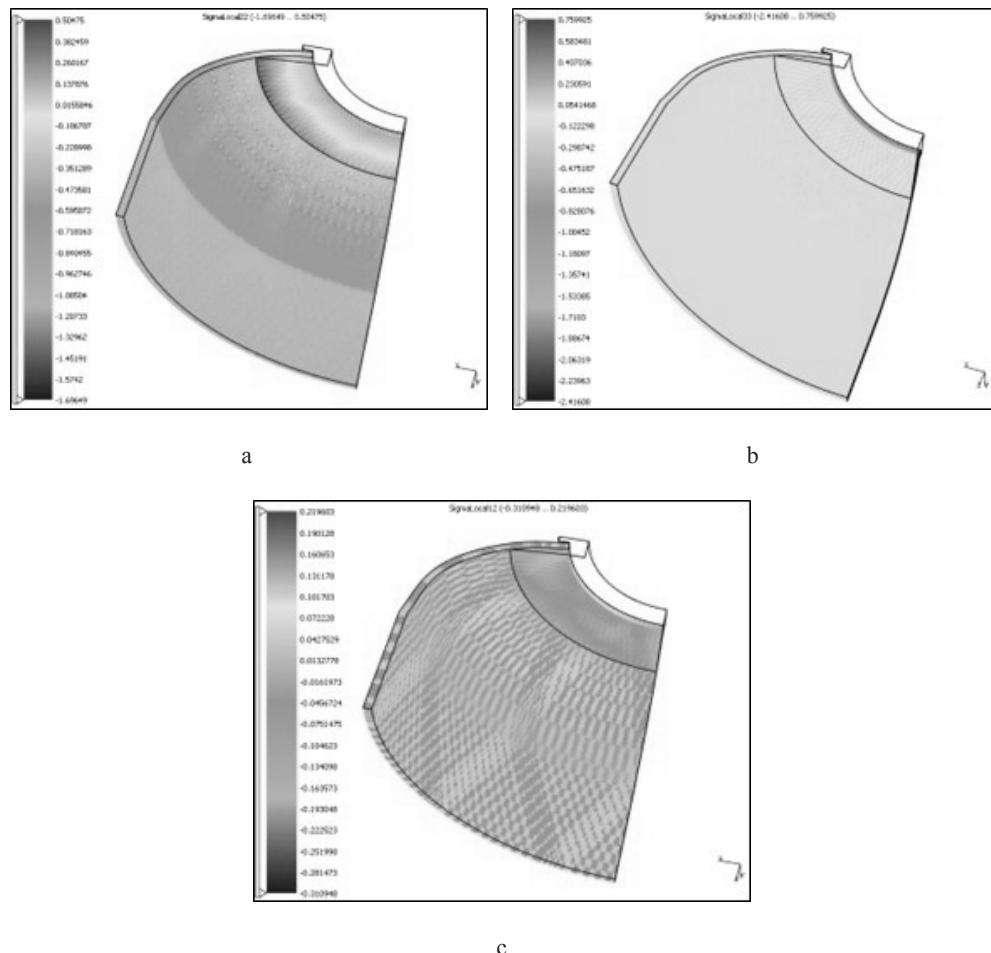


Fig. 8. Stress field:
a — σ_{22}^{loc} , GPa; b — σ_{33}^{loc} , GPa; c — σ_{12}^{loc} , GPa

Conclusion

A geometric3D model of the pressure cylinder was created, taking into account the spiral winding of composite threads along geodesic lines. Ball has developed a finite element method for modeling the stress-strain state of a winding composite pressure cylinder, taking into account curvilinear anisotropy. Numerical modeling of the stress-strain state of a winding composite pressure cylinder was carried out.

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Вычисление асимптотической ковариационной матрицы для обобщённой экспоненциальной авторегрессионной модели Озаки для метода наименьших квадратов

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Математические модели высоких порядков и их теоретические свойства — предмет активных исследований на протяжении последних нескольких десятилетий. Они играют важную роль в решении современных проблем в областях экономики, финансов, инжиниринга и медицины. Одним из их наиболее популярных и используемых на практике примеров является обобщенная экспоненциальная авторегрессионная модель Озаки. Вычислена асимптотическая ковариационная матрица этой модели для метода наименьших квадратов с помощью разложения в ряд Тейлора. Асимптотическая ковариационная матрица позволяет предсказать поведение модели на бесконечно большом наборе тренировочных данных.

Ключевые слова: обобщенная экспоненциальная авторегрессионная модель, метод наименьших квадратов, асимптотическая ковариационная матрица, разложение в ряд Тейлора

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Calculation of the Asymptotic Covariance Matrix for the Generalized Exponential Ozaki's Autoregressive Model for the Least Square Method

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High-order mathematical models and their theoretical properties have been the subject of active research over the past few decades. They play an important role in solving modern economic, financial, engineering and medical problems. One of their most popular examples is the generalized exponential autoregressive Ozaki's model. In the proposed work the asymptotic covariance matrix of this model is calculated for estimation by the least squares method by its Taylor expansion. The asymptotic covariance matrix allows to predict the behavior of the model on an infinite number of observations.

Keywords: *generalized exponential autoregressive model, least squares method, asymptotic covariance matrix, taylor series expansion*

Introduction

Active development and cheapening of modern hardware computing systems stimulates the complication of mathematical modeling methods and their free parameters number increase. It results in improvement of predictions quality of the latter. Today, high-order models are used along with neural networks and other machine learning methods in a number of promising areas of science and engineering: algorithmic trading on stock exchanges [1], bioinformatics [2], insurance risk assessment [3] and seismic stability testing of architectural projects [4]. One of the families of such models is the generalized exponential autoregressive Ozaki's model [5] and its various modifications. Despite the renewed interest in high-order classical mathematical models, their theoretical properties are still not researched enough.

Purpose

This paper aims to find the asymptotic covariance matrix of the generalized Ozaki's model for least squares estimation method, which gives understanding of model's behavior on an infinitely large number of data points.

Method

Problem statement. The generalized exponential autoregressive Ozaki's model is defined by the following equation:

$$X_t = \sum_{i=0}^{p-1} (a_i + b_i \cdot e^{-c \cdot X_{t-1}^2}) \cdot X_{t-(i+1)} + \xi_t, \quad (1)$$

where $a_0, b_0, a_1, b_1, \dots, a_{p-2}, b_{p-2}, a_{p-1}, b_{p-1}, c$ — rational model's parameters;

$\xi_t, t = 0, 1, \dots$ — a sequence of independent random variables, satisfying the following conditions:

- $E\xi_t = 0$, i. e. it has zero mean;
- $D\xi_t = E\xi_t^2 = \sigma^2 < +\infty$ — finite variance.

The sequence ξ_t is called renewal process.

Let's assume, that process X_t satisfies equation (1), and there are n its observations: $X_0, X_1, \dots, X_{n-2}, X_{n-1}$. So its parameters can be estimated via the least squares method (LSM), which is a solution of optimization problem of the following function:

$$g_{l.s.m.}(a_i, b_i, c)_{i=0,1,\dots,p-1} = \sum_{t=p}^n (X_t - \sum_{i=0}^{p-1} (a_i + b_i \cdot e^{-c \cdot X_{t-1}^2}) \cdot X_{t-(i+1)})^2.$$

The task is to obtain the asymptotic behavior of the estimates of the least squares method (the behavior of the estimates for $n \rightarrow +\infty$), that is, to calculate the asymptotic covariance matrix of the estimate $g_{l.s.m.}(a_i, b_i, c)_{i=0,1,\dots,p-1}$. For brevity, henceforth $g_{l.s.m.}(a_i, b_i, c)_{i=0,1,\dots,p-1}$ will be denoted as $g(a_i, b_i, c)$.

Asymptotic covariance matrix calculation. Let's approximate the function $g(a_i, b_i, c)$ with the Taylor's expansion in the vicinity of a specified point $(\tilde{a}_i, \tilde{b}_i, \tilde{c})_{i=0,1,\dots,p-1}$, where \tilde{a}_{i_1} and \tilde{b}_{i_2} are arranged sequentially at $i_1 = i_2$ up to the second order inclusively:

$$\Theta = \sqrt{n} \cdot \left((a_i - \tilde{a}_i), (b_i - \tilde{b}_i), (c - \tilde{c}) \right)_{i=0,1,\dots,p-1},$$

$$A = \frac{1}{\sqrt{n}} \cdot \left(\frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial a_i}, \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial b_i}, \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial c} \right)^T_{i=0,1,\dots,p-1},$$

$$B = \frac{1}{n} \cdot \begin{pmatrix} \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial a_i \partial a_j} & \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial a_i \partial b_j} & \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial a_i \partial c_j} \\ \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial b_i \partial a_j} & \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial b_i \partial b_j} & \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial b_i \partial c_j} \\ \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial c \partial a_j} & \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial c \partial b_j} & \frac{\partial^2 g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial c^2} \end{pmatrix}_{i=0,1,\dots,p-1, j=0,1,\dots,p-1}$$

where the derivatives (second derivatives) by a_{i_1} and b_{i_2} (a_{j_1} and b_{j_2}) are placed sequentially when $i_1 = i_2$ ($j_1 = j_2$).

In these notation:

$$g(a_i, b_i, c) = g(\tilde{a}_i, \tilde{b}_i, \tilde{c}) + A^T \cdot \Theta + \frac{1}{2} \cdot \Theta^T \cdot B \cdot \Theta + \delta(a_i, b_i, c),$$

where $\delta(a_i, b_i, c)$ — an infinitesimal function, which order is higher than order of $\sum_{i=0}^{p-1} ((a_i - \tilde{a}_i)^2 + (b_i - \tilde{b}_i)^2) + (c - \tilde{c})^2$, when $(a_i, b_i, c)_{i=0,1,\dots,p-1} \rightarrow (a_i, b_i, c)_{i=0,1,\dots,p-1}$.

Let's make a direct differentiation of column-verctor A , and then a direct differentiation of Hessian matrix B , taking into account that $(X_t - \sum_{i=0}^{p-1} (a_i + b_i \cdot e^{-c \cdot X_{t-1}^2}) \cdot X_{t-(i+1)})^2 = \xi_t^2$. Calculations are skipped for short.

It can be assumed that the considered model (1) is stationary and ergodic. It depends on the following conditions [6]:

- $c > 0$ — otherwise, the multiplier $e^{-c \cdot X_{t-1}^2}$ tends to infinity;
- $|a_i| < 1, i = 0, 1, \dots, p-1$;
- $\sigma^2 < +\infty$.

The consequence of the stationarity and ergodicity of the model is the presence of the limit $\lim_{n \rightarrow \infty} B$. Let's calculate it. Further calculations depend on the fact that the product of two stationary and ergodic sequences is a stationary and ergodic sequence [7]. It's worth to note, that all members, which include ξ_t , are equal to 0, because $E\xi_t = 0$ by paper's assumptions. Calculations are skipped for short.

Thus, $\lim_{n \rightarrow \infty} B = 2 \cdot K$, where elements of the matrix K are the corresponding limits of derivatives divided by n .

Hence, $g(a_i, b_i, c) = g(a_i, b_i, c) + A^T \cdot \theta + \theta^T \cdot K \cdot \theta + \delta(a_i, b_i, c)$.

Let's prove that asymptotic distribution of $(\hat{a}_i, \hat{b}_i, \hat{c})_{i=0,1,\dots,p-1}$, the minimum point of function $g(a_i, b_i, c)$, is nothing else than the asymptotic distribution of the minimum point for quadratic form $A^T \cdot \theta + \theta^T \cdot K \cdot \theta$, and its minimum is $-2 \cdot K^{-1} \cdot A$.

Let's introduce an error in the calculation of true values X_t :

$$E_t = \sum_{i=0}^{p-1} \left((a_i + b_i \cdot e^{-c \cdot X_{t-1}^2}) \cdot X_{t-(i+1)} + \xi_t \right) - (\hat{a}_i + \hat{b}_i \cdot e^{-\hat{c} \cdot X_{t-1}^2}) \cdot X_{t-(i+1)},$$

where $\hat{a}_i, \hat{b}_i, \hat{c}, i = 0, 1, \dots, p-1$ — approximations of true values $a_i, b_i, c, i = 0, 1, \dots, p-1$.

Let's define the quadratic error function as

$$L(\hat{a}_i, \hat{b}_i, \hat{c}) = \sum_{t=p}^n (\rho(E_t) - \rho(\xi_t)), \rho(x) = x^2.$$

Let's use variable substitution $\hat{a} = \sqrt{n} \cdot (\hat{a}_i - a_i, \hat{b}_i - b_i, \hat{c} - c)$ and rewrite $L(\hat{a}_i, \hat{b}_i, \hat{c})$ with its infinite Taylor's expansion:

$$L(\hat{a}) = \sum_{k=1}^{\infty} \frac{\partial^k \sum_{t=p}^n E_t}{\partial \hat{a}^k} \cdot \hat{a}^k \cdot \frac{1}{k!} = \sum_{k=1}^{\infty} \frac{\partial^k \sum_{t=p}^n E_t}{\partial (\hat{a}_i, \hat{b}_i, \hat{c})^k \cdot \sqrt{n}^k} \cdot \hat{a}^k \cdot \frac{1}{k!}.$$

Let's use the modified first order Taylor's expansion formula with the remainder term in Lagrange form and calculate the vector of the first derivatives and the Hessian matrix of the second derivatives of the function $L(\hat{a})$. Obviously, the latter, up to notation, will coincide with the first and second derivatives of the function $g(\tilde{a}_i, \tilde{b}_i, \tilde{c})$.

The result of it is $L(\hat{a}) = A^T \cdot \hat{a} + 2 \cdot \hat{a}^T \cdot B \cdot \hat{a} + \beta(\hat{a})$, $\beta(\hat{a}) = \hat{a}^T \cdot \left(\frac{\partial^2 L}{\partial \hat{a}^2}(\tilde{a}) - \frac{\partial^2 L}{\partial \hat{a}^2}(0) \right) \cdot \hat{a}$, where $\tilde{a} \in [0, \hat{a}]$. Let's show that $\beta(\hat{a}) \rightarrow 0$ when $n \rightarrow \infty$.

To do this, let's explicitly calculate the coordinate-wise values of the matrix $\left(\frac{\partial^2 L}{\partial \hat{a}^2}(\tilde{a}) - \frac{\partial^2 L}{\partial \hat{a}^2}(0) \right)$ elements, taking into account the fact that both X_t and ξ_t are stationary and ergodic. Calculations are skipped for short.

It was shown, that $E|\beta(\hat{a})| \rightarrow 0$ when $n \rightarrow \infty$, which means that $\beta(\hat{a}) \rightarrow 0$ when $n \rightarrow \infty$ by probability.

Let's define α as a minimum of new function $\tilde{L}(a) = A^T \cdot a + 2 \cdot a^T \cdot W \cdot \tilde{a}$, where $W = E(\rho''(\xi_t)) \cdot K < \infty$, then it's obvious, that $\tilde{a} = W^{-1} \cdot A$ due to the fact, that $\tilde{L}(a)$ is a quadratic form.

Since $E((\xi_t^2)') = E(2 \cdot \xi_t) = 0$ and $E(2 \cdot \xi_t)$ is independent from X_t , then $E[\rho'(\xi_t) \cdot X_t | \mu_{t-1}] = 0$, where μ_t is a sequence σ -algebras, generated by the set $\xi_s, s \leq t$. According to the central limit theorem for martingals [8] it can be shown that column column-vector A is asymptotically normal with zero mean and covariance matrix $K \cdot E[(\xi_t')^2]$. As a result of it random variable $\tilde{a} = W^{-1} \cdot A$ is also asymptotically normal with zero mean, and its covariance matrix value is $K^{-1} \cdot E[(\xi_t')^2]$. Therefore, it remains only to prove that $\hat{a} - \tilde{a} \rightarrow 0$ by probability.

To prove the latter, let's introduce an arbitrary one $\delta > 0$ and show, that $P[|\hat{a} - \tilde{a}| \leq \delta] \rightarrow 1$. To do this, let's fix some δ [9].

Since \tilde{a} is asymptotically normal, it is also bounded by distribution, which means that \exists such a compact set $C \in \mathbb{R}^2$ with a probability, infinitely close to 1, which contains for all n values at once spheres with center \tilde{a} and radius δ .

As a consequence of the large numbers law we get that $B \rightarrow W$ when $n \rightarrow \infty$, and hence $L(a) - \tilde{L}(a) \rightarrow 0$ when $n \rightarrow \infty$ by probability. Therefore a convex function $L(a) + +A^T \rightarrow \frac{1}{2}a^T \cdot W \cdot a$ when $n \rightarrow \infty$. So, $\beta(\tilde{a}) \rightarrow 0$ uniformly for \forall compact. According to [10] this implies, that $\Delta = \sup_{a \in C} |\beta(a)| \rightarrow 0$ when $n \rightarrow \infty$ by probability.

Let e be an arbitrary normalized vector such that the equalities hold:

- $a^* = \tilde{a} + \delta \cdot e$;
- $a = \tilde{a} + t \cdot e, t > \delta$.

Then from the convexity of $L(a)$ it turns that $L(a^*) \geq \left(1 - \frac{\delta}{t}\right) \cdot L(\tilde{a}) + \frac{\delta}{t} \cdot L(a)$ and hence $L(a) \geq L(\tilde{a}) + \frac{t}{\delta} \cdot (L(a^*) - L(\tilde{a})) \geq L(\tilde{a}) + \frac{t}{\delta} \cdot (\tilde{L}(a^*) - \tilde{L}(\tilde{a})) + \beta(a^*) - \beta(\tilde{a})$. It is obvious, that matrix W is positively defined, therefore $\tilde{L}(a^*) - \tilde{L}(\tilde{a}) = \frac{1}{2} \cdot \delta^2 \cdot e^T \cdot W \cdot e > 0$, and hence $\inf_{a \notin C} L(a) = L(\alpha) + \inf_{t > \delta} \frac{t}{\delta} \cdot (L(\alpha a^*) - L(\tilde{a})) \geq L(\tilde{a}) + \frac{1}{2} \cdot \delta^2 \cdot e^T \cdot W \cdot e - 2 \cdot \Delta$. Therefore, with unit probability, the minimum of $L(a)$ lies inside the compact set C , which means that the minimum of the function g really coincides with the minimum of the quadratic form, is asymptotically normally distributed and equals to $-0.5 \cdot K^{-1} \cdot A$.

In order to find the asymptotic distribution of a random vector $-0.5 \cdot K^{-1} \cdot A$, let's firstly prove, that its component, column-vector A , is asymptotically normal, i.e., it converges to a normal random vector by distribution when $n \rightarrow \infty$.

Let A_t be an events σ -algebra, generated by the set $\{X_s, s \leq t\}$. The consequence of this is that X_{t-1} is measurable with respect to A_{t-1} . Taking into account the fact that ξ_t is independent from A_t we get that $E[\xi_t \cdot X_{t-1} | A_{t-1}] = X_{t-1} \cdot E[\xi_t | A_{t-1}] = X_{t-1} \cdot E\xi_t = 0$ [11].

In addition due to the fact that $D\xi_t = E\xi_t^2 = \sigma^2 < +\infty$, it's obtained that $EX_{t-1}^2 < +\infty$, and hence by the central limit theorem for martingales [12] the sequences

$$\frac{1}{\sqrt{n}} \cdot \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial a_i}, \frac{1}{\sqrt{n}} \cdot \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial b_i}, \frac{1}{\sqrt{n}} \cdot \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial c}$$

are normal.

Since the random variables X_{t-1} and ξ_t are independent and by paper assumption that $E\xi_t = 0$ then:

$$\begin{aligned}
 E \frac{1}{\sqrt{n}} \cdot \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial a_i} &= \frac{2}{\sqrt{n}} \sum_{t=p}^n E [\xi_t \cdot X_{t-(i+1)}] = \\
 &= \frac{2}{\sqrt{n}} \sum_{t=p}^n E \xi_t \cdot EX_{t-(i+1)} = \frac{2}{\sqrt{n}} \sum_{t=p}^n 0 \cdot EX_{t-(i+1)} = 0, \\
 E \frac{1}{\sqrt{n}} \cdot \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial b_i} &= \frac{2}{\sqrt{n}} \sum_{t=p}^n E [\xi_t \cdot e^{-c \cdot X_{t-1}^2} \cdot X_{t-(i+1)}] = \\
 &= \frac{2}{\sqrt{n}} \sum_{t=p}^n E \xi_t \cdot E e^{-c \cdot X_{t-1}^2} \cdot X_{t-(i+1)} = \frac{2}{\sqrt{n}} \sum_{t=p}^n 0 \cdot E e^{-c \cdot X_{t-1}^2} \cdot X_{t-(i+1)} = 0; \\
 &\quad \square \\
 E \frac{1}{\sqrt{n}} \cdot \frac{\partial g(\tilde{a}_i, \tilde{b}_i, \tilde{c})}{\partial c} &= \frac{2}{\sqrt{n}} \sum_{t=p}^n E \left[\xi_t \cdot \sum_{i=0}^{p-1} b_i \cdot X_{t-(i+1)} \cdot X_{t-1}^2 \cdot e^{-c \cdot X_{t-1}^2} \right] = \\
 &= \frac{2}{\sqrt{n}} \sum_{t=p}^n E \xi_t \cdot E \sum_{i=0}^{p-1} b_i \cdot X_{t-(i+1)} \cdot X_{t-1}^2 \cdot e^{-c \cdot X_{t-1}^2} = \frac{2}{\sqrt{n}} \sum_{t=p}^n 0 \dots = 0.
 \end{aligned}$$

Taking into account that $D\xi_t = E\xi_t^2 = \sigma^2 < +\infty$ corresponding variances can be calculated. Calculations are skipped for short.

Thus, in all cases, we obtain a zero mathematical expectation and finite variances, which can be calculated using the formulas given above.

By analogy, limits of mathematical expectations of pairwise products of elements of the column vector A can be calculated.

By calculating all variances and mathematical expectations, it can be concluded that the random vector A is asymptotically normal with zero mathematical expectation and covariance matrix $4 \cdot \sigma^2 \cdot K$. Therefore, the asymptotic covariance matrix of the vector $-0.5 \cdot K^{-1} \cdot A$ is $\sigma^2 \cdot K^{-1}$ [13].

Taking into account that the asymptotic distribution of $-0.5 \cdot K^{-1} \cdot A$ coincides with the asymptotic distribution of the minimum point of the function $g(a_i, b_i, c)$, it's obtained, that the asymptotic covariance matrix of the generalized exponential Ozaki's autoregressive model for the least squares method of estimation is $\sigma^2 \cdot K^{-1}$.

Relevance and novelty

Despite the renewed interest in high-order classical mathematical models, their theoretical properties are still not researched enough. So finding of asymptotic covariance matrix is really actual and useful from both practical and theoretical views.

Conclusions

In this paper is was shown, that the asymptotic covariance matrix of the generalized exponential Ozaki's autoregressive model for the least squares method of estimation is $\sigma^2 \cdot K^{-1}$.

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Многостадийный сценарий индуцированного подвижностью фазового разделения в ланжевеновской динамике

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Разделение фаз, индуцированное подвижностью (MIPS), является одной из отличительных особенностей систем активных самодвижущихся частиц. Несмотря на недолгую историю изучения этого феномена, есть много результатов. Однако большинство результатов получено для броуновских систем, а эффекты инерции изучены слабо. Одним из немногих известных эффектов инерции для MIPS являются разные значения средней кинетической энергии в конденсированной и газовой фазах. Эти эффекты открывают путь для взаимодействия между энерговыделением, фазовым составом системы и некоторыми другими механизмами. В результате MIPS эволюционирует не монотонно по своей фазовой диаграмме. В частности, можно выделить несколько областей разного поведения dK/dA , где K — средняя кинетическая энергия системы, а A — активность частиц.

Ключевые слова: активная материя, активная частица, MIPS, мягкая материя

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The Multi-Stage Scenario of Motility Induced Phase Separation in Langevin Dynamics

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The motility induced phase separation (MIPS) is one of the distinguishing features of active self-moving particles systems. Despite the short history of this phenomenon studies, there are a lot of results. However, most results are obtained for Brownian systems, while inertia effects are poorly studied. One of the few known effects of inertia for MIPS is different mean kinetic energy values in condensed and gas phases. These effects open a way for interplay between energy release, phase composition of the system, and some other mechanism. As a result, MIPS evolute not monotonously through its phase diagram, what we show in the present work. In particular, it is possible to distinguish several regions of different dK/dA behaviour where K is the mean kinetic energy of the system, and A is particle activity.

Keywords: active matter, active particle, MIPS, soft matter

Introduction

Active matter or active system is non-equilibrium system whose particles (active or self-propelled particles) can absorb energy from environment and transform it into unique type of motion [1], for example mesoscale turbulences [2]; migration, spontaneous creation and destruction of particle domains [3], swarming [4]. Thanks to this and for large pervasiveness in life [5], the big perspective in medicine [6], micro-robots system [7], materials science [8], clearance of environment [9] the collective dynamics of active particles attracts much attention of researchers. The most remarkable from the point of view of condensed matter physics is the motility induced phase separation effect of the separation (MIPS) without attraction between particles [10]. This effect has been systematically studied in experiments

with colloidal particles [11] and MD simulations [12]. MIPS phase diagram [13], corresponding mean-field models for MIPS [14], has been studied in over-damped (Brownian) dynamic regime. But in Langevin dynamics where inertial effects become relevant, MIPS has been studied worse than in the Brownian regime. Due to inertial effects, there are boundary values of the MIPS formation and destruction activities and different values of kinetic energy in the condensed and gas phases. And to the best of our knowledge, MIPS formation and evolution across activity in Langevin dynamics have not been systematically studied so far. In this work, we performed several series of MD simulations of a many-body active systems with Langevin dynamics. We have established that the MIPS inside the region of existence goes through several stages (regions), with a different type of particle dynamics and a characteristic form of the system. These areas can be clearly traced in the form of the derivative of the kinetic energy and the structural phase states.

MD details

We performed MD simulation of a 2D many-particles ensemble, with the following equations of motion:

$$m\ddot{\mathbf{r}} = \gamma_t \dot{\mathbf{r}} + \mathbf{F}_i + \mathbf{F}_{A,i} + \sqrt{2k_b T \gamma_t} \cdot \eta_i(t), \dot{\theta} = \sqrt{2k_b T \gamma_t} \cdot \xi_i(t)$$

where $m, \mathbf{r}_i, \theta_i$ are the mass, radius of the vector and the angle of orientation of the i -th particle, respectively. $\gamma_t = 2.0$; $\gamma_r = 0.05$ are the rates of translational and rotational damping, \mathbf{F}_i is interparticle force describing by potential of the system, $F_{A,i} = A(\cos\theta_i, \sin\theta_i)$ the active force, $A = 1, 2, 3, \dots, 56$ — the amount of activity, $\eta_i(t), \xi_i(t)$ — Gaussian zero mean white noise, $T = 0.01$ is the thermostat temperature, k_B is the Boltzmann constant.

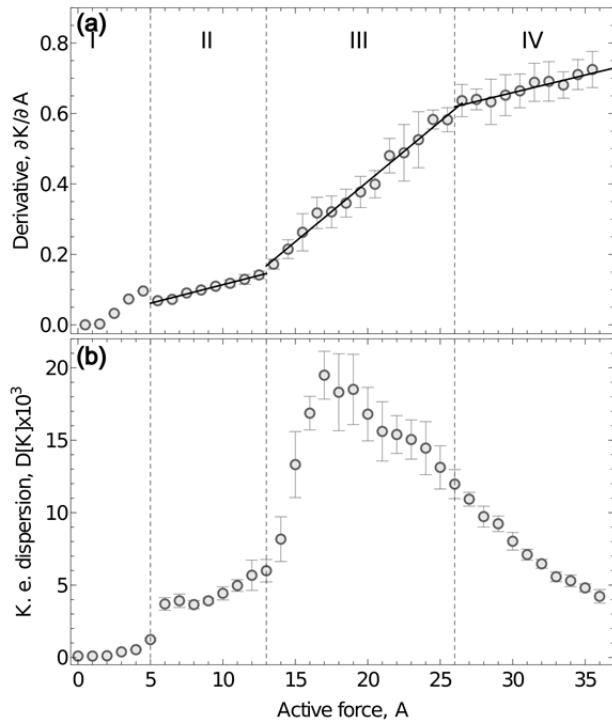
We have considered the repulsive interaction using the inverse power law potential:

$$\varphi(r) = \epsilon \left(\frac{\sigma}{r} \right)^{12}$$

where $\epsilon = 1, \sigma = 1$ are the magnitude and interaction length, respectively. We used a region box with periodic boundaries and constant average density in system $n = \frac{N}{s} = \sigma^{-2}$. The cutoff radius $r_c = 5\sigma$ the numerical time step $\Delta t = 7.7 \times 10^{-4} \sqrt{m\sigma^2/\epsilon}$. All simulations we performed using dimensionless units in HOOMD-blue [15] package, where the first $5 \cdot 10^6$ were used to relax the system, and the subsequent $5 \cdot 10^6$ for data analysis.

Results and discussion

In recent works, the critical activity values for MIPS formation and destruction for Langevin dynamics have been calculated. Analyzing the MD simulation, We found that a system with increased activity goes through several stages with different types of dynamics and system appearance. This is most clearly reflected in the form of the dependence of the derivative of the average kinetic energy on the activity, which is shown on Figure (a). Round symbols show the values of $\partial K / \partial A$ obtained by the numerical method. Solid black lines show linear fit. The error bars were obtained by averaging the indicators over 7 series of simulations. The beginning of each area is accompanied by a break in $\partial K / \partial A$, as well as discontinuities and changes in the asymptotic behavior of the dependence of the kinetic energy dispersion in the system on the activity of Figure (b).



Dependence of the derivative of the average kinetic energy on the activity:
a — multi-stage MIPS scenario on the example of the derivative of kinetic energy;
all activity value areas are colored in a unique color; b — multi-stage MIPS scenario
on the example of the kinetic energy dissipation in the system

In the first region, with the absence of activity and at its low value $A <= 1$, a horizontal shelf is visible, where the crystal lattice is preserved and the particles vibrate about their equilibrium position. With an increase in activity, the value of the derivative begins to increase, which is accompanied by the destruction of the crystal lattice of the system due to the heating of the system caused by the active force. Unstable micro-cavities of small size and short lifetime are observed. The first break in the $\partial K / \partial A$ dependence is associated with the formation of coexisting a condensed phase and a stable gas cavity in the system and its successive increase to a characteristic gas gap as the activity increases. In the third activity range, a stable gas gap is observed in the thermostat. In the latter area, MIPS becomes unstable and collapses with increased activity, thus the system goes into a hyperactive fluid state.

Conclusion

In the present paper, we have considered of inertia effect on MIPS evolution in Langevin dynamics. Analysis of MD simulation we identified four regions with different types of dynamics and system appearance. This is most clearly seen in the the dependence of the derivative of the average kinetic energy on the activity, where the beginning of each

region is accompanied by a kink. To our knowledge, the multi-stage scenario of dynamic states inside the region of MIPS is observed for the first time. We believe that our work will stimulate corresponding experiments and further theoretical studies, and will be interesting for a broad community in active matter and nonequilibrium dynamic.

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**Инженерные
технологии**

**Engineering
Technologies**

УДК 62-53

Организация управления оборудованием на предприятии и ее влияние на качество выпускаемой продукции

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Во всех областях человеческой деятельности точные, надежные и прослеживаемые измерения обеспечивают жизненно важные экономические и технические преимущества и, в конечном итоге, качественную и безопасную жизнь. Рассмотрено влияние эффективного управления оборудованием на производство качественной и конкурентоспособной продукции. Сделан вывод, что качество и безопасность продукции напрямую зависит от использования оборудования. Предложен метод повышения эффективности ухода за оборудованием.

Ключевые слова: экономическая эффективность, качество, оборудование, метрологическое обеспечение

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Organization of Equipment Management at the Enterprise and Its Impact on the Quality of Products

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In all fields of human activity, accurate, reliable and traceable measurements, more than anything else, provide vital economic and technical advantages and, ultimately, a quality and safe life. This paper examines the impact of effective equipment management on the production of quality and competitive products. The study concludes that the quality and safety of products is directly dependent on the use of equipment, and proposes a method to improve the effectiveness of universal equipment care.

Keywords: *economic efficiency, quality, equipment, metrological support*

Introduction

The modern economy and the state of domestic industry requires the development of managerial approaches to the organization of its economic activities, the development of integrated methods. The sharp change in the structure of the economy could not but affect the life of enterprises in any industry. Due to global problems associated with the spread of various viruses, climate change and other changes in the world, there are regular violations of production and economic, socio-economic and financial relationships not only within the enterprises themselves, but also between suppliers and consumers. The situation is exacerbated by the constant intensification of competition, where only those enterprises survive that are focused on the production of quality products and goods. Any enterprise lacks a flexible system that allows the development of economic and organizational-production relations in the enterprise [1].

Methods

Various types of analyses are conducted to identify problem and weak areas, reasons for failures, negative trends in development, and criticism from consumers. There are many of them in the assortment — complex economic analysis, monitoring of service provision, internal audit, inspection checks, analysis by top management, results of the year in numbers, etc., etc. Depending on the particular business entity: from concerns and companies, enterprises and organizations, laboratories and test centers, private structures to state organizations providing various services to the population, they conduct at least once a year some kind of evaluation of all their activities.

Constantly changing economic realities and growing demands of consumers make it necessary for all production systems of enterprises to switch to competent production management. When introducing innovative approaches and tools in matters of product quality improvement at enterprises, an in-depth study of related areas of knowledge in production begins. Accordingly, in practice it is necessary to face a wide range of knowledge in the field of environmental support, metrological support, economic and sales support, production and technical support.

Considering in narrow sense the complex economic analysis is the internal analysis of economic activity of the organization, directed on definition of influence of all set of technical-economic factors on efficiency of its industrial, financial and investment activity [2].

Activity of any enterprise today is under strict control of observance of requirements of normative and technical documents to production, service and application of equipment. To ensure the quality of measurements in technological processes at control and management of technological parameters it is necessary to carry out metrological analysis of all aspects of measurement procedures [3].

Metrological support of an enterprise is one of the important aspects of building a system of high-quality production. Thanks to the whole infrastructure of technical regulation and metrology it is possible not only to control quality at all stages, where measurements and tests are carried out, starting from production technology and finishing with realization, but also to estimate the level of product quality. We should not forget about the safety of manufactured products, because the final product, before being released on the market, must pass the mandatory regulatory and technical requirements and certification tests. In reality, the issue of product safety and quality is controlled at the federal and interstate level when moving goods to neighboring countries of the Customs Union and Commonwealth of Independent States.

The growing control of safe goods issued by enterprises of the Eurasian Economic Union member countries (the EAEU countries are the Republic of Armenia, the Republic of Belarus, the Republic of Kazakhstan, the Kyrgyz Republic and the Russian Federation) is evidenced by the constant implementation of measures to update technical regulations and normative legal acts in industry, medicine, ecology, food safety and other sectors of the economy. In particular metrological regulations are specified in national standards, various measurement procedures and instructions for equipment operation, in addition to mandatory requirements in the field of state regulation according to the Government Decree of the Russian Federation of April 6, 2011 No. 246 "On the implementation of the federal state metrological supervision" the list of measurements carried out in the field of state regulation of ensuring the uniformity of measurements is established [4].

Results and discussion

The whole complex of production and economic activities today involves measuring the current quality indicators, the identification of losses and analysis of production and technical factors, assessment of the effectiveness of improvements, as well as the consolidation of the effect achieved. Conducting an analysis of the indicator — material assets or equipment, one of the disadvantages in the operation of equipment, is the following:

- the high cost of technical and service maintenance of high-precision measuring instruments;
- shortage of highly qualified engineers and technicians because of the specific configuration of the equipment and complex operating principle;
- fast depreciation of equipment due to irrational operation of equipment.

The devices and machines themselves can serve without failures up to full physical and moral wear, if timely complex estimation, analysis of all technical risks, working out of service-preventive measures, systematization of repair cycle work, operative notification of sudden equipment failure, minimization of losses from idle time are obligatory and regularly carried out. Often enterprises resort to early prediction of the average lifetime of the equipment, a joint inventory with the economic unit to determine depreciation and depreciation, as well as other measures of industrial and technical nature.

The output of low-quality products is also influenced by the implementation of all technological operations and measurements on devices with expired periods of calibration,

uncalibrated measuring instruments, and uncertified testing equipment. All these inconsistencies can be identified as a result of internal audits, during verification by federal state metrological supervision, during inspections by accreditation system experts and other internal forms of audits in accordance with the implemented quality management system. It is not unimportant that product quality depends directly on the proper organization of labor and resources of an enterprise. The whole system of management or management does not forgive deliberate mistakes and the assumption of violation of all technological norms and methods of measurements, in which all engineering and technical personnel and production facilities are involved.

The emphasis on the implementation of all technical activities for the maintenance of the equipment in use was described in the scientific works of Soviet engineers and quality specialists. In particular, with preventive maintenance at the enterprise they suggested to use the system of assignment to the brigade (elimination of impersonality), appropriate instruction and training of those working with the equipment). The responsibility for the condition of equipment of foremen, masters and receivers of equipment or repair was significantly strengthened. Care and supervision of equipment were regulated in special instructions to operating and supervising personnel [5].

At all times and up to the present time the quality of a product or commodity depended on correctly built work and rational management of all processes. Foreign scientists K. Ishikawa, E. Deming and J. Juran made a great contribution to the theory of quality management, who were able to revive and multiply the potential of the Japanese economy destroyed after World War II based on the idea of quality [6].

In addition and nowadays there are different methods to improve quality, take for example the innovative approach of the Lean Manufacturing concept. Lean production (Lean manufacturing) — is a process approach to the management of the organization, aimed at improving the quality of work by reducing losses. This approach extends to all aspects of activity — from design and production, to product sales [7].

Modern enterprises are large complex dynamic and technical systems consisting of technical elements (technical subsystem), as well as people interacting with each other in processes (social subsystem). It is generally accepted that priority is given to the improvement of equipment and technology, but not to the development of human potential in the context of process organization (organization of continuous and coordinated order of flow of interrelated operations and processes in production). Each following step of technical perfection demands more and more efforts from the personnel and timely tools for increase of efficiency of productivity and quality of let out production. System Lean — is directed on improvement of quality of work by means of reduction of losses, namely technical losses in view of equipment downtime — from the main material fund of any enterprise. The essence of the given tool of lean production consists in increase of operation term of the equipment and its efficiency, and also to involve each employee of the company to maintenance of the equipment, instead of experts-technicians.

Investments aimed at expanding the resource base of the enterprise can be considered as funds going to increase the production capacity of the enterprise — increase the equipment fleet, expansion of physical production areas (new workshops) [8].

Conclusion

In practice, there are many discussions on the topic of effective management of the production and technical fund of the enterprise and its impact on quality. In fact, one thing

is unambiguous, that any used equipment, both in production of products and goods, and in the provision of various kinds of services (medical and other services) to the population, should use the equipment certified or calibrated and used as intended, checked for compliance with all its metrological and technical characteristics, timely undergo maintenance and service and preventive measures.

Anyway, in these market times many companies realize and understand that annual investments of billions in equipment can be replaced by introduction of rational and innovative methods of general equipment maintenance, which simultaneously lead to systematic elimination and implementation of preventive measures for reduction of equipment and other production resources downtime.

The importance of management of equipment, which determines the quality and safety of products, which in the process of its creation passes all stages in accordance with the requirements established for it, is substantiated. The market is a self-regulating economic system, in which mutually beneficial relations between the consumer and the producer are established, so the stimulation of the production of accurate and reliable measurements is necessary at all stages of production of quality products.

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УДК 623

Экспериментальные исследования точностных характеристик астроинерциальной навигационной системы

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Рассмотрены основные технологические аспекты развития астроинерциальных систем. Проведено экспериментальное исследование точностных характеристик навигационных параметров астроинерциальной системы проекционного типа в режиме астрокоррекции. Рассмотрена методика астронаблюдений астроинерциальной системы проекционного типа. Описан стенд для испытаний астросистемы. Проведена оценка точности астросистемы проекционного типа.

Ключевые слова: навигация, навигационная система, инерциальная навигационная система, астроинерциальная навигационная система, астрокоррекция

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Testing of the Accuracy Characteristics of the Navigation Parameters of the Stellar-inertial Navigation System

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The main technological aspects of the development of astroinertial systems are considered. An experimental study of the accuracy characteristics of the navigation parameters of an astroinertial projection-type system in the astroc糸ction mode is carried out. The method of astroinertial observations of an astroinertial projection-type system is considered. A test bench for the astrosystem is described and the accuracy of the projection-type astrosystem is made.

Keywords: navigation, navigation system, inertial navigation system, stellar-inertial navigation system, stellar correction

Introduction

The technique of astronomical observations has for many years served as a reliable and sometimes the only method of determining the location and course of an object of navigation. Even ancient Phoenicians and Egyptians used primitive astronomical navigation observing the Sun and stars to determine the correct direction. The direction to the geographic north could be recognized by the position of the Pole Star in the sky and by the position of the Sun at noon one could roughly determine the direction to the geographic south.

Astronomical navigation aids are autonomous and immune to interference, they have an unlimited range, they can be used anywhere in the world. The accuracy of navigation tasks solution with the use of astronomical means does not depend on the time of measurement or on the length of an object's path. The main disadvantage of astronomical ground navigation is its dependence on weather conditions (clouds, fog, etc.).

By the end of the 20th century astronavigation devices used for navigation and space applications and astronavigation systems of surface ships and submarines were widespread [1–4]. In marine astronavigation autonomous one- or two-channel optical (as well as radio) astronavigation systems were created. Such devices used precision optical elements to measure astronavigation parameters — heights and azimuths of single luminaries — navigation stars. Onboard catalogs of marine systems contained up to 200 names of navigational stars.

By the late 1990s and early 2000s aircraft sextants and ship-based astronavigation systems were superseded by satellite navigation systems due to their improved operational characteristics, high level of automation and accuracy. In addition to the above mentioned sea-based systems were losing their popularity due to considerable weight and size characteristics, high cost and, in general, low efficiency of combat application [4]. Thus, means and methods of astronavigation in aviation and on fleet were considered as reserve means of correction. The period of exclusion of astronavigation systems from naval navigation means began in the navy. Navigators returned to the traditional methods of measurement using a hand sextant or visual direction finder to solve the problems of positioning and correcting the heading system. The only improvement is refinement of software and mathematical support of electronic cartographic navigation systems for automated solution of astronavigation tasks. Thus, according to some experts astronavigation systems began to lose their relevance.

At the same time, during this period there was active scientific and practical research in the field of creating astronavigation systems in manned and autonomous cosmonautics. Stellar orientation sensors were significantly developed, electronic fundamental catalogs of new generation containing coordinates of several thousands of luminaries as well as optoelectronic devices of high resolution based on CMOS-matrices were created [5–7].

The above processes as well as qualitative changes in the production of inertial sensors (gyroscopes and accelerometers) have led to the emergence of a new generation of astro-inertial navigation systems (AINS) in airborne and space navigation [8, 9].

A new generation of astronavigation systems is based on a wide-angle lens with a matrix receiver of optical signals (an astro-measuring unit or star sensor (SG)), an inertial measurement unit (IMU) based on fiber-optic (VOG) or laser (LG) gyroscopes, accelerometer and calculator structurally implemented on a common platform, where the above components are placed [10]. Let us refer to the systems of the above design as astroinertial navigation systems of projection type, their operation being based on digital maps of the starry sky or on the field of astronavigation landmarks.

Due to modern technological achievements, AINS of projection type have a small weight and dimensions, has the necessary accuracy and performance characteristics and can be installed on air and sea carriers of different classes. The appearance of such systems and real data on possible suppression or impossibility to use global satellite navigation systems resulted in the need of return of astronavigation systems on sea objects. Such systems in sea navigation become especially important for the estimation of navigational data production quality by modern complexes and navigational systems, first of all, control of course accuracy far from observable reference points, which are obtained by astronomical methods. There remains the dependence on the state of clouds but the experience of application even at polar latitudes shows the possibility of periodic daily observation of stars.

For installation on marine objects it is advisable to use stabilization systems to compensate for rocking and pointing to luminaries in cloud gaps.

From the point of view of astronavigation methods a fundamental difference of new developments from the first generation astronavigation systems is both the way of sighting of astronavigation landmarks and the measured astronavigation parameters themselves.

The purpose of this research is to experimentally investigate the accuracy of the navigation parameters of an astroinertial system of projection type in astrocorrection mode. The goal of the study was to determine the time dependences of the product coordinates and compare them with the reference ones from a satellite. The time dependence of the course angle was also determined. The practical significance of this work lies in the development of test methods for testing the accuracy characteristics of the astroinertial system of the projection type under operational conditions.

Performing measurements in astrocorrection mode

The research was conducted on a specially equipped site in Tarasovka village, Pushkinsky district, Moscow region.

The coordinates of the field test bench are $55^{\circ}58' 3''\text{N}$, $37^{\circ}51' 38''\text{E}$ (Fig. 1).

Description of the test bench. Elements of the test bench (Fig. 2) are given below:

- 1 — the model of an astrosystem (Fig. 3);
- 2 — the rotary table KPA-5;
- 3 — a laptop with installed software;

- 4 — INSTEK GPS-74303A power supply;
bubble level 1: 1000;
5 — a set of technological harnesses and cables;
a set of laboratory furniture (trolley, chairs).
The test bench is powered with AC at 220 V, 50 Hz.

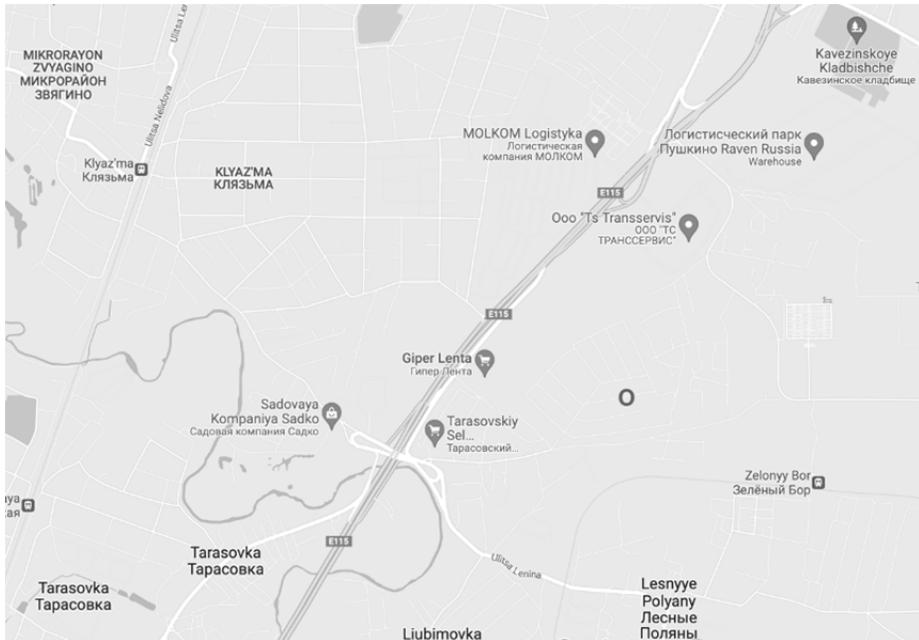


Fig. 1. Map showing the bench tests location



Fig. 2. The test bench



Fig. 3. The model of an astrosystem on a KPA-5 turntable

A block diagram of the test bench is shown in Fig. 4.

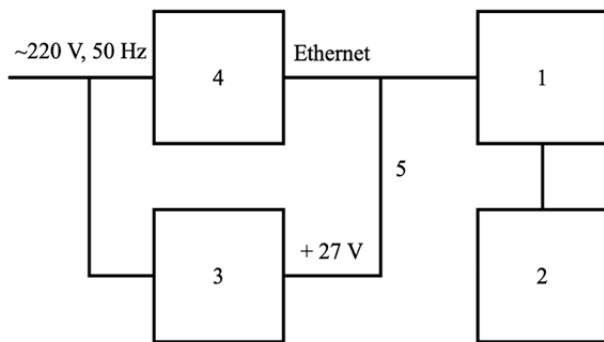


Fig. 4. Block diagram of the test bench

The technical characteristics of the KPA-5 turntable are given below:

Turning angles:

- around the vertical axis — not less than ± 360 ;
- around the horizontal axis — not less than ± 25 ;
- around the second horizontal axis — not less than ± 45 .

Horizontal table setting accuracy (with zero level readings and offset of zero divisions of nonius and scales) — up to ± 10 .

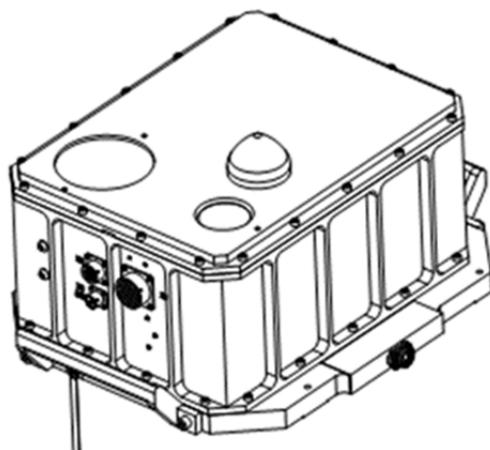


Fig. 5. External view of the astronavigation system layout

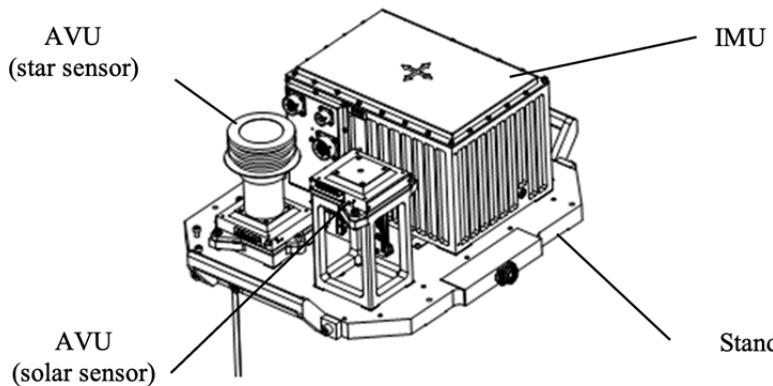


Fig. 6. The layout of the astronavigation system with the protective cover removed

The main components of such AINS (Fig. 5) are an astrovisioning device (AVU) and a free-form inertial navigation system (BINS) (Fig. 6). As noted above, a distinctive feature of AINS design is the rigid connection of the AVU to the BINS housing. It provides immobility of the instrumental axes of AVU and BINS relative to each other and minimizes errors of recalculation of angles of spatial orientation measured by these devices.

The measurements were carried out in the mode of astrocorrection on 4 rhombuses with a turn relative to the initial position by 180° within 1 hour for each rhombus. For this purpose, we made a turn in relation to the initial position by 180° along the course, and then we made a turn to the initial position. The results of measurements on rhumb 0 are shown in Fig. 7 and 8. For technical reasons, there was no 180° turn in relation to the initial position. The results of measurements at 90° rhumb are shown in Fig. 9 and 10. The results of measurements at the rhumb of 180° are shown in Fig. 11 and 12. The measurement results for the 270° rhumb are shown in Fig. 13 and 14.

Results

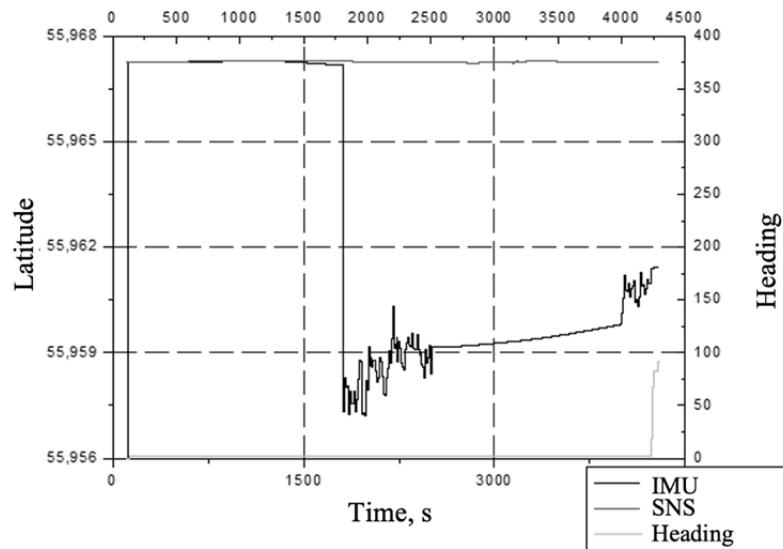


Fig. 7. Dependence of latitude on measurement time at the rhumb of 0

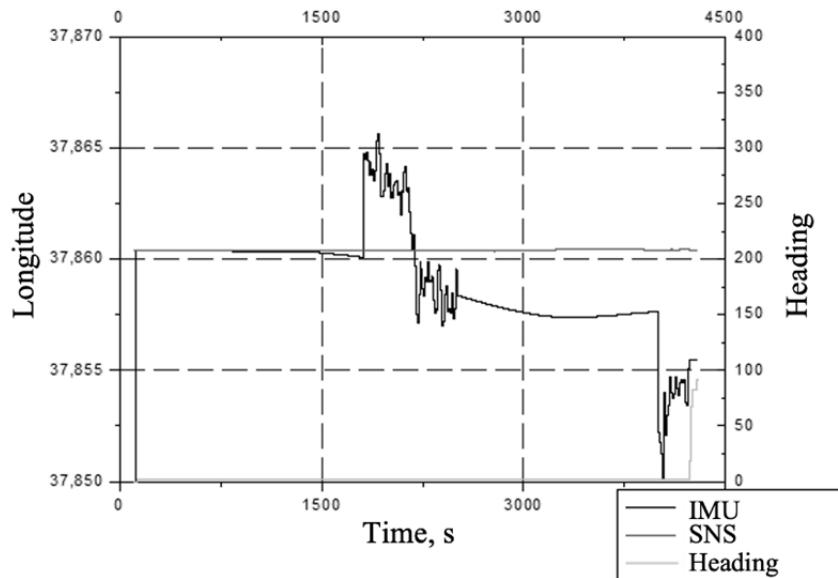


Fig. 8. Dependence of longitude on the measurement time at the rhumb of 0

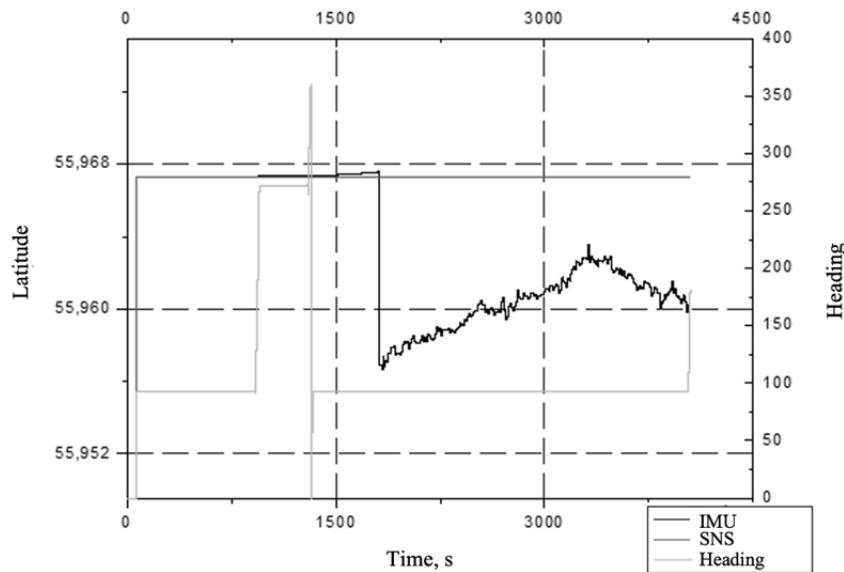


Fig. 9. Dependence of latitude on measurement time at rhumb of 90°

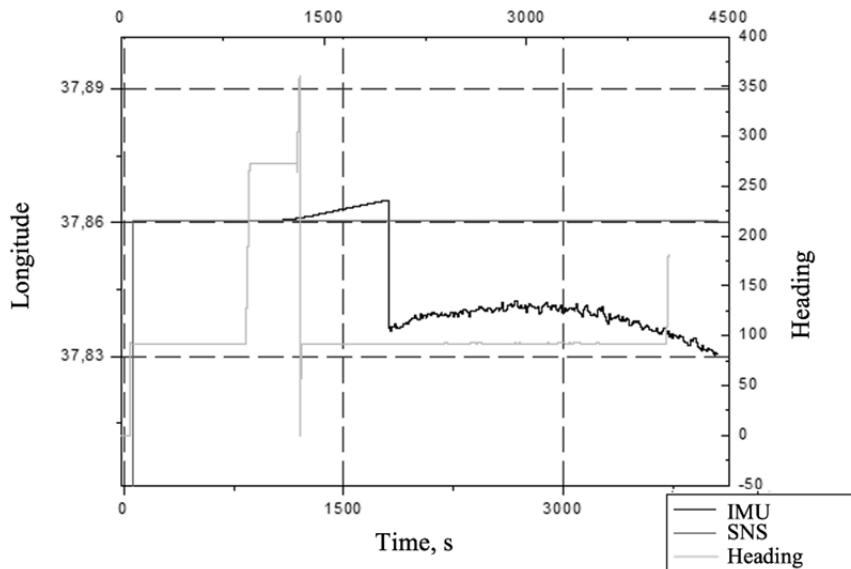


Fig. 10. Dependence of longitude on the measurement time at the rhumb of 90°

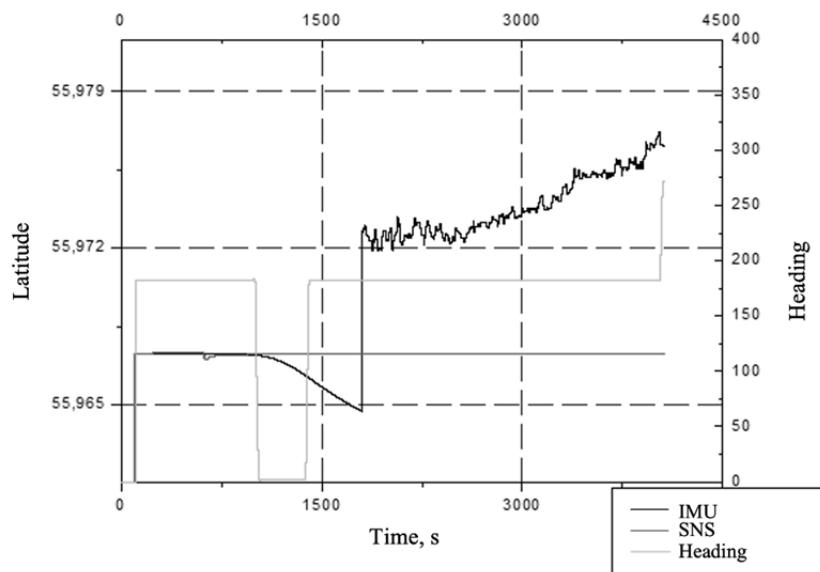


Fig. 11. Dependence of the latitude on the measurement time at rhumb of 180°

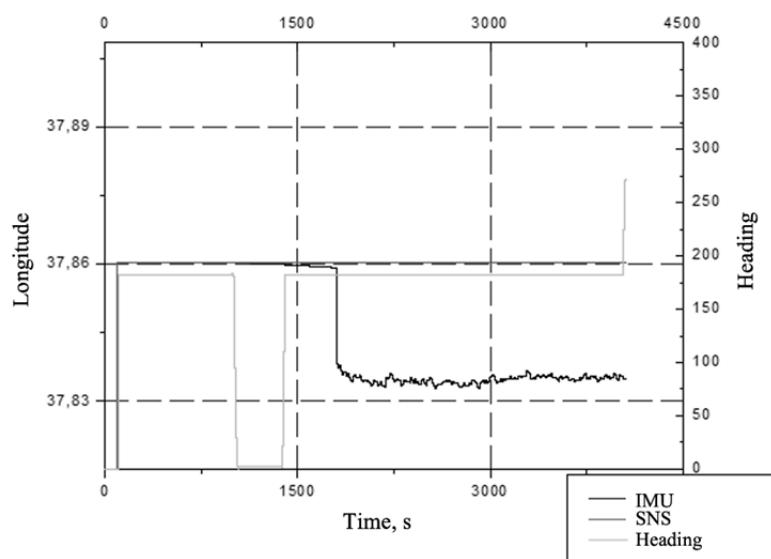


Fig. 12. Dependence of longitude on the measurement time at the rhumb of 180°

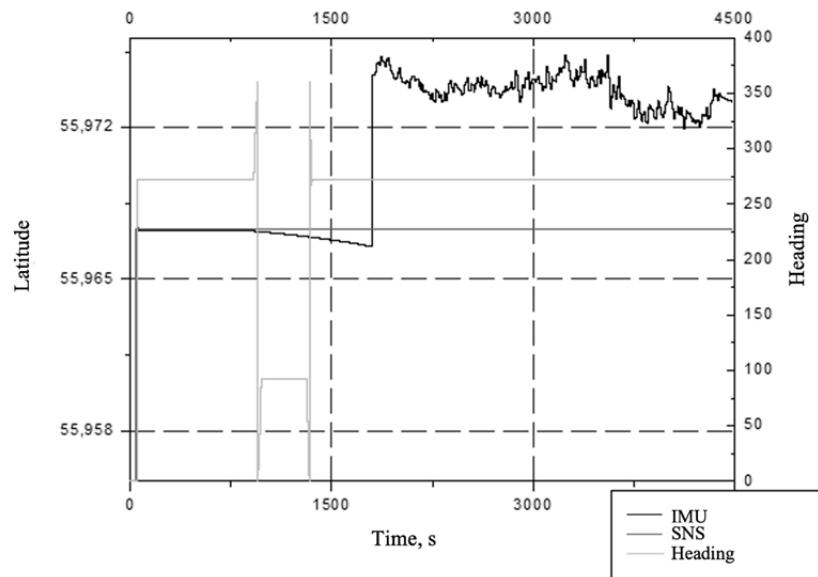


Fig. 13. Dependence of latitude on measurement time at the rhumb of 270°

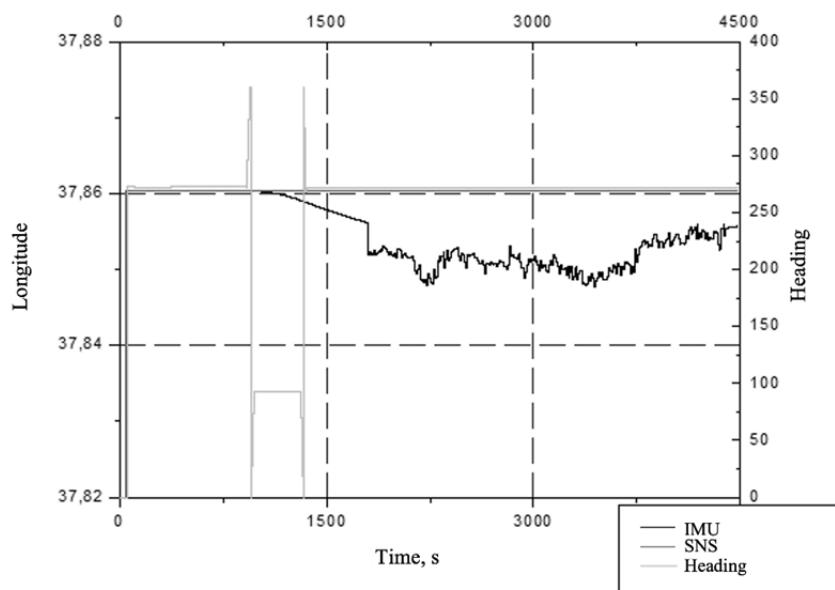


Fig. 14. Longitude dependence on measurement time at the rhumb of 270°

Discussion

According to the results of measurements we can show that:

- a comparative analysis of the output navigation parameters latitude astroinertial and longitude astroinertial on the opposite loops showed changes in their values of the order of 0.01 degrees, which confirms the influence of external disturbing factors on the accuracy of the system but remains within the calculated values;
- fast change of equipment deployment object direction does not lead to significant changes in the output navigation parameters of latitude, longitude and heading, which confirms the correct work of AINS of projection type.

Conclusion

The current conflicts show the disadvantages of satellite navigation, due to which the subject of astronomical navigation will grow more and more important. Unlike inertial navigation systems, astronomical navigational aids have no limitations on geographical latitude of application, i.e. provide globality of application. This paper shows that astronomical means and methods of determining directions and coordinates can be used for independent solution or correction of navigation systems and complexes of objects of dual application.

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УДК 528.7

Современные методы и технологии навигации с использованием изображений

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Рассмотрены основные подходы к определению собственного местоположения, используемые в области навигации с использованием изображений. Приведены ключевые методы, средства и технологии, применяемые для извлечения навигационной информации из изображений, указываются их основные достоинства и недостатки. Представлен обзор технологических достижений, которые произошли в области навигации по изображениям. Показано, что существующие навигационные технологии на основе оптического анализа окружающего пространства предоставляют возможность определения достаточно большого объема навигационной информации: координат местоположения, ориентации в пространстве, компонент вектора скорости, расстояний до отдельных ориентиров.

Ключевые слова: навигация по изображениям, техническое зрение, абсолютное позиционирование, визуальная одометрия, одновременная локализация и картографирование, стереоскопическая съёмка, стадиометрия

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State of the Art of Image-Aided Navigation Methods and Technologies

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The main approaches used in the field of navigation using images are considered. The key methods, tools and technologies used to extract navigation information from images are given, their main advantages and disadvantages are indicated. An overview of the technological advances that have taken place in the field of image navigation is presented. It is shown that the existing navigation technologies based on the optical analysis of the surrounding space provide the ability to determine a fairly large amount of navigation information: location coordinates, orientation in space, velocity vector components, distances to individual landmarks.

Keywords: image-aided navigation, technical vision, absolute positioning, visual odometry, SLAM, stereoscopic imaging, stadiometry

The first navigation solutions using video images were developed for autonomous ground robots [1–3]. In recent years, the visual navigation system has been widely used in autonomous vehicles, unmanned aerial vehicles (UAVs) and underwater robots, which further contributed to the study of an integrated navigation algorithms based on computer vision [4]. A fairly wide range of research in this area has been carried out in Europe and the USA. For example, the University of California used visual navigation for autonomous landing of an unmanned helicopter [5]. Flight tests show that a visual navigation system can provide an accuracy of up to 5 cm in determining the location of a helicopter on the ground. The University of Florida has developed a method for determining the angle of roll and pitch of an aircraft using images. These surveys are based on visual navigational information and do not involve combining information from multiple sensors.

As for the integrated navigation system, which includes GNSS/SINS/technical vision, the paper [6] reports on the achievement of centimeter accuracy of vehicle positioning. In [5], an integrated GNSS/INS/technical vision system for low-altitude aircraft was

developed, which provides positioning accuracy at the level of 5 m in difficult urban conditions.

There are three main approaches to solving a navigation problem using visual navigation technology [7, 8]. The first approach involves determining the coordinates of the navigation object based on the results of comparing the visible image with the expected one, built on the basis of a pre-prepared digital map of the area, which has an exact reference to the geographic coordinate system. This approach can be called absolute positioning. With absolute positioning, you need a database of image objects and their locations. The position of the navigation object is determined by comparing the characteristic features highlighted in the resulting image with the characteristic features stored in the database. With absolute positioning, matching the unique features of the resulting image with information from the database is usually more complex than with visual odometry, since the images used to create the database are usually obtained under different lighting conditions, distances, directions of the object, or cameras. The advantage of this approach is accurate coordinate reference of the navigation object, similar to how it occurs when using GNSS [9–11]. At the same time, the quality of the navigation solution largely depends on the geometry of the location of landmarks relative to the camera. In general, the further the landmarks are “scattered”, the better the position estimate is formed. In cases where landmarks are far from the camera and observed in a relatively narrow field of view, a high correlation may occur between the position estimate obtained by changing the orientation of the navigation object and the position estimate obtained by moving the navigation object, which leads to an increase in errors in navigation determinations. At the same time, if the orientation of the navigation object is known (for example, using an inertial navigation system), the absolute positioning algorithm based on computer vision, which evaluates only three spatial coordinates of the object (three Degrees of Freedom), will form more accurate navigation solution than a more general algorithm that computes both position and orientation (6DOF) parameters. Similarly, knowledge of the location coordinates can significantly improve the estimation of the navigation object orientation [12].

The second possible approach can be called visual odometry [7, 8]. With this approach, successive images (usually taken by the same camera) are used to determine the movement that occurs between the acquisition times. Classical visual odometry operates with two images, but the method can be extended to more than two images using the so-called Bundle adjustment (a method for updating the camera position and the observed point cloud simultaneously, which involves minimizing objective function [13]). Visual odometry approaches are based on feature matching between images, which requires some degree of overlap between parts of the images that display the same scene. Since visual odometry algorithms most often use images from the same camera, taken at about the same time and at the same angle (so that the lighting and point of view are the same), features between images are usually fairly easy to establish. The advantages of visual odometry are simplicity and speed, however, if a sufficient set of matches is not found between two images, large errors in navigation decisions may occur, especially with highly maneuverable navigation object movement, which will further accumulate. At the same time, it is important to emphasize that the use of visual odometry makes it possible only to determine the relative displacement and does not allow establishing the absolute position of the navigation object. Thus, due to the cumulative nature of errors, visual odometry can be used rather as a means of correcting an external navigation system than as a source of reference navigation information.

The third approach to visual navigation is the combined use of visual odometry and absolute positioning [7, 8] and is often referred to as Simultaneous Localization and Mapping (SLAM). When using SLAM approaches, objects are identified in a sequence of images, and both object locations (“localization”) and camera position (“mapping”) are simultaneously evaluated. At the same time, SLAM approaches allow absolute positioning if any object (or set of objects) has known geographical coordinates. However, SLAM algorithms are inherently dead reckoning algorithms. Thus, their disadvantage may be the unlimited growth of position and orientation errors over time. SLAM methods are mainly used in an unfamiliar environment and provide information about the location relative to it [14].

All of the above mentioned methods involve identifying feature points in images. The point detectors are SIFT [15] or SURF [16] algorithms, which allow finding affine transformations between images [17, 18].

Let's move on to the consideration of currently used measuring systems that use images to obtain navigation information. Image sensors in such systems operate in active and passive modes, depending on whether they provide a signal to observe the space of an object or simply perceive some part of the spectrum. Some of the active sensors, such as LiDAR [23], can provide real-time 3D data, and they integrate quite well with conventional navigation systems [19–22]. In [23], it is indicated that, to date, the use of LiDAR provides accuracy in determining the range at the centimeter and millimeter level.

One of the important features in image acquisition is that when using a monocular camera alone, it is impossible to determine the distance and absolute orientation (only relative movement and relative rotation). To determine the distance, it is necessary to somehow add additional information characterizing the scale to the system. Knowing the distance allows a complete assessment of the relative movements with six degrees of freedom (6DOF). To enter additional information, the following are used: several binocular cameras (stereoscopic imaging, in which the base line between the cameras is known); stadiometry (performing object recognition of objects with known physical dimensions); identification of multiple objects that are in a known position relative to each other (inclusion of a priori knowledge about the position and ratio of objects in the scene). Each method has its own advantages and disadvantages.

Stereoscopic imaging is attractive due to the ease of estimating the distance to landmarks of interest using feature matching algorithms. Such systems are essentially passive and do not require knowledge of the scene itself. However, this method requires additional sensors and computing resources. In addition, stereo images must be synchronized and calibrated, which requires additional equipment and time. At the same time, the very accuracy of determining the range achieved using this approach is proportional to the distance between the cameras and the distance to the object, as a result of which a large base between the cameras is required for accurate depth estimation at large distances, which can lead to the bulkiness of the entire system. Therefore, stereoscopic photography is usually used in situations where landmarks are located close to the cameras [24, 25].

The advantage of the stadiometric method of determining the range is that it is completely passive and requires only one image sensor. The main disadvantage of this technology is the need to select and identify physical objects in the image to determine the physical size, which is a rather difficult task, and if the objects are identified incorrectly, then the resulting range estimate may be fundamentally wrong.

An example of indoor navigation, in which navigation information is generated based on the identification of several objects that are in a known position relative to each other, is

presented in [26]. In this system, a building's perpendicular structure is detected using an integrated line-tracking algorithm. From the collection of lines, the orientation of the camera relative to the cardinal directions of the building (for example, two horizontal directions and one vertical). Close connection with the INS [27] provides a continuous and stable orientation estimate.

Thus, today there are different approaches to the problem of extracting information about location, orientation and/or their time derivatives using image sensors. They largely depend on the type of a sensor, the availability of a priori information (database on the terrain, partially known state vector of the navigation object), as well as the availability of computing resources. Regardless of the architecture of the systems and the applied algorithms, image processing is able to provide both obtaining a complete navigation object state vector with the most significant components — location and orientation, and only its partial components or derivatives, for example, distances to individual point landmarks, components of the velocity vector or values height above a given plane (for example, a runway).

At the same time, it should be noted that many aspects of image navigation are quite common for images obtained in different wavelength ranges, therefore, technical solutions developed, in particular, for systems using the visible range, can also be used in systems operating, for example, infrared, or radio. The use of multi-band systems can greatly mitigate one of the main disadvantages of visible image navigation systems, which is the inability to work in low light conditions, rain, fog, etc.

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Практическое применение зон ожидания вида Holding-to-Altitude: обзор и перспективы

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Зоны ожидания вида *Holding-to-Altitude* — важный инструмент в процессе обслуживания воздушного движения, используемый для управления потоками и обеспечения установленных интервалов между воздушными судами. Концепцию «Траектория и указатель ее окончания» используют для определения траектории полета воздушного судна и точки, в которой воздушное судно должно вернуться на исходный путевой угол. Такие зоны ожидания являются гибкими и могут быть скорректированы с учетом изменений в потоке воздушного движения, погодных условиях или других факторах. Пилоты должны следовать по предписанной траектории в сторону от точки начала выполнения зоны ожидания, вернуться на исходный путевой угол и поддерживать требуемую скорость и высоту. Определенные формулы используют для расчета времени, радиуса разворота, длины входящих участков и участков удаления и угла коррекции ветра. В качестве реальных примеров зон ожидания H2A можно привести международный аэропорт О'Хара в Чикаго, аэропорт Сиднея Кингсфорд Смит в Австралии и амстердамский аэропорт Схипхол в Нидерландах. Зоны ожидания H2A являются достаточно удобным инструментом для управления воздушным движением и обеспечения безопасных полетов.

Ключевые слова: организация воздушного движения, управление воздушным движением, стандарт ИКАО, проектирование воздушного пространства, схема удержания, навигация, зональная навигация

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Real-life Applications of H2A Holding Patterns: Case Studies from Around the World

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Holding-to-Altitude (H2A) holding patterns are a critical tool in air navigation used to manage air traffic and ensure safe separation between aircraft. The Path and Terminator concept is used to establish a path for the aircraft and a point where the aircraft must turn back to the inbound course. These holding patterns are flexible and can be adjusted to accommodate changes in air traffic flow, weather conditions, or other factors. Pilots must follow a prescribed path away from a holding fix, turn back to the inbound course and maintain required speed and altitude. The H2A holding pattern is used in high traffic and adverse weather conditions. Formulas are used to calculate the time, turn radius, length of inbound/outbound legs and wind correction angle. Real-life examples of H2A holding patterns include O'Hare International Airport in Chicago, Sydney Kingsford Smith Airport in Australia, and Amsterdam Airport Schiphol in the Netherlands. H2A holding patterns are a vital tool for managing air traffic and ensuring safe operations.

Keywords: air traffic management, air traffic control, ICAO standard, airspace design, holding pattern, navigation, area navigation

Area navigation holding patterns

Area Navigation (RNAV) holding patterns are a type of holding pattern used in air navigation. A holding pattern is a procedure that an aircraft follows when it is not able to land or proceed to its destination due to traffic congestion, weather, or other reasons. Holding patterns help aircraft to remain in a safe location, maintain their altitude, and wait for clearance to proceed.

RNAV holding patterns are designed to provide precise and efficient navigation for aircraft. They are based on GPS or other navigation systems that allow the aircraft to follow a specific course and maintain a precise location. RNAV holding patterns are preferred over conventional holding patterns because they require less fuel and time, and they can be tailored to meet specific operational requirements.

In an RNAV holding pattern, the aircraft follows a specific course, which is defined by a series of waypoints. The waypoints are located at specific distances and angles from each other, and they are programmed into the aircraft's navigation system. The aircraft follows the waypoints in a specific sequence, maintaining a specific altitude and airspeed. The pilot may adjust the aircraft's speed or altitude as needed to maintain the correct position in the holding pattern.

RNAV holding patterns have several advantages over conventional holding patterns. They allow aircraft to fly more precise courses, reducing the risk of collisions or other incidents. They also allow for more efficient use of airspace, reducing delays and improving overall efficiency. Additionally, RNAV holding patterns can be easily programmed into the aircraft's navigation system, making them easier for pilots to use and reducing the risk of human error.

However, there are some potential drawbacks to RNAV holding patterns. They require advanced navigation equipment and training, which may not be available in all aircraft or for all pilots. They also require careful planning and coordination with air traffic control, to

ensure that multiple aircraft do not conflict with each other in the holding pattern. Finally, RNAV holding patterns may not be suitable for all situations, such as in areas with poor GPS coverage or high levels of electromagnetic interference.

To sum up, RNAV holding patterns are a useful tool in air navigation, providing precise and efficient navigation for aircraft. They offer several advantages over conventional holding patterns, including greater precision, efficiency, and ease of use. However, they also require advanced navigation equipment and training, careful planning and coordination, and may not be suitable for all situations. As technology continues to advance, it is likely that RNAV holding patterns will become even more important in air navigation [1, 2].

Holding-to-altitude method

The Holding to Altitude (H2A) method is a concept that is used in conjunction with the Path and Terminator concept in air navigation. The Path and Terminator concept refers to a navigational method that involves defining a path along which an aircraft should fly and a point at which the aircraft should terminate that path. This concept is often used in RNAV operations to help aircraft navigate more efficiently and safely.

The H2A method is used in situations where an aircraft needs to hold at a specific altitude before proceeding along a path. In this method, the holding pattern is designed to ensure that the aircraft maintains a specific altitude while waiting for clearance to proceed. The holding pattern is based on the Path and Terminator concept, which defines the path that the aircraft will follow and the point at which the aircraft will terminate that path.

The H2A method involves several steps. First, the aircraft is directed to fly along a specific path, which is defined by a series of waypoints. The waypoints are located at specific distances and angles from each other, and they are programmed into the aircraft's navigation system. The aircraft follows the waypoints in a specific sequence, maintaining a specific altitude and airspeed.

When the aircraft reaches the point at which it is required to hold, it is directed to fly a holding pattern. The holding pattern is designed to ensure that the aircraft maintains the required altitude while waiting for clearance to proceed. The holding pattern typically consists of a series of turns, in which the aircraft turns around a specific point and flies back along the same path. The holding pattern may be designed to ensure that the aircraft remains within a specific area or corridor, to avoid conflicts with other aircraft [3].

The H2A method is often used in RNAV operations, where it is necessary to ensure that aircraft maintain a specific altitude before proceeding along a path. This method is preferred over conventional holding patterns because it allows for more precise navigation and more efficient use of airspace. Additionally, the H2A method can be easily programmed into the aircraft's navigation system, making it easier for pilots to use and reducing the risk of human error.

The International Civil Aviation Organization (ICAO) provides guidance on the use of the H2A method, including procedures for designing and executing holding patterns. The ICAO defines the standard dimensions of a holding pattern, including the holding fix, inbound leg, outbound leg, and turn radius [4].

There are special mathematical formulas that can be used to calculate various parameters related to H2A holding patterns, which can be used to calculate various parameters related to H2A holding patterns, including timing, turn radius, length of inbound leg, and wind correction angle. They are used by pilots and air traffic controllers to ensure that aircraft maintain the required altitude and speed while holding.

Implementation in real traffic control procedures

The H2A method is used by air navigation service providers around the world, including the Federal Aviation Administration (FAA) in the United States, Eurocontrol in Europe, and the Civil Aviation Authority (CAA) in the United Kingdom. These organizations provide guidance and procedures for the use of the H2A method, and they work to ensure that it is used consistently and effectively in air navigation operations.

One example of a H2A holding pattern being used in real life is at the O'Hare International Airport in Chicago, USA. The airport uses H2A holding patterns to manage air traffic congestion during peak periods. The holding pattern is established at a holding fix known as DEERE, located northwest of the airport [5].

Another example is at the Sydney Kingsford Smith Airport in Australia. The airport uses H2A holding patterns to manage air traffic congestion and maintain safe separation between aircraft. The holding pattern is established at a holding fix known as BANKS, located south of the airport.

In Europe, the Amsterdam Airport Schiphol in the Netherlands also uses H2A holding patterns to manage air traffic congestion. The holding pattern is established at a holding fix known as RAVEL, located southwest of the airport.

These are just a few examples of real-life applications of H2A holding patterns. In general, H2A holding patterns are used in many parts of the world to manage air traffic, ensure safe separation between aircraft, and maintain the required altitude and speed during holding [6].

In conclusion, the Holding to Altitude method is a standard procedure used in air navigation worldwide, particularly in RNAV operations. It is used in a variety of air traffic control environments, and it is designed to ensure that aircraft maintain a specific altitude while waiting for clearance to proceed. The H2A method is supported by the International Civil Aviation Organization and used by air navigation service providers around the world.

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Применение программы ANSYS для оценки защищенности помещений от утечки информации по виброакустическому каналу

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Для защиты информации от утечки по виброакустическому каналу используют виброизлучатели. Оценивают качество их применения путем измерения отношения «сигнал — шум». Предложен метод оценки защищенности помещения на основе компьютерного моделирования распространения звука. Последовательно рассмотрено распространение колебаний в оконном стекле. При воздействии источника звука в помещении (динамики), а затем при воздействии излучателя вибрации, прикрепленного к стеклу, для проверки качества защиты, оценивают отношение «сигнал — шум» всей поверхности стекла.

Ключевые слова: акустика, безопасность, метод конечных элементов, канал утечки информации, виброакустический излучатель, ANSYS, защищенность

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Application of ANSYS for Assessing Protection of Premises from Information Leakage through Vibroacoustic Channel

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To protect information from leakage through the vibroacoustic channel vibration emitters are used. The quality of their application is assessed by measuring the signal-to-noise ratio. The method of assessing the security of a premise based on computer modeling of sound propagation is proposed. The propagation of vibrations in a window pane is consistently considered. Under the action of a sound source in the premise (speakers) and then under the action of a vibration emitter attached to the glass to check the quality of protection, the signal-to-noise ratio of the entire surface of the glass is evaluated.

Keywords: acoustics, security, finite element method, information leakage channel, vibroacoustic emitter, ANSYS, protection

Introduction

The use of finite element analysis for solving acoustic problems makes it possible to study complex spatial configurations of premises that in practice cannot be studied using analytical and graphical methods [1, 2]. Computer modeling makes it possible to obtain data at any point in the model, which eliminates the need for numerous measurements at

control points. This feature can be used to protect premises from information leakage through the vibroacoustic channel.

The environment for the propagation of acoustic signals withindoors is the air and the structures of the building (walls, ceiling, floor), and mini highly sensitive microphones and contact stethoscopes are used to intercept them [3]. The sound transmitted through the air and through the structure, due to different propagation paths, have different information content [4, 5]. As a means of protecting premises, vibration emitters installed on the structures of a building are often used, which are classified as active means of protection [6, 7]. The security assessment of premises is carried out by measuring the signal-to-noise ratio at control points [8]. However, this process is quite time-consuming, and the sample of control points to be measured is usually small [9].

As noted above, the possibilities for assessing the propagation of sound in a premise by analytical methods are limited. The application of numerical methods for solving these problems has begun. For example, in [10, 11], the application of the finite element method for calculating the pressure field in a premise is considered. This does not take into account the propagation of sound in the walls of the premise.

This paper proposes a method for assessing the security of a premise based on finite element modeling of sound propagation. As an example, the propagation of vibrations in the glass of a window of a model premise, arising under the action of a sound source (speakers) located inside the premise is considered. The obtained values of the oscillation amplitude have been compared with the magnitude of the vibration oscillations in the glass of the window of the premise, arising under the action of the vibration emitter. To check the quality of protection, an estimate has been made of the signal-to-noise ratio over the entire glass surface. The calculations have been carried out using the finite element program ANSYS [12].

Purpose of the study

To propose a method for analyzing the protection of a premise from leakage through a vibroacoustic channel based on computer modeling of sound propagation in air and solids. The method will allow to determine the vulnerabilities of the protected premises.

Materials and methods of research

Consider a system consisting of a sound source, a noise generator and a partition, the composition of which corresponds to a typical protected system [13]. To do this, we build a premise model in the form of a parallelepiped with a panoramic double window pane and a vibroacoustic emitter attached to it from the inside. Glass has two layers, with air between the layers. The dimensions of the premise are $2 \times 2 \times 3$ m (Fig. 1).

Inside the premise filled with air, at a distance of one meter from the glass, there is a sound source (column) with dimensions of $0.05 * 0.05 * 0.05$ m. The sound source is made of steel. One of the surfaces of the sound source, as well as that of the vibration generator, oscillates along the z axis. The sound source generates a volume level signal of 80 dB (in this work, we assume that this is the loudest sound that can be reproduced by a person during a conversation).

A vibration emitter is fixed on the inner side in the center of the window. The contact of the vibration emitter with the glass surface is an imperfect contact of two rough bodies. Since the finite element modeling of such contacts requires significant computational resources [14–16], the first approximation represents the contact of the vibration emitter

and glass as the contact of two flat surfaces. The surface of the emitter connected to the glass performs harmonic oscillations along the z-axis with a given frequency.

The vibration emitter and the sound source cause vibrations at a frequency of 1000 Hz, directed perpendicular to the glass surface (along the z axis).

A finite element model is formed in the ANSYS program. All three-dimensional bodies are interconnected using the GLUE command of the ANSYS program [17].

The rational grid partition selected in this work is shown in Fig. 2.

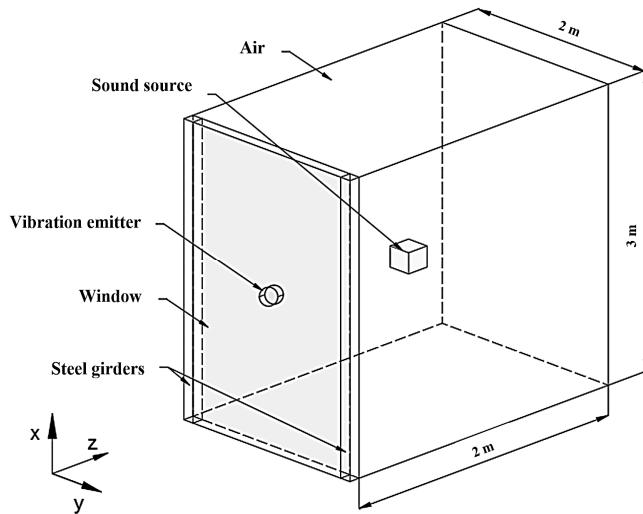


Fig. 1. Model of the investigated premise

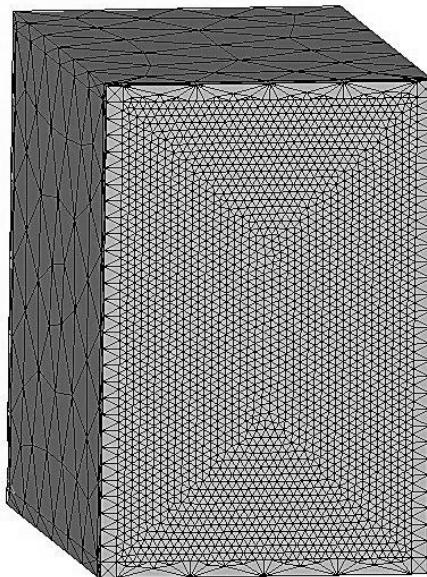


Fig. 2. Splitting the model into finite elements

In order to check whether the vibroacoustic radiator protects the window, it is necessary to calculate the maximum allowable amplitude A_{max} . These are glass vibrations when the vibrator is turned on. Let us assume that there is no information leakage through the vibroacoustic channel if the signal level from the vibration emitter on the glass exceeds the signal level from the source by 10 dB.

Results

A cycle of calculations has been carried out for different frequencies. In this article, for brevity, we present the results for a frequency of 1000 Hz. The results for other frequencies do not qualitatively differ and correspond to the conclusions made in the work.

Consider a model with the noise generator turned on and the sound source turned off. The results of calculating vibration displacements on a panoramic window (inner layer) fixed with steel beams at a frequency of 1000 Hz are shown in Fig. 3.

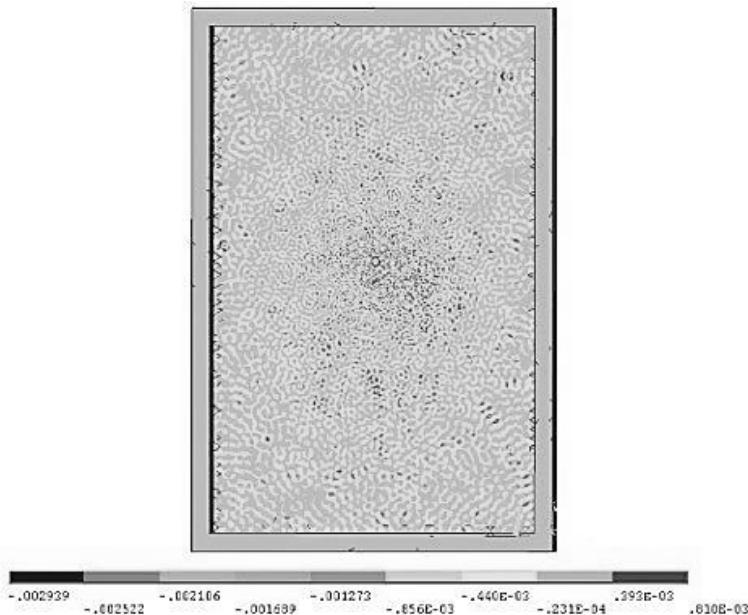


Fig. 3. Vibrating vibrations of glass along the z axis when the vibration emitters are turned on (view from inside the premise), in meters

As can be seen from the figure, the values of the oscillation amplitudes obtained as a result of the calculation are in the range up to $8 \cdot 10^{-4}$ m. If the oscillation values obtained in the second calculation, when only the sound source is turned on, turn out to be greater than this value, then it will be possible to conclude that the glass is not protected.

The results of calculating the vibration displacement on panoramic glass fixed with steel beams in the model with the sound source turned on and the vibration emitter turned off are shown in Fig. 4. In this case, the glass vibration amplitudes are noticeably smaller and are in the range up to $2.5 \cdot 10^{-6}$ m. At the same time, these ranges intersect and there are places in the structure where the amplitude of oscillations from the sound source can exceed the amplitude of oscillations from the vibration emitter.

For a frequency of 1000 Hz on the glass Fig. 5 shows the distribution of the excess of vibration amplitudes from the sound source over the vibration amplitudes from the vibration emitter. Information leaks can occur in these places. The gray color in this figure indicates the places where the glass is protected from listening.

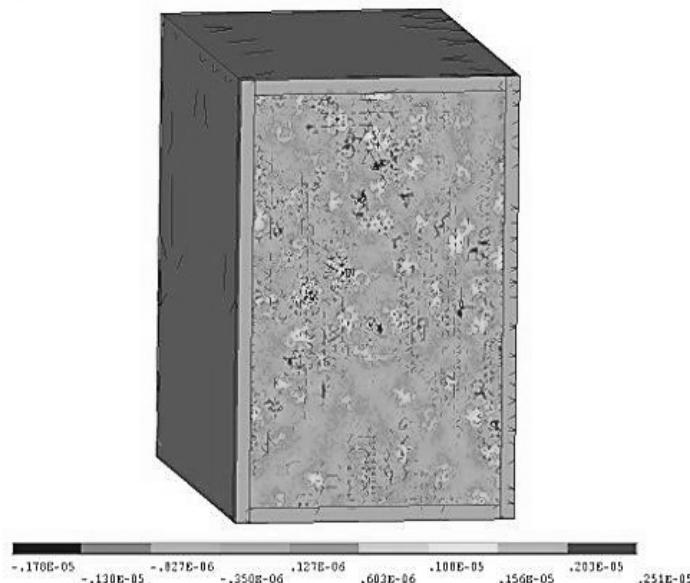


Fig. 4. Glass vibrations along the z axis when the sound source is switched on, in meters

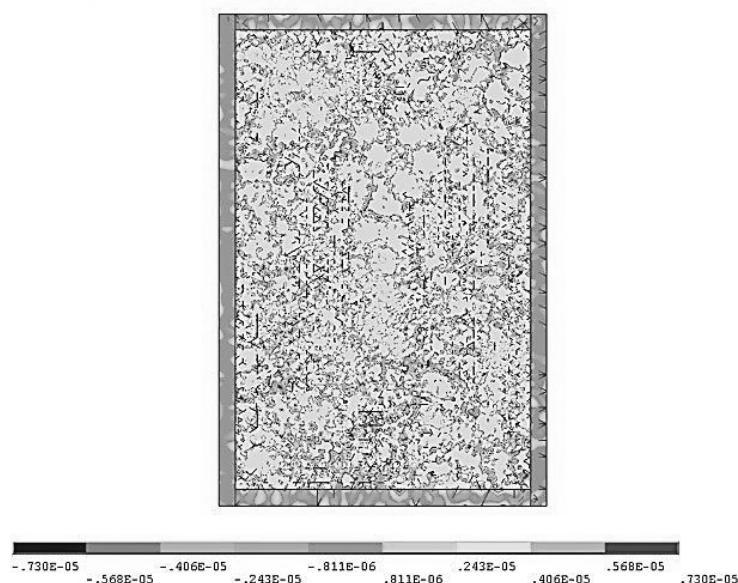


Fig. 5. Glass vibrations along the z axis (the color on the glass marks the areas where the protection of speech information is not provided), in meters

Conclusion

Noise modeling for industrial plants and equipment is rare in the scientific literature, although acoustics provides many methods for approximate sound level prediction, which are mainly applied to the design of theaters and music halls. The publications on sound modeling in the field of information security. Despite the fact that the physics of sound is quite well studied, prediction and analysis still require significant scientific efforts due to the versatility of sound phenomena, depending on space, time, frequency, properties of propagation media, as well as on the type of sound source and propagation conditions [4].

This paper proposes a method for analyzing the protection of a premise from leakage through a vibroacoustic channel, based on computer simulation of sound propagation in air and solids. The method allows you to determine the vulnerabilities of the protected premises.

The study showed that when using a typical single-axis vibroacoustic generator, the premise remains unprotected. The location of vulnerabilities has been identified. To ensure the protection of such a premise, it is necessary to change the location of the vibration emitter or consider installing several means of protection, including another type.

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Исследование методов устранения «мертвых зон» в распределенном волоконно-оптическом акустическом датчике на основе двойного интерферометра Саньяка

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Проведено исследование методов устранения «мертвых зон» в волоконно-оптическом акустическом датчике на основе двойного встречного интерферометра Саньяка. Разработана функциональная зависимость чувствительности интерферометра Саньяка в зависимости от координаты акустического воздействия на его контур, а также разработана методика ее экспериментального измерения. Теоретически обоснован и экспериментально подтвержден принцип формирования «мертвых зон» в распределенном волоконно-оптическом акустическом датчике на основе интерферометра Саньяка с различной длиной петли. Предложены два метода устранения «мертвых зон», перспективные для интеграции интерферометра Саньяка в сложные системы мониторинга и использования его в качестве самостоятельного распределенного акустического датчика.

Ключевые слова: волоконно-оптический датчик, интерферометр Саньяка, чувствительность, восстановление фазы сигнала, мертвые зоны

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Investigation of "Dead Zones" Elimination Methods in a Distributed Fiber-Optic Acoustic Sensor Based on a Double Sagnac Interferometer

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In the paper a study of "dead zones" in a fiber-optic acoustic sensor based on a double Sagnac interferometer was carried out. A function of a Sagnac interferometer sensitivity depending on a position of acoustic disturbances affecting the loop has been developed. Two methods for its experimental measurement has been proposed. The "dead zones" formation principle in a fiber-optic acoustic sensor based on a double Sagnac interferometer has been theoretically substantiated and experimentally proven. Two methods for eliminating "dead zones" are proposed, both showing considerable promise for integrating a Sagnac interferometer into complex monitoring systems and using it as a separate distributed acoustic sensor.

Keywords: distributed fiber optic sensor, Sagnac interferometer, sensitivity, signal phase unwrapping, dead zones

Introduction

Today fiber optic distributed acoustic sensor (DAS) is widely used due to the fact that it allows solving problems of remote monitoring and is convenient for using as a security system of pipelines, railways, long perimeters and other extended objects [1]. Unlike one-point (undistributed) sensors, distributed ones allow measuring the intensity and frequency of external acoustic disturbances affecting a fiber-optic cable along its entire length localizing an acoustic disturbance source with high accuracy [2] as well as measuring its parameters, such as frequency and intensity. There are two main principles for creating fiber optic DAS's based on either interferometers or reflectometers. DAS's, which are widely used today, are based on a phase-sensitive optical time domain reflectometer (ϕ -OTDR), which is a widely spread DAS's allowing identifying separate detection disturbances on fiber with a high resolution of 10 meters and monitoring objects with the perimeter length of up to 80 km without signal amplifiers installed in a line [3]. However, it is often required to increase the sensitive fiber length, which leads to decreasing spatial resolution [4] and sensitivity [5, 6] at the end of the fiber cable. It becomes a significant drawback of a fiber optic DAS based on ϕ -OTDR. Thus, fiber optic DAS's based on interferometers become attractive for developers and potential users since they are compatible with ϕ -OTDR systems. On the one hand fiber optic DAS's based on interferometers allow localizing the external acoustic disturbances with high accuracy of tens of meters [3], on the other hand they provide for high sensing fiber length of more than a hundred kilometers, at the same time being implemented using highly available components, which leads to their low cost.

DAS's based on interferometers are developing rapidly, so that every year developers solve many new problems. It makes it possible to improve the quality of such systems, which means an increase in the accuracy of acoustic disturbance localization and the length

of a sensing fiber and even the possibility of multiple disturbances detection. Various types of fiber-optical interferometer-based DAS's have been proposed [2] using a Mach-Zehnder interferometer (MZI), a Michelson interferometer (MI) and a Sagnac interferometer (SI). SI is an optical fiber loop closed at the outputs of a fiber-optical coupler. It has significant advantages compared to MZI and MI since it has a high sensitivity and its output interference signal does not depend much on environmental temperature and pressure fluctuations. It provides for a high signal-to-noise ratio at the output, which is necessary for high-precision localization of acoustic disturbances, so that systems based on SI do not require using narrow-band highly stabilized lasers [4]. Applying a laser diode with a wide spectrum significantly reduces the cost of such DAS's. It also helps to increase the length of a sensing fiber since the threshold power of such nonlinear effects as SBS [2] increases. As a result, the sensing length of a fiber-optical DAS based on an SI can reach 150 km [7] without signal amplifiers along the fiber. At the same time, they provide for the localization of acoustic disturbances with an error of up to ± 30 m, which is a very good result. It makes SI-based fiber-optical DAS's promising systems for high-precision monitoring of extended objects.

A distributed fiber-optic acoustic sensor based on a double Sagnac interferometer scheme

Since the 1990s when research into fiber-optical DAS's based on SI started more than a dozen schemes of such sensors have been proposed. However, the most promising interferometer-based DAS utilizes a double SI with wavelength division multiplexing [5] shown in Fig. 1.

In the scheme coarse wavelength division multiplexing modules (CWDM) are implemented to form two oppositely directed Sagnac loops with the same length of L . A light beam with the wavelength of λ_1 from the Laser source 1 propagates through the first loop (these sections are marked in orange), while a light beam with the wavelength of λ_2 from the Laser source 2 propagates through the second loop (the sections are marked in green). Two loops also have a common sensing fiber between CWDM. Light beams with the wavelengths of λ_1 and λ_2 interfere in the coupler C1 and in the coupler C2, respectively, after passing both loops in clockwise and counterclockwise directions. When an acoustic disturbance affects a sensing fiber, an output interference signal changes. The changes are recorded by two photodetectors PD1 and PD2. An example of the signals is shown in Fig. 2. The signals are time-shifted by an amount of a delay which depends on a disturbance position d_1 . The position d_1 can be easily determined by detecting the time delay.

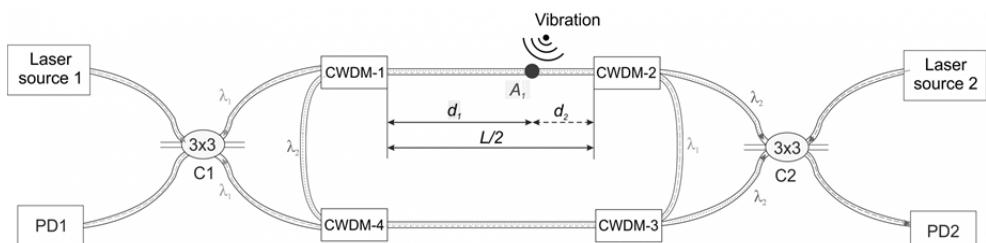


Fig. 1. A distributed fiber-optic acoustic sensor based on a double Sagnac interferometer

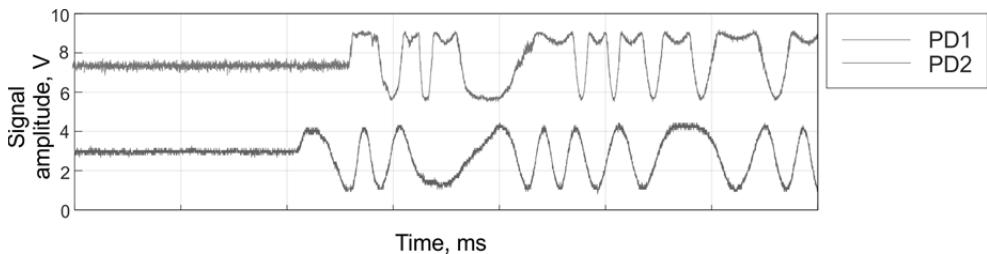


Fig. 2. An example of signals in the output of the loops

In the previous paper it was shown that a DAS based on a double Sagnac interferometer with the sensing length of 50 km allows localizing the disturbance with an error of up to 24 m, which is an impressive result [5]. However, an SI has a significant drawback, which limits its application in security systems. There are areas along the loop where the disturbance cannot be detected, the so-called “dead zones”. “Dead zones” can lead to skipping of a disturbance, therefore an issue of “dead zones” elimination is extremely important for security systems.

Investigation of “dead zones” in a Sagnac interferometer

In order to study the reasons of “dead zones” appearing and to develop ways for their elimination it is necessary to analyze the sensitivity of the SI. Sensitivity can be estimated by a phase difference at the output of the loop. If the phase difference formed is less than a threshold power of photodetectors, the SI is insensitive and external disturbances on the loop cannot be detected. The previous investigation [5] showed that the phase difference at the output of the SI loop is a function of two variables, which are the frequency of the phase oscillation fluctuations f_t and the disturbance coordinate d_1 .

To provide for an experimental study of the sensitivity distribution in the SI a setup was developed and implemented. It consisted of a single Sagnac loop with the length of L , which was influenced by a piezoelectric in different points as shown in Fig. 3.

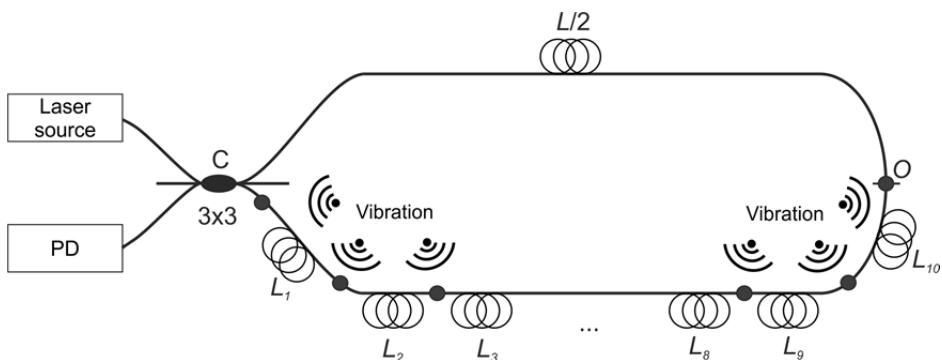


Fig. 3. A setup for experimental study of a sensitivity distribution in the IS

The first half of the loop was implemented with a fiber coil with the length of $L/2$, and the second half of the loop was divided into ten sections, each having the same length of L_i , $i = 1 \dots 10$. A diode laser based on a Fabry-Perot resonator with the central wavelength of

$\lambda = 1550 \text{ nm}$ was used. At the output of the loop interference signals were detected by two photodetectors before being converted by an ADC with the sampling frequency of 25 MHz and transmitted to a PC, where the signal phases were unwrapped and the amplitudes of the phases differences were calculated. The loop length was $L = 20 \text{ km}$ in order to study the sensitivity of a long loop. Experimental results and their comparison with numerically simulated curves are shown in Fig. 4.

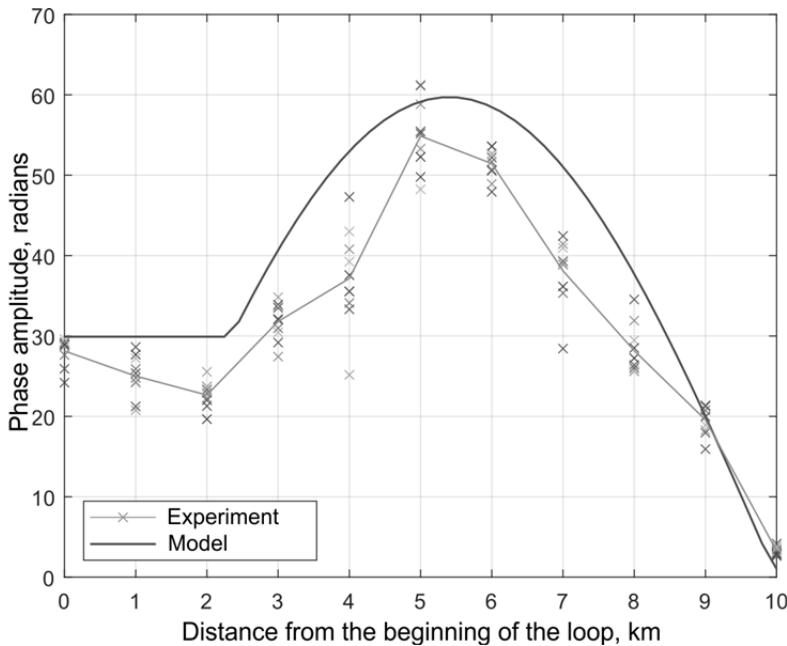


Fig. 4. SI sensitivity dependence on the disturbance position a for loop length of 20 km

As one can see, an experimental sensitivity maximum was demonstrated for the disturbance coordinates in the region closer to a quarter of the loop $d_6 = L/4 = 5 \text{ km}$, while in the middle of the loop at $d_{11} = L/2$ a phase difference range is less than 5 radians. Considering a photodetector being able to detect a phase difference higher than 20 radians, a “dead zone” is formed in the middle of the loop. Fig. 3 shows agreement between experimentally obtained sensitivity curves and numerically simulated ones.

Development of a distributed fiber-optic acoustic sensor based on a double Sagnac interferometer without “dead zones”

Based on the research conducted we propose two ways of upgrading a distributed fiber-optic acoustic sensor based on a double Sagnac interferometer, which makes it possible to avoid “dead zones”.

The first method utilizes a compensation coil with the length of $L_k = 3 \text{ km}$ in the middle of the each loop. The length of the coils was chosen so that the “dead zone” remains completely within the coil. In both cases demonstrated in the experiments a “dead zone” in a $\pm 1.5 \text{ km}$ region in the middle of the loop remains inside the coil. Thus, a phase difference magnitude is at least 20 radians along the length of the sensing fiber. This method is simple

and can be easily implemented but has a disadvantage of additional power losses in the system because of a compensation coil.

The second way is to avoid “dead zones” by adding an additional channel with the wavelength of λ_3 in the scheme as shown in Fig. 5. CWDM are located so that the sensing fiber between the pairs has the length of $L/3$. In this case “dead zones” in each loop do not overlap as they are shifted by each other by the length of $L/3$. For every disturbance position there is an interference signal at the outputs of at least two loops, so the disturbance can always be localized.

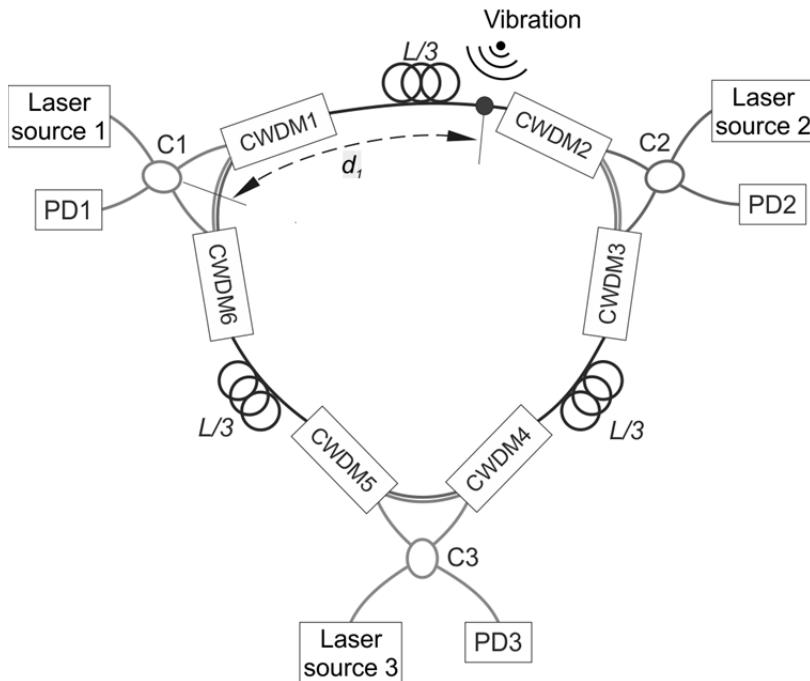


Fig. 5/ A three-channeled DAS based on a Sagnac interferometer

A disadvantage of this method is that a scheme becomes more complicated, so an additional set of components is required, i.e. two CWDM, a light source and a photodetector as well as one more ADC channel for registering the third signal, which increases the cost of the system. At the same time there is an advantage that the entire length of the sensing fiber operates without loses, which is convenient for circled perimeters. In addition, it becomes possible to localize the disturbance by comparing two time delays simultaneously, which reduces disturbance localization errors. It will be studied in further research.

Conclusion

Thus, we have proposed two methods of dead zones’ elimination and compensation in a distributed fiber-optic sensor based on a double Sagnac interferometer. A theoretical analysis has been carried out as well as numerical simulations and experimental studies, which demonstrated a “dead zones” formation process.

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Разработка нейронной сети для анализа данных металлооксидных газовых сенсоров в системе искусственного носа

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Предложено использовать нейросетевую модель для анализа данных сенсоров газа оксидов металлов в системе искусственного носа. При изучении алгоритмов анализа данных наилучшие результаты были получены при использовании многослойного персептрона. Многослойные персептроны — наиболее часто используемыми типами нейронных сетей. Применяя алгоритм обратного распространения для обучения, их можно использовать для решения широкого круга задач. Выяснилось, что использование такой модели значительно улучшает распознавание сигнала при обнаружении газа.

Ключевые слова: нейронная сеть, искусственный нос, искусственный интеллект, металлооксид-полупроводник, сенсор газа, многослойный персепtron, радиальная базисная функция

Сенсоры газа измеряют концентрацию различных газов, исходящих от вещества. Модель ИИ извлекает ключевые характеристики этих газов и использует их для определения соответствующего запаха. Предполагаемый результат отображается пользователю. Существует множество отраслей, которые могут извлечь выгоду из интеллектуальных устройств, способных чувствовать запахи [1–3].

Искусственный нос можно, например, использовать в сфере обслуживания зданий, чтобы определить, когда необходимо убрать офис или ванную комнату или в косметической промышленности, чтобы заменить ингредиенты в парфюмерии на более экологичные, сохраняя при этом аромат прежним. Или вы можете просто использовать его дома для выпечки. Затем показания сенсоров, а также обнаруженные запахи могут быть отправлены на платформу IoT, что позволяет получать оповещения и отчеты в режиме реального времени. Например, оператор технического обслуживания может автоматически получать уведомления об обнаружении утечки газа в цехе или потребители могут быть предупреждены об испорченных продуктах в холодильнике [4–11].

Исследования в этой области ведутся уже 35 лет и достигли значительного прогресса. Современные устройства используют электронное считывание аромата для сравнения, идентификации, количественной оценки и даже хранения и восстановления данных. Электронные носы состоят из трех основных элементов: системы доставки (Массив сенсоров), системы обнаружения и вычислительной системы. Свойства используют электронное считывание аромата для сравнения, идентификации, количественной оценки и даже хранения и восстановления данных [12].

Электронные носы состоят из трех основных элементов: системы доставки (массив сенсоров), системы обнаружения и вычислительной системы. «Искусственный нос» представляет собой систему, которая действует аналогично носу человека [13], как показано на рис. 1.

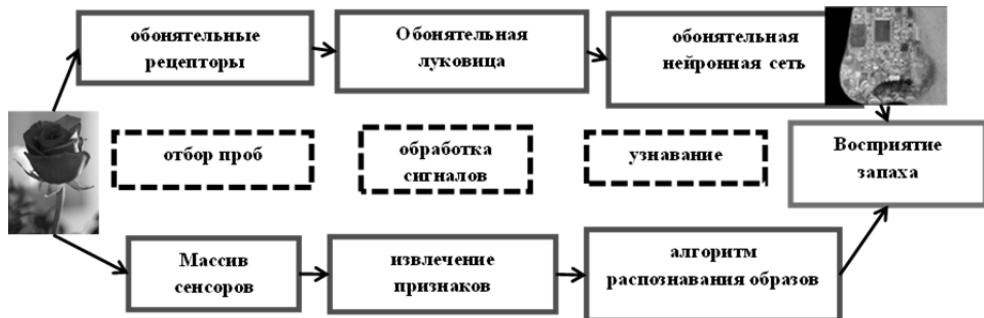


Рис. 1. Типовые архитектуры электронного носа и обонятельной системы человека

Сенсор воспринимает информацию, и искусственные нейронные сети ее анализируют. По сути дела, система состоит из двух блоков: сенсора и искусственной нейронной сети [14, 15], как показано на рис. 2.



Рис. 2. Искусственный нос на основе электрических и/или оптических сенсоров, имитирующих обонятельную систему человека

Как правило, для создания полупроводниковых сенсоров используются широкозонные полупроводники, такие, как SnO_2 , ZnO , TiO_2 , и WO_3 .

SnO_2 наиболее популярен в силу своей изученности, технологичности и низкой стоимости. Обратимая хемосорбция активных газов на поверхности полупроводниковых окислов и халькогенидов сопровождается обратимыми изменениями проводимости. В связи с этим полупроводниковые материалы перспективны в качестве газочувствительных элементов. Для полупроводниковых газовых сенсоров характерны низкая стоимость, малые размеры, высокая чувствительность и надежность.

Высокая чувствительность к токсичным и взрывоопасным газам резистивных сенсоров на основе металлооксидных полупроводников позволяет создавать на их основе детекторы утечки природного газа. Разработкой и производством таких сенсоров занимаются ведущие мировые производители (Rilken Keiki, NipponMonitors, Figaro, Taguchi) [16].

Системы ИИ постоянно совершенствуются, и продвижения в области машинного интеллекта обеспечивают бесшовное взаимодействие между человеком и цифровыми сенсорными системами. Хотя внедрение ИИ в электронные устройства проходит медленно, оно обеспечивает гибкость, возможность настройки и высокую надежность. Новые машинные системы превосходят операторов-людей в большом круге задач, и количество этих примеров растет. ИИ все больше проникает в повседневную жизнь, и уже появляется возможность сочетать мощность человеческого мозга и производительность компьютера для анализа, дедукции, обмена информацией и создания новых концепций [17, 18].

Их главное назначение заключается в создании конкурентоспособных сенсорных систем и приложений. Среди других технологических разработок, которые, вероятно, повлияют на сенсорные системы, можно отметить методы глубинного анализа данных, системы с несколькими агентами, распределенные самоорганизующиеся системы. Для создания систем сбора данных об окружающей среде необходимо интегрировать микропроцессоры и датчики в повседневные бытовые устройства, чтобы сделать их интеллектуальными. Устройства смогут собирать информацию об окружающей среде, обмениваться данными друг с другом и взаимодействовать с человеком. Они будут помогать пользователю решать текущие задачи интуитивным путем. По большому счету, ИИ применим во всех производственных процессах [19–22].

Методы

Моделирование НС было выполнено с использованием набора данных [23, 24], представленных на рис. 3.

Выборка состоит из 6 хороших образцов солодки, 6 плохих образцов солодки и 6 средних плохих образцов. Временной режим представляет собой непрерывную шкалу времени, в которой сигнал сенсора измеряется в течение 120 с каждые $\frac{1}{2}$ с. Двенадцать сенсоров, основанных на технологии металл оксид-полупроводник (МОП), использовались для регистрации летучих соединений из образцов. Это означает, что размер X будет $18 \times 241 \times 12$.

Результаты и обсуждение

Данные устанавливают в программе STATISTICA Neural Networks. Архитектура сети «Обучение» показана на рис. 4. Для анализа данных сенсоров газов оксидов металлов использовалась искусственная нейронная сеть. Алгоритм был реализован на основе универсальных НС таких, как многослойный персепtron (MLP), сеть радиальных базисных функций (RBF) и линейная.

Обучающее множество: выборка состоит из 6 хороших образцов солодки, 6 плохих образцов солодки и 6 средних образцов. Тестовое множество: выборка состоит из 5 образцов (2 хороших образца солодки, 2 плохих образца солодки и 1 средний образец). Игнорированные значения: выборка состоит из 5 образцов (1 хороший образец солодки, 2 плохих образца солодки и 2 средних образца), как показано на рис. 5.

Технология решения задач

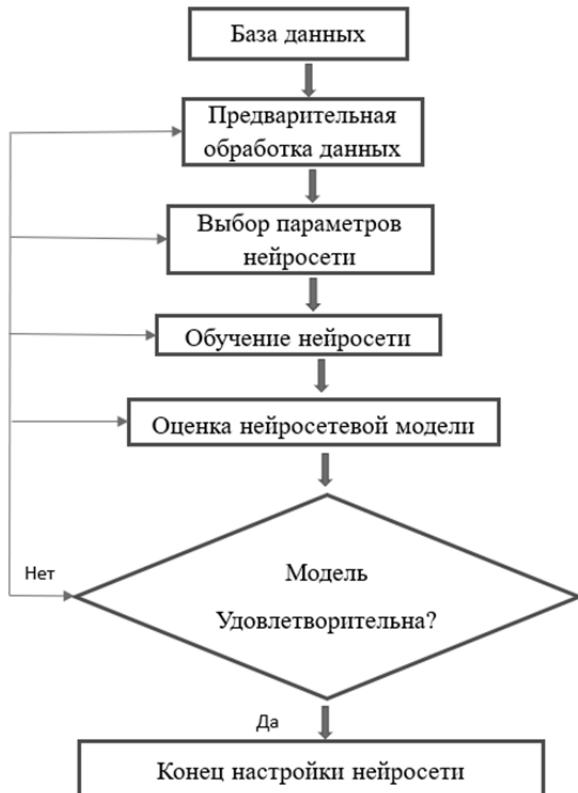


Рис. 3. Технология решения задач



Рис. 4. Схема эксперимента:
 $K = 12$, $I = 60 + 60 + 60$, $J = 241$

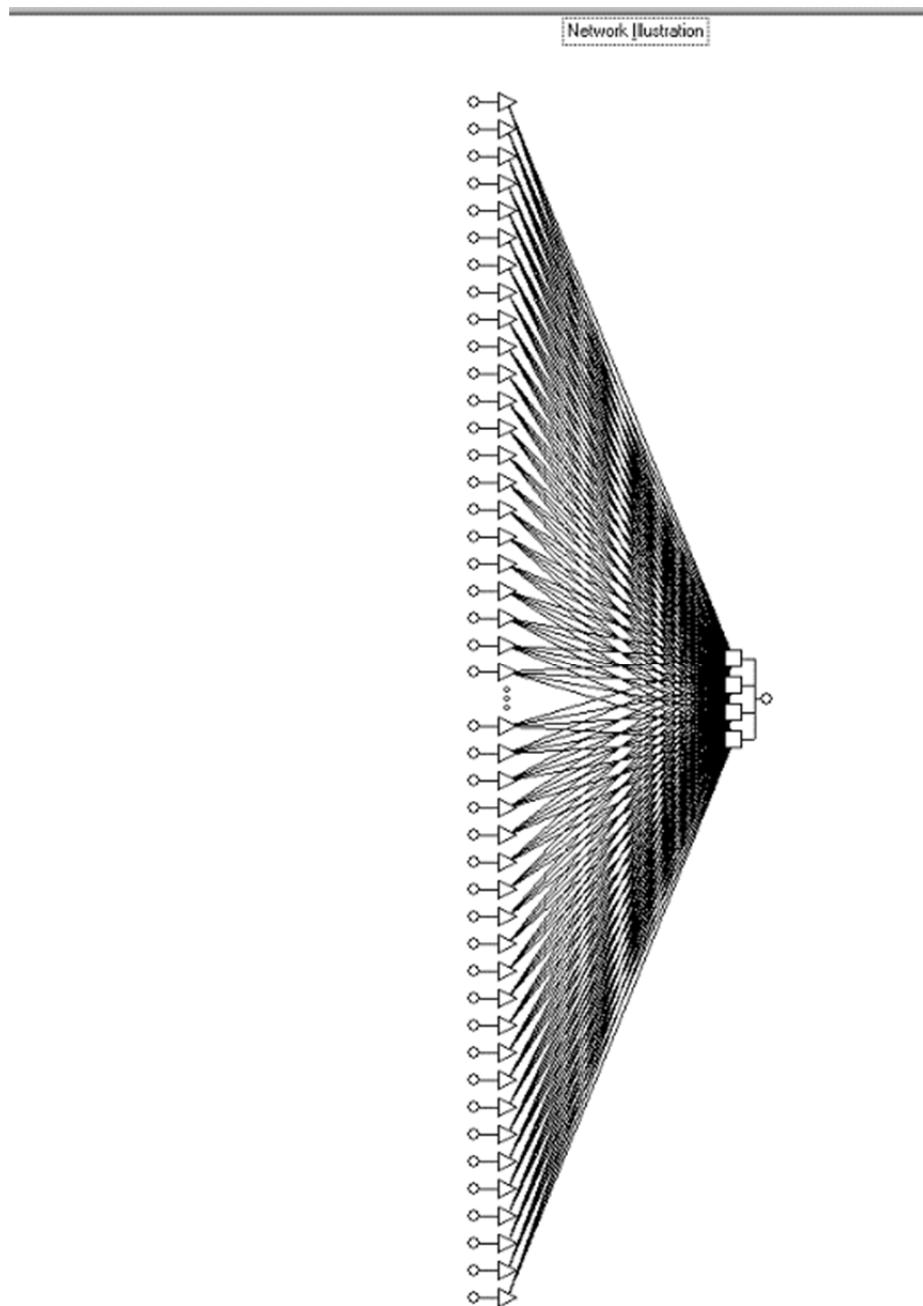


Рис. 5. Архитектура сети «Обучение»

Полученные результаты показали, что многослойный перцептрон (MLP) и линейная сеть проявили себя лучше, чем сети с радиально базисной функцией (RBF), как показано на рис. 6.

The figure displays two windows from the STATISTICA Neural Networks software.

Data Set Editor (data)

Variables	1	Cases	27	0	5
01	0	0,5	1	1,5	2
02	4,62	4,61	4,62	4,62	4,63
03	338	338	338	338	339
04	571	571	571	577	598
05	241	241	241	241	241
06	307	307	307	308	309
07	44	44	44	44,48	46,9
08	53	53	53,1	53	53
09	29,5	29,5	29,5	29,5	29,5
10	62,7	62,7	62,7	62,7	62,6
11	30,9	30,9	30,9	30,9	30,9
12	63,3	63,4	63,3	63,3	63,3
13	39,4	39,3	39,3	39,4	39,4
14	4,63	4,63	4,63	4,63	4,63
15	241	241	241	241	241
16	579	579	580	579	609
17	243	243	243	243	243
18	309	310	310	309	310
19	44	44,2	44,2	44,2	45
20	54,6	54,7	54,7	54,6	54,6
21	29,8	29,9	29,8	29,8	29,8
22	64,3	64,3	64,3	64,3	64,3
23	31,2	31,2	31,2	31,2	31,2
24	64,2	64,2	64,1	64,2	64,1
25	40,6	40,6	40,6	40,6	40,6
26	4,66	4,66	4,66	4,66	4,66
27	339	340	339	339	340
28	571	571	571	571	581
29	242	242	242	242	242
30	308	308	308	308	310
31	44	44	43,9	44	45,1
32	54,5	54,6	54,5	54,5	54,5
33	29,8	29,8	29,7	29,8	29,7
34	63,9	63,9	63,8	63,8	63,8
35	31,2	31,2	31,2	31,2	31,2

Network Set Editor (data)

Current network	Type	Error	Inputs	Hidden	Performance
01	RBF	2,24352	1	1	0
02	RBF	0,4069239	1	1	0,3703704
03	RBF	0,4027801	1	2	0,4074074
04	MLP	0,3097413	9	33	0,6296296
05	MLP	0,05205	153	53	1
06	MLP	0,04722	70	51	1
07	Linear	4,981e-13	238	-	1
08	Linear	4,889e-13	241	-	1
09	Linear	3,05e-13	237	-	1
10*	Linear	2,697e-13	234	-	1

Рис. 6. Данные обучения сети и полученные результаты

Проанализированы возможности нейросети при работе со случайными данными. Для проверки возможностей работы сети с произвольными данными представим входные данные пяти экспериментов и сравним выданные результаты с истинными, как показано на рис. 7.

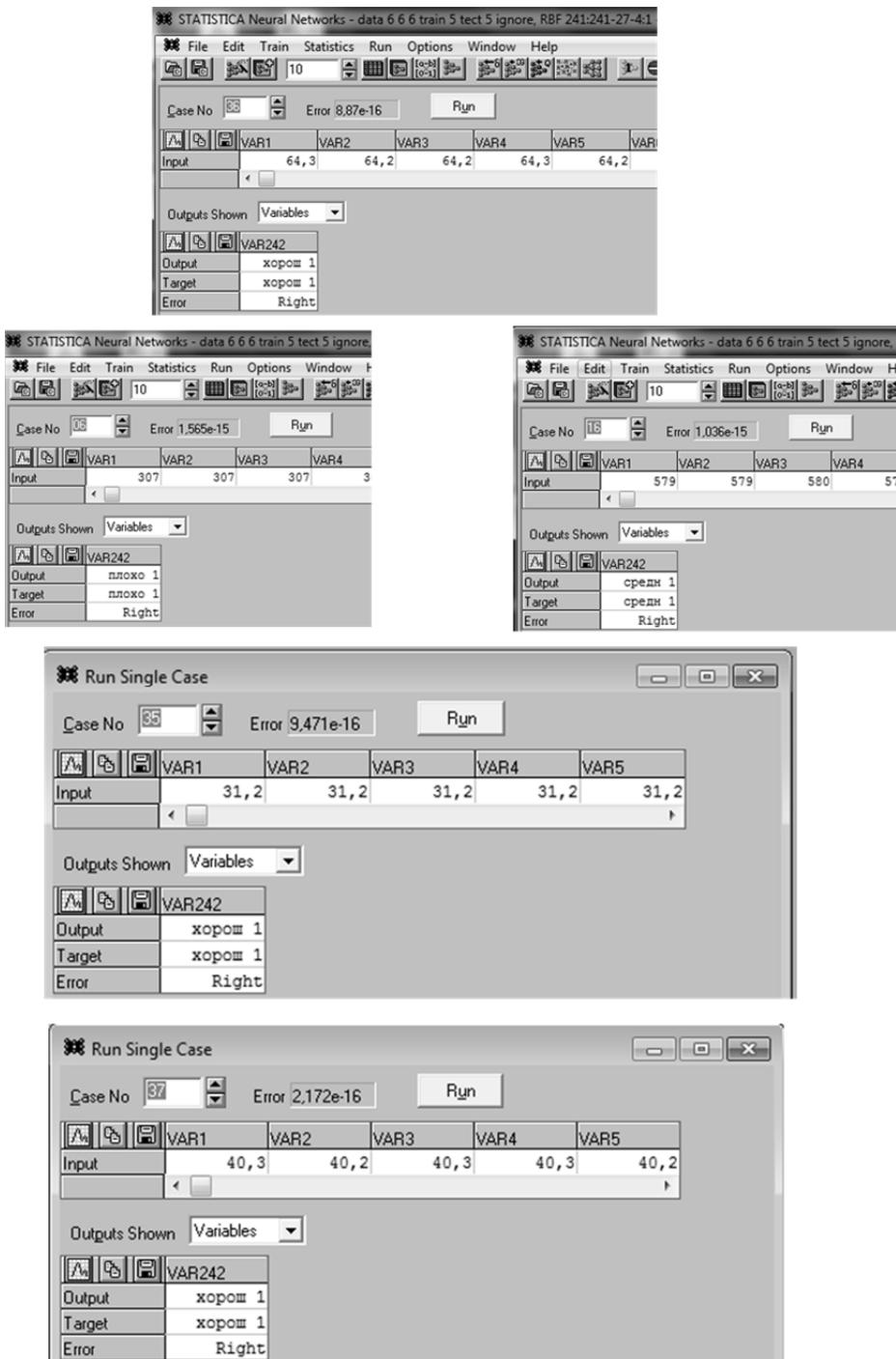


Рис. 7. Проверка возможностей работы сети с произвольными данными

Полученные результаты показали, что модель удовлетворительна. Структуры нейронных сетей были проанализированы для получения наиболее эффективных моделей, чтобы в дальнейшем можно получать значения различных входных параметров без экспериментов.

Заключение

Нейросетевые модели стали мощным инструментом управления оборудованием для инженеров и ученых. Концепция моделирования нейронных сетей имеет широкое применение в области прикладной науки и техники. Метод моделирования нейронной сети, используемый для оценки солодки, дает возможность прогнозировать результаты экспериментов по определению качества хорошее, среднее или плохое. Авторы планируют Расширение сетевых параметров и сложности для снижения уровня ошибок, что может быть вызвано малым количеством обучающих данных, неверно выбранной архитектурой нейронной сети или малым диапазоном изменения входных параметров переобучения. Для того чтобы избежать переобучения, необходимо использовать в процессе обучения контрольное множество данных для промежуточной оценки ошибок обучения. Выявлено, что искусственная нейронная сеть типов многослойный персептрон и линейная могут быть использованы для распознавания сигналов при проведении газовой сенсорики. В дальнейшем планируем использовать нейросетевую модель для анализа данных не только сенсоров газа оксидов металлов в системе искусственного носа, но и сенсоров газа на основе фотонного кристалла.

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Development of a Neural Network for Analysis of the Data of Metal Oxide Gas Sensors in the Artificial Nose System

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In the present work, it is proposed to use a neural network model for analysis of the data of metal oxide gas sensors in the artificial nose system. When studying algorithms data analysis, the best results were obtained using a multilayer perceptron. Multilayer perceptrons are the most commonly used types of neural networks. By using the backpropagation algorithm for training, they can be used for a wide range of applications. It was revealed that the use of such a model significantly improves the signal recognition during gas sensing.

Keywords: neural network, artificial nose, artificial intelligence, metal-oxide semiconductor, gas sensor, multilayer perceptron , radial basis functions

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Измеритель углов подвижного объекта

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Госкорпорация «Росатом»

Представлен прототип измерительного прибора для считываания углов отклонения транспортируемого изделия. Рассмотрены последовательные этапы проектирования составных частей прибора, разработки программного обеспечения и технологии сборки корпуса устройства. Изучены вопросы доступности покупных компонентов изделия, стойкости конструкции к возможным внешним силовым воздействиям и точности, считываемых во время работы, показаний устройства.

Ключевые слова: Bosch MEMS , GPS, гироскоп, акселерометр, 3D-печать

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Angle Meter of a Moving Object

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This article presents the prototype of the measuring device for calculating angle deviations of a transported object. The successive stages of designing the device components, software development and assembly technology of the product body are considered. The issues of the availability of purchased components of the product, the stability of the structure to possible external force effects and the accuracy of the instrument readings during operation are analyzed.

Keywords: Bosch MEMS , GPS, gyroscope, accelerometer, 3D-printing

Introduction

The assembling process of any technically complex device includes transportation operations that can cause the transported product to be damaged. To reduce any risks, it is suggested to use a device that can be easily installed on the transported object to measure deviations by means of specially designed software that can issue an error warning.

There are some analogues of this device in the Russian market, but they are too expensive, have low repairability or work only in static measurement mode.

Pre-design Tasks

The purpose of this scientific work is to create a unified and competitive device that can measure the angles of roll and pitch during the movement of the object on which it is installed, and the error of the deviation angles should not exceed 0.1 degrees.

The designed model consists of commonly available parts of the boards like BOSH gyro and GPS Module, which can be easily replaced in case of any breakdown. The body of the device is made by 3D-printing.

The autonomous work of the device is achieved by a built-in battery. Moreover, the Wi-Fi technology interface allows to communicate with the device from any electronic unit.

The device also has a memory card used for storing digital information and supports autonomous operation, which is provided by means of a built-in Smart Buy battery with a capacity of 2000 mAh. It also assumes the measurements during the movement of the object which it is installed on, therefore, the signals from both the angular velocity sensor and the accelerometer are used to measure its movement.

Mathematical Simulation

Numerical simulation of this algorithm is calculated in Matlab Simulink. Signals from BOSCH BMI-160 are processed by Kalman filtering because the system is built on coarse sensors, and it has large errors that need to be minimized [1]. Errors from the BMI-160 sensor are sent to the algorithm as input errors [2]. The simulation results are shown in Fig. 1. It is confirmed that the numerical values obtained during the simulation fulfilled the task.

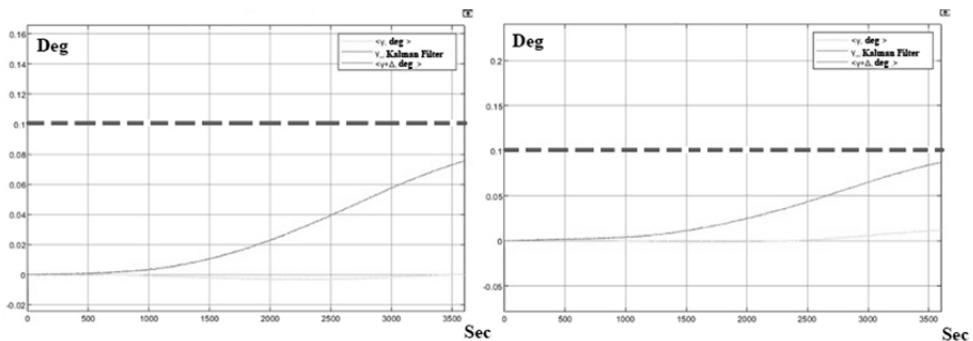


Fig. 1. Change of roll and pitch angles

Development

The main idea of creating this case is to ensure simple assembly and production. Therefore, the case is produced by industrial 3D-printing [3]. This method is characterized by cheapness and speed of production, without losing quality. The assembly is carried out from various standard modules. If the module breaks down, you need to remove the case cover and replace the module.

The device has passed laboratory tests for resonant frequencies, single and multiple shock effects [4]. This leads to the conclusion that the device meets the requirements of the technical specification.

The operability of the device is provided not only in static measurement mode, but also in dynamic mode. Therefore, the signals from BOSCH BMI-160 are used to measure its movement. These signals are processed by a recalculation unit and a navigation algorithm, which calculates coordinates by integrating accelerations and calculates object movement speeds by integrating coordinates. The general scheme of the algorithm is shown in Fig. 2.

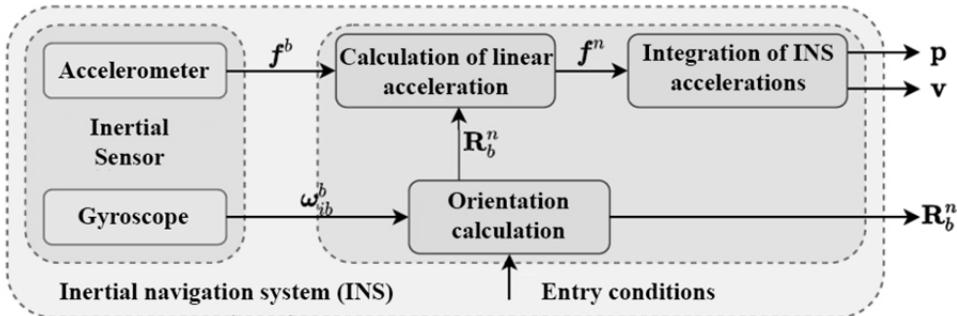


Fig. 2. The principle of functioning of the INS algorithm

At the next stage GPS signals are processed by Kalman filtering because the system is built on coarse sensors [2]. They have large errors that need to be minimized. The Kalman filter works in parallel to the algorithm and includes modes of predicting and eliminating errors by introducing feedback and outputs estimated parameter errors that are fed into the system to correct measurements.

The software of this device is written by means of the Arduino IDE open-source software. One of the features of the Arduino IDE is a relatively low entry limit, and the availability of ready-made libraries for working with common electronic devices, such as the ESP-32 module used in the work, makes it possible to simplify the process of configuring devices greatly.

Conclusion

As a result of this research, a working model of the device is designed. All necessary tests are carried out to prove its workability and correctness of the theoretical approaches and solutions chosen.

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Применение программного комплекса QForm для моделирования процессов штамповки свинцом тонкостенных деталей полусферической формы

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Проведен сравнительный анализ уравнений и принципов, заложенных в программных комплексах *Deform* и *QForm*. Проведено математические моделирования в *QForm* процесса штамповки свинцом полусферических деталей из алюминиевого сплава АМгб с учетом рекомендаций из литературы и статей. Проведена верификация полученных результатов моделирования в программе *QForm* процесса формообразования заготовки в жесткую полусферическую матрицу свинцом, и выявлены направления по модернизации техно-логического процесса по критерию уменьшения толщины детали в купольной части.

Ключевые слова: штамповка свинцом, формообразование, математическое моделирование, *QForm*, алюминиевые сплавы

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Use of the QForm Software Package for Modeling Lead Stamping Processes of Thin-Walled Hemispherical Parts

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A comparative analysis of the equations and principles laid down in the Deform and QForm software is carried out. Mathematical modeling of the process of lead stamping of hemispherical parts made of aluminum alloy is performed with recommendations from literature and papers. The verification of the received simulation results in the QForm program of the process of forming the workpiece into a rigid hemispherical matrix with lead is pursued. The directions for the modernization of the technological process according to the criterion of reducing the thickness of the dome part are revealed.

Keywords: lead stamping, shaping, mathematical modeling, QForm, aluminum alloy

Introduction

Improving the quality of products is an important task for the companies in the machine-building manufacturing. Workpieces and parts what are made by plastic deformation methods must have the required strength properties, as well as meet the requirements of design documentation. In particular, a large number of shell-shaped aluminum products are used in fuel systems with high operating pressures in rocket and space technology products.

One of the ways to improve the quality of such parts is the use of lead stamping technology, studied at the Department SM12 of BMSTU. The use of lead stamping makes it possible to simplify die tooling and adapt the stamping technology for use in multi-nomenclature multi-batch production, while ensuring the quality of stamped parts due to the forming of useful friction forces on the surface of the workpiece [1, 2].

In [3–7], the results of simulations in the Deform program (USA) are presented. QForm, as well as Deform, is a software for modeling pressure treatment processes, which allows to reduce the cost of conducting experiments and producing the technological processes. The choice of the QForm software package is based on the requirement of use national software products. In this regard, it is necessary to justify the possibility of using QForm in the tasks of modeling lead stamping processes based on the analysis of documentation, simulation results and experiments.

Analysis of documentation

According to the documentations [8, 9] it is established that in the case of DEFORM, the basic idea of FEM is embedded in QFORM, based on the position that any continuous function f can be approximated by a set of simpler functions φ_m , ($(m=1 \dots M$, M — number of sections), each is defined on one site. For example, in the piecewise linear approximation of a continuous one variable function $f(x)$, the domain of the function definition is divided into a certain number of sections, on each the real function is replaced by a straight $\varphi_m(x)$ passing through the boundary points (Fig. 1). The coefficients defining the equations of these lines depend on the values of the function at the boundaries of the plots. Thus, a continuous function is replaced by a set of values at individual points, and the behavior of the function between points is determined approximately (Fig. 2). An increase in the number of plots leads to an increase in the accuracy of the approximation.

$$f(x) = \sum_{m=1}^M \varphi_m(x), \quad (1)$$

$$\varphi_m(x) = \frac{(f_{n+1} - f_n)}{(x_{n+1} - x_n)}(x - x_n). \quad (2)$$

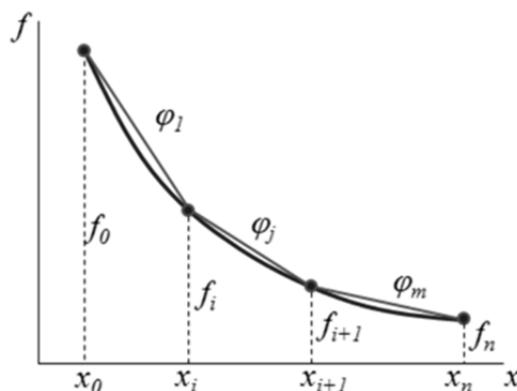


Fig. 1. Piecewise linear approximation of a continuous function of one variable

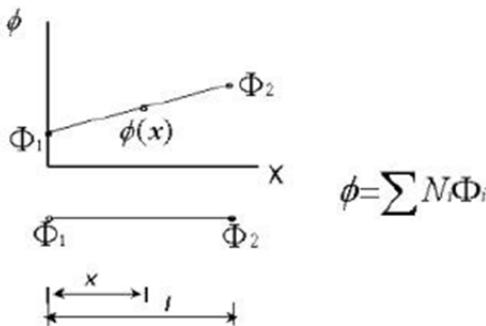


Fig. 2. Generalized equation of the form function

Modeling of plastic deformations in a workpiece is performed with the Levi-Mises equation:

$$\dot{\varepsilon}_{ij} = \frac{3}{2} \frac{\dot{\varepsilon}}{\bar{\sigma}} \sigma'_{ij}, \quad (3)$$

where $\bar{\sigma}$ – effective stress;

$\dot{\varepsilon}$ – effective strain rate (strain rate intensity);

$\dot{\varepsilon}_{ij}$ – strain rate tensor;

σ'_{ij} – stress deviator.

And the defining principle of the problem of modeling the deformation of the workpiece is the variational Markov principle, according to which the functional:

$$\Phi = \iiint_V \sigma \varepsilon dV - \iint_S F_i u_i dS \quad (4)$$

It takes the minimum value for the actual velocity field. The first integral of the functional reflects the power of plastic deformation, and the second — the power of external forces.

Thus, the algorithm of the QFORM and DEFORM programs assumes a consistent solution of deformation mechanics problems. To solve the problems of determining the stress-strain state, a system of equations of deformable body mechanics is used [8, 9]:

1. Equation of equilibrium

$$\frac{d\sigma_{ij}}{dx_i} = 0, \quad i, j = 1, 2, 3. \quad (5)$$

2. Equation of the relationship between the velocity field of material points and

$$\dot{\varepsilon}_{ij} = \frac{1}{2} \left(\frac{dv_i}{dx_j} + \frac{dv_j}{dx_i} \right), \quad i, j = 1, 2, 3 \quad (6)$$

3. Levi-Mises equation:

$$\dot{\varepsilon}_{ij} = \frac{3}{2} \frac{\dot{\varepsilon}}{\bar{\sigma}} \sigma'_{ij}, \quad (7)$$

4. Incompressibility condition (constant volume law):

$$3\dot{\varepsilon}_{ij} = \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} = 0, \quad (8)$$

5. Mises plasticity criterion:

$$\sigma_{eq} = \frac{1}{\sqrt{2}}[(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2]^{0.5} \quad (9)$$

6. Rheological model of the material (resistance of the material to plastic

7. Boundary kinematic and force conditions on the surface.

Modeling

At the first stage of modeling, the conclusions given in [3, 5] were considered. Thus, in [3], the results of simulations of technological processes of lead stamping are presented in order to determine the dependence between matrix's geometry and the thinning of the dome part of sheet details.

In [5], the influence of the size of the conical protrusion in the lead block on the thinning of the detail's dome part during the formation by the lead block was analyzed. In the considered works, modeling was carried out in the Deform software package and graphs are presented in relative coordinates for the development of technological processes of lead stamping.

In order to confirm the considered dependencies, the scheme presented in Fig. 3 was designed. This scheme implements the process of lead stamping of hemispherical parts with varying geometric parameters of the die tooling (dimensions of the conical extrusion of the lead block, the radius of the entrance part of the matrix).

Table 1 shows the dimensions of the considered geometric parameters in the analyzed scheme.

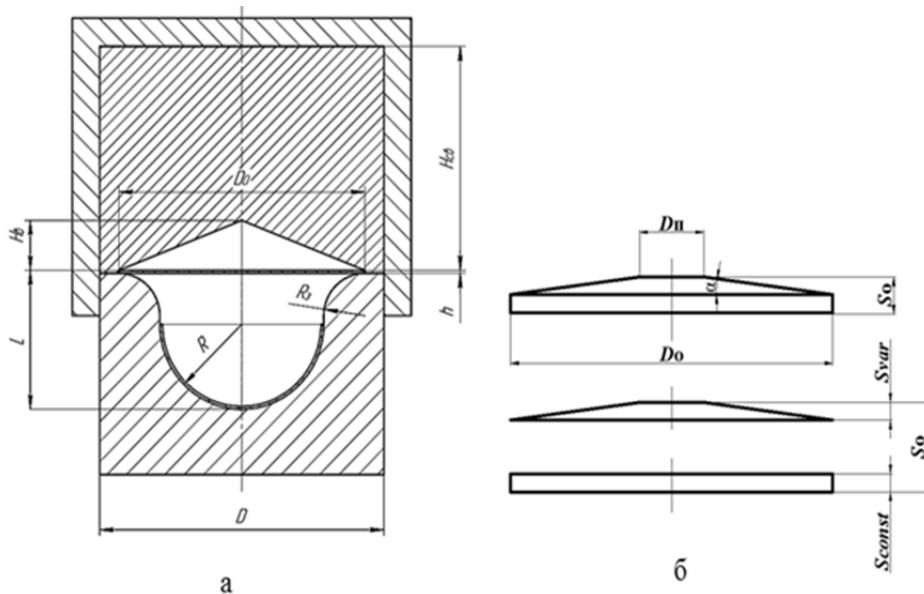


Fig. 3. The scheme of stamping hemispherical parts: a — die tooling; b — workpiece

Table 1

Geometric parameters of models for the analysis of the stamping process of hemispherical parts from plastic aluminum alloy

Description	R	R ₃	D ₀	D	h	H _{CB}	H _B	l	S ₀	S _{var}
Numeric values, mm	85	20, 42,5, 60, 85, ∞	270	280	5	150	0, 15, 30, 42,5, 60, 70	143	5	5

Aluminum alloy and lead, respectively, are used as the materials of the workpiece and the plastic medium. The characteristics of the materials are presented in Table 2.

Table 2

Numerical values of physical and mechanical parameters of lead and aluminum alloy

Characteristic	Aluminum alloy	Lead
p ₀ , $\frac{g}{cm^3}$	2,64	11,34
σ_T , GPa	0,16	0,025
Y, GPa	0,35	0,025
E, GPa	71	14
E ₁ , GPa	71	14
E ₂ , GPa	0,50	0,05
K, GPa	60,50	46,70
G, GPa	26,30	4,80
v	0,31	0,45

The friction in the «lead – billet» and «matrix – billet» pairs is set in different ways. In the «lead – billet» pair, friction is set according to Siebel's law, which links the occurrence of friction forces with the plastic deformation of the surface layer of metal. Thus, when plastic deformation occurs on the surface of the workpiece in contact with the tool, a combination of plastic shear and boundary friction is realized.

$$t = f_\sigma \sigma_T, \quad (10)$$

where f_σ – index of friction forces;

σ_T – yield strength of deformable metal, MPa.

The coefficient of friction in this pair is assumed to be 0,012.

In the pair «matrix – workpiece», the friction is set according to Coulomb's law (small contact pressures):

$$t = \mu \sigma_N, \quad (11)$$

where μ – coefficient of friction;

σ_N – contact pressure, MPa.

In such pair, the coefficient of friction value is assumed to be 0.1. The value of the stamp speed is 1 mm/s. The accepted parameters do not contradict the results of previous experiments [10].

The effect of hardening on the change in the mechanical properties of materials was taken into account with the stated law [11]:

$$\sigma_{b,\varepsilon} = \left(1 + \left[\frac{(1+n)^{1+n}}{n^n} - 1 \right] \varepsilon^{0.5+n} \right) \sigma_b, \quad (12)$$

where n – hardening index;

σ_b – tensile strength of deformable metal, MPa;

ε – current strain value.

To implement the dependence in the QFORM software package, a postprocessor program was written, which allows you to set the values of the hardening index and the tensile strength for a specific material. So for the AMg6 alloy: n = 0.35, σ_b = 440 MPa and C0: n = 0.5, σ_b = 12 MPa [11].

Results

Fig. 4 shows the results of numerical simulation of the lead stamping process with different values of conical extraction in a lead block.

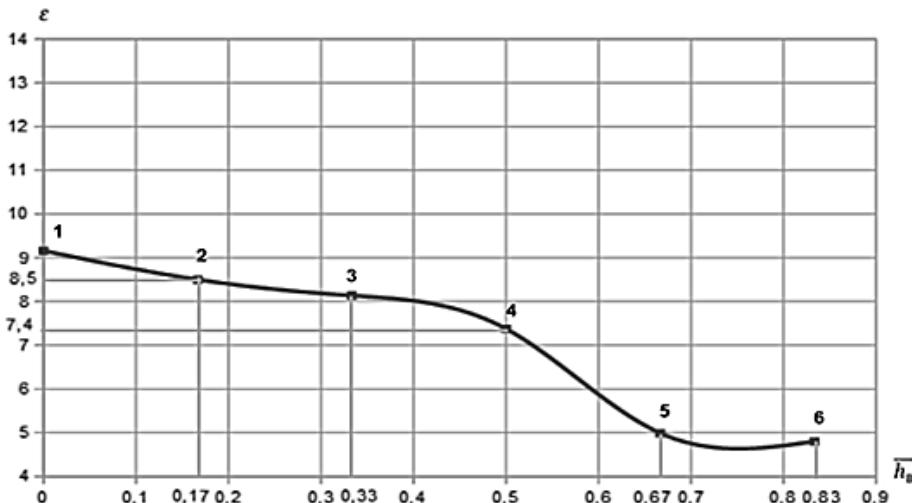


Fig. 4. Dependence of the thinning in the dome part on the size of conical extraction:
 1 — $H_B = 0$; 2 — $H_B = 15$ mm; 3 — $H_B = 30$ mm; 4 — $H_B = 42.5$ mm;
 5 — $H_B = 60$ mm; 6 — $H_B = 70$ mm

Where $\overline{h_B} = \frac{H_B}{R_{sph}}$ — relative depth of extraction (H_B — the depth of the conical extraction in the lead block; R_{sph} — the radius of the hemisphere; $\varepsilon = \frac{S_w - S_p}{S_w} * 100$ — relative drowning in the dome (S_w — thickness of the workpiece; S_p — the thickness of the dome part)). The height of the conical protrusion in the lead is marked in terms of relative coordinates.

Fig. 5 shows the results of numerical simulation of the lead stamping process with varying the size of the radius of the entrance part of the matrix.

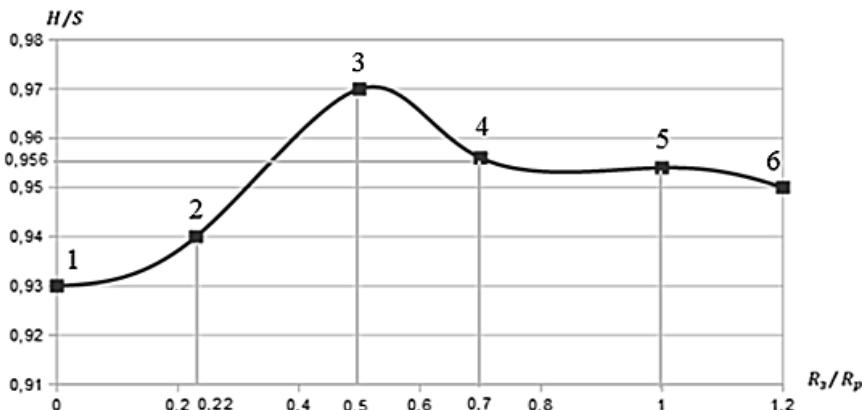


Fig. 5. Dependence of the thickness of the dome part on the radius of the entrance part of the matrix:

1 — $R_3 = \infty$; 2 — $R_3 = 20$ mm; 3 — $R_3 = 42,5$ mm; 4 — $R_3 = 60$ mm; 5 — $R_3 = 85$ mm;
6 — $R_3 = 100$ mm

Where S — thickness of the workpiece, H — the thickness of the dome part, R_p — radius of the working part of the matrix, R_3 — the radius of the entrance part of the matrix. The dimensions of the entrance parts of the matrices are marked in terms of relative coordinates.

Conclusion

The following conclusions can be conducted as the results of analyzing the dependencies (Fig. 4, 5) obtained during modeling in the QForm software package:

1. The received dependences do not contradict with the results of modeling in the DEFORM software package described in [3, 5], which were confirmed by previously performed studies [10, 11]. At the same time, the percentage of discrepancy between the simulation results does not exceed 5 %.

2. The best indicator for the thickness of the dome part is achieved when $\frac{R_3}{R_p} = 0,5$;

3. In order to increase the thickness of the dome part, it is necessary to raise the size of the conical extrusion in the lead block, thereby increasing the time of lead coming into contact with the workpiece during the stamping process;

4. In the range of the considered values \bar{h}_B (0...0,83) the change of the part's thinning has a non-monotonic character:

- in the range (0...0,67) — the relative change of the thinning in the dome part is 48 % of the maximum thinning for hemispherical parts;

- in the range (0,67...0,83) — the relative change of the thinning in the dome part is 4 % of the maximum thinning for hemispherical parts.

Thus, based on the analysis of the literature and the results of mathematical modeling, the rationality of using the national QFORM software in the modeling of technological processes of lead stamping of thin-walled hemispherical parts was confirmed.

At the same time, the recommendations obtained should be used in the design of technological processes of lead stamping of hemispherical parts made of aluminum alloys.

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УДК 10167

Модификация эпоксидных смол неорганическими связующими веществами

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Для улучшения механических и термических свойств композитов была получена новая матрица на основе эпоксидной смолы, неорганического связующего и триэтилентетрамина. В качестве реагентов использовали связующие, которые были синтезированы и получены в Российской Федерации в целях замены зарубежных продуктов. Разработаны полимерные композиционные материалы с различным количеством модифицирующей добавки в системе. Термостойкость изделий на основе неорганических связующих и эпоксидных смол увеличена с 64,7 до 90,5 °C без изменения стандартного процесса отверждения. Прочность композиционного материала с содержанием 0,001 объемной доли увеличена в 2,5 раза.

Ключевые слова: композитные материалы, эпоксидные смолы, механические свойства, неорганические добавки, эпоксидные матрицы, динамический механический анализ

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Modification of Epoxy Resins with Inorganic Binders

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A new matrix based on epoxy resin, inorganic binder and triethylenetetramine was obtained in order to improve the mechanical and thermal properties of composites. The reagents used were binders that were synthesized and obtained in the Russian Federation in order to replace foreign products. Polymer composite materials with different amounts of a modifying additive in the system were developed. The thermal resistance of products based on inorganic binders and epoxy resins increased from 64.7 to 90.5 °C degrees without changing the standard curing process. The strength of the composite material with a content of 0.001 volume fraction increased by 2.5 times.

Keywords: composite materials, epoxy resins, mechanical properties, inorganic binders, epoxy matrix, dynamic mechanical analysis

Introduction

This paper considers the modification of epoxy resins with inorganic binders to improve thermal and mechanical properties of composites. Organic resins are used in many industries, but one of their few serious drawbacks is the restriction for their use at temperatures above 100 °C preserving their physical and mechanical properties. Flame retardants or inorganic binders are often used to increase the heat resistance of epoxy resin materials, which makes it possible to use them in various fields of industry.

Recently, active research was done in this field [1–3]. The most promising trend is adding inorganic binders to the polymer matrix of epoxy resins. Due to this method, the physical-chemical and mechanical properties of composites are improved. The authors have used ammonium polyphosphate as an additive. The advantage of ammonium polyphosphate over a halogen flame retardant is that it emits less smoke during combustion, it has low toxicity and is environmentally friendly, and also has chemical and thermal stability [2, 3]. According to the data [1], the inorganic additive has a high polarizability, sensitivity, which limits its use as a fire-resistant additive in polymer materials. Based on the results of the article [1], Xiaoguo Zhang and other researchers concluded that the toughness, tensile strength and heat resistance of the hybrid polymer increased with the addition of an inorganic binder. Researchers attribute this to the good interaction of the matrix with ammonium polyphosphate and an epoxy resin. The researchers emphasize that epoxy resins are widely used in the manufacture of laminates, coatings, adhesives due to their excellent physical and mechanical properties, good chemical and corrosion resistance, as well as high adhesion [4–6]. Shuang Yang, Qiaoxin Zhang and Yefa Hu could increase the fire resistance of the material made with organic and inorganic binders because of the synthesis of a boron based binder, phosphorus and nitrogen [4]. D. Matykiewicz, B. Przybyszewski, R. Stanik and A. Czulak also show that the use of phosphorus-containing additives to epoxy resin increases resistance to high temperatures and makes it possible to use it where previously it was impossible due to high flammability, for example: civil

engineering, railway industry or automotive industry. It is significant that the modified matrix for composite materials combined with a fast and highly efficient resin powder molding production process may affect the materials market in the future [7].

The Russian Federation has been sanctioned by many foreign states. That is why there is an active import substitution in our country. The goal of this research is to use domestic binders to modify epoxy resins as inorganic. The main task of the study is to analyze the physical-mechanical and physical-chemical properties of modified epoxy resins components produced in Russian.

Materials and methods

Materials. For this study the following materials were used:

1) an indigenous epoxy resin, which was obtained in Federal State Unitary Enterprise named after Sverdlov (Fig. 1).

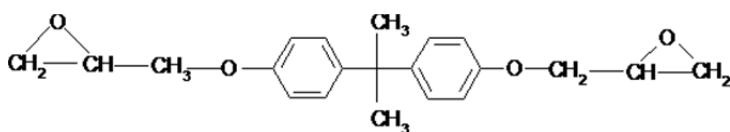


Fig. 1. Structural formula of ED-20 epoxy resin

ED-20 resin is a soluble and fusible reactive oligomeric product based on epichlorohydrin and diphenylolpropane. ED-20 is used in industry in its pure form, or as components of composite materials — filling and impregnation compounds, adhesives, sealants, binders for reinforced plastics, protective coatings.

The uncured ED-20 epoxy resin can be converted into a non-melting and insoluble state by curing agents (hardeners) of various types: aliphatic and aromatic di- and polyamines, low molecular weight polyamides, di- and polycarboxylic acids and their anhydrides, phenol-formaldehyde resins and other compounds. Depending on the hardener used, the properties of the cured ED-20 epoxy resin can vary widely (Table 1).

Table 1
Basic properties of the epoxy resin

Specifications	Quantity/Quality	Dimension
Density	1.2	kilogram/m ³
Mass fraction of epoxy groups	20	%
Dynamic viscosity	15	Pa*s
Mass fraction of the chlorine ion	0.001	%
Colour	transparent	—

2) triethylenetetramine hardener (Aminoplast LLC, Russia) is shown in the Fig. 2.

Finished products with triethylenetetramine have (Table 2):

- good mechanical strength;
- chemical purity;
- its shade (the hardener does not affect the color of the products).

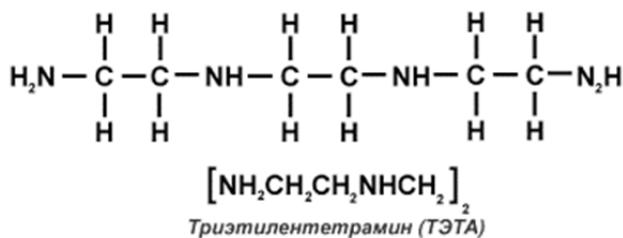


Fig. 2. Structural formula of Triethylenetetramine

Table 2
Basic properties of triethylenetetramine

Specifications	Quantity/Quality	Dimension
density	0.98	kilogram/m ³
Mass fraction of epoxy groups	20	%
Dynamic viscosity	30	mPa*s
colour	yellow	-

3) an aluminum phosphate binder (Table 3), which is produced at the Foskon enterprise in Kostroma (Russia).

A high-temperature binder is based on boron and aluminum phosphates. It is used as a binder in metallurgical production in the manufacture of molds and rods, in the production of refractory products, dyes for coloring mineral sprinkles for roofing tiles and colored roofing material based on aluminum phosphates and borates, etc. «Foskon 350» with the Foskon 355 hardener is used in manufacturing cold-hardening mixtures, i.e. Foskon process.

Table 3
Basic properties of inorganic binder

Specifications	Quantity/Quality	Dimension
density	1500-1760	kilogram/m ³
colour	White	-

Methods. To determine the strength of the samples, the method of determining the static bending strength was used. (ISO 178:2010). The samples were tested on a bursting machine Zwick Roell Z100. Before starting the tests, the samples were measured with a caliper with an accuracy of 0.01 mm. The method is to determine the maximum strength of a flat sample with a constant rectangular cross-section, which lies on two supports with a constant loading rate until the moment of destruction of the sample or until the moment when the tensile strain on the outer surface of the sample reaches a preset value. Samples should have a smooth, even surface without blisters, chips, cracks, delamination and other defects that are visible to the naked eye. The number of samples must be at least five.

Before testing, the samples are marked. The test is carried out at a constant temperature and relative humidity. Before performing the experiment, the length, width and thickness of the samples are measured in the center and along the edges of each test sample. Supports and a punch are installed on the machine. A specially prepared steel beam is installed on the supports and the supports and the punch are already aligned along it in order to achieve the necessary parallelism of the support surfaces. Set the speed of movement of the active capture in accordance with regulatory documents. After the destruction of the sample, all the data is entered into the table and all the necessary dependencies are built.

In this method a sample, which has a shape of a flat rectangular strip, is placed in a DMA device and subjected to vibrations with a frequency of 1 Hz and heating at an adjustable speed. In order to preserve the possibility of comparing the results with different humidity, the same heating frequency and speed are used. The glass transition temperature T_g DMA is defined as the temperature at which a strong drop in the dynamic modulus of elasticity E is observed. In order to compare results, the peak temperature is determined, which is called the tangent of mechanical losses T_i , as well as T_g DMA. Two samples are used to determine the glass transition temperature. The size of the sample must comply with the requirements of the operating manual of the device. As a rule, the size corresponds to a range of 22 mm in length, 3 in width and 1.5 in thickness. The sample is measured using a caliper and the values obtained are recorded in the program. Next, the sample is installed on the DMA device, taking into account the clamping method. The sample is fixed in accordance with the selected loading mode, in this case a three-point bend. When installing the sample, we follow the instructions of the equipment manufacturer. The material is installed exactly in the middle so that it is parallel to the base of the device. Next, the program is turned on, after which the computer displays graphs on the screen and the received data is exported to the desired program. After that, the oven is cooled. Further, the graphs are processed using a special program «Proteus Analyze» of the equipment manufacturer.

Results

Determining the static bending strength. In this research, we present a composite material production technology step by step:

1. An inorganic binder with a volume of 0.001, 0.01 and 0.06 was added to the epoxy resin.
2. Then it was stirred on a magnetic stirrer for 10 minutes until the mixture was homogenized.
3. After that, the hardener triethylentetramine was added to the mixture and also stirred for 10 minutes.
4. Then the mixture was poured into silicone molds and the samples were cured for 4 hours at a temperature of 60 degrees.
5. After curing, the samples were visually checked for chips, scratches and other defects.
6. Next, the samples were mechanically processed for two types of tests using a grinding machine.

After conducting static bending tests, the following results were obtained (Table 4).

According to the results of Table 4, we constructed the dependence of the bending strength on the volume fraction of the filler, that is, an inorganic phosphorus-containing binder of the Foskon-350 brand.

Table 4
Experimental data for determining the bending strength of ED-20 modified
with a Foscon-350 phosphorus-containing binder

No.	$\varphi_{n,v.f.}$	Flexural strength- σ_f , MPa
3	0.01	143.31
4	0.06	79

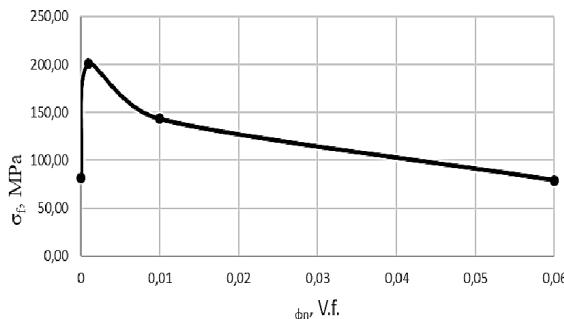


Fig. 3. Dependence of bending strength on the volume content of Foscon-350 in the matrix

Special attention should be paid to samples with a volume fraction of the modifying additive 0.001 and which were cured for 4 hours at a temperature of 60 °C (Fig. 3). The strength of these matrices exceeds the strength of matrices based on ED-20 and THETA hardener by almost 2.5 times. With a content of 0.01 vol. d. of filler in the composition, the strength index also exceeds the properties of the unmodified sample by 2 times.

Dynamic mechanical analysis. In order to understand the conditions under which the material can be operated, a dynamic mechanical analysis was made. The tests were carried out on proprietary NETZCH DMA 242 equipment, and the «PEGASUS ANALYZE» program was used to process the graphs. The following diagrams were constructed (Fig. 4–7) on the base of the results obtained with the software program.

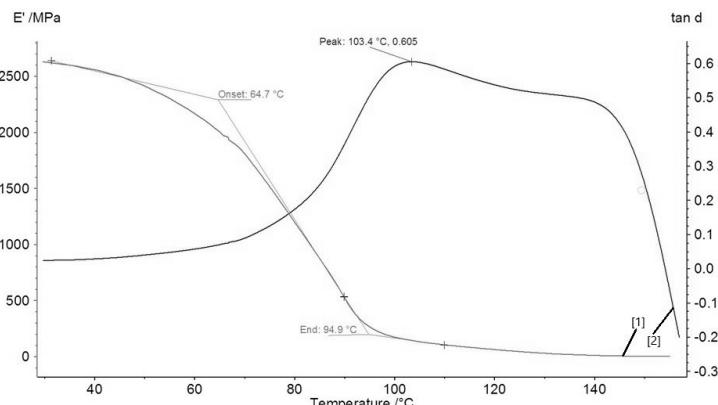


Fig. 4. DMA diagram for a composite based on ED-20 and a THETA hardener, where 1 corresponds to the modulus of elasticity, and 2 corresponds to the tangent of mechanical losses

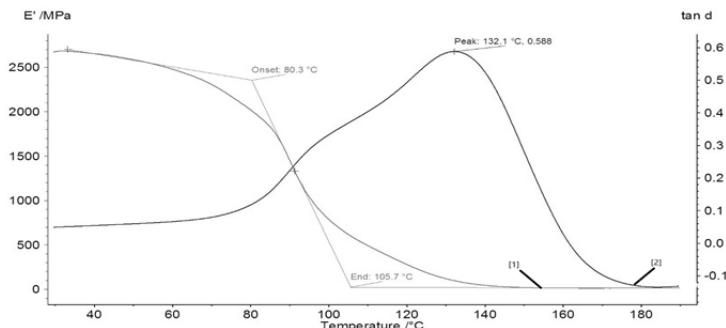


Fig. 5. DMA diagram for a composite based on ED-20 and a modifying additive Foskon-350 in the amount of 0.001 v. f., where 1 corresponds to the modulus of elasticity, and 2 corresponds to the tangent of mechanical losses

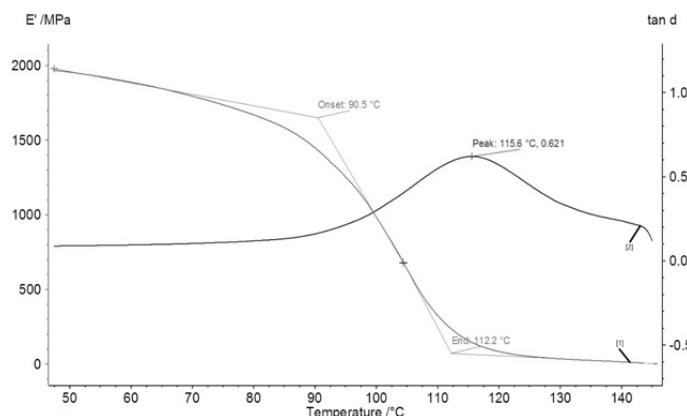


Fig. 6. DMA diagram for a composite based on ED-20 and a modifying additive Foskon-350 in the amount of 0.01 v. f., where 1 corresponds to the modulus of elasticity, and 2 corresponds to the tangent of mechanical losses

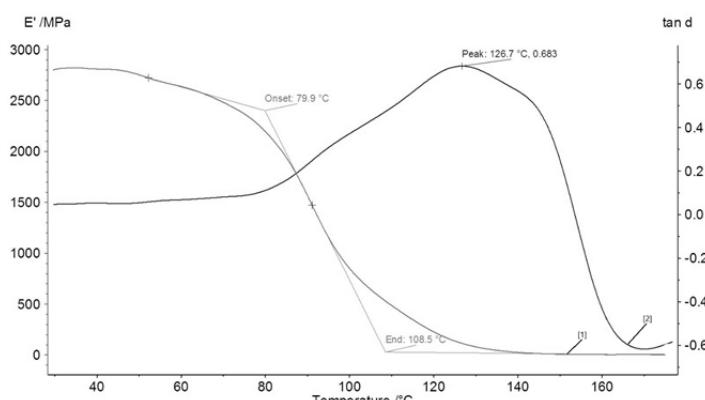


Fig. 7. DMA diagram for a composite based on ED-20 and a modifying additive Foskon-350 in the amount of 0.06 v. f., where 1 corresponds to the modulus of elasticity, and 2 corresponds to the tangent of mechanical losses

With an increase in the fraction volume of the phosphorus containing inorganic additive in the composition, the glass transition temperature of the polymer and the tangent of mechanical losses increase. In other words, the introduction of an inorganic binder has a positive effect on the properties of the material. In the diagrams shown in Fig. 4–7, we can note that the glass transition temperature increases with an increase in the proportion of filler in the system. It is also worth noting that with φ_n , the properties of the system are comparable to samples without a modifier. Thus, when the system is oversaturated, the inorganic phosphorus-containing binder ceases to modify the matrix based on epoxy resin.

According to the results of Table 5, the dependences the tangent of the angle of mechanical losses and the glass transition temperature on the volume fraction of the filler in the system are constructed.

Table 5

Experimental data for determining the modulus of elasticity, the tangent of mechanical losses and the glass transition temperature of matrices based on ED-20 and the inorganic additive «Foskon-350»

No.	φ_n , v.f.	E' , MPa	$T, ^\circ\text{C} (\text{Tan}_d)$	$T_{\text{gl}}, ^\circ\text{C}$
1	0	2631	103.4	64.7
2	0.001	2684	132.1	80.3
3	0.01	1964	115.6	90.5
4	0.06	2797	126.7	79.9

Fig. 8 shows the nonlinear dependence of the tangent of the angle of mechanical losses on the volume fraction of the modifier in the composite. In the graph shown above, there is a maximum point at 0.001 vol. d. of inorganic phosphorus-containing binder in the system.

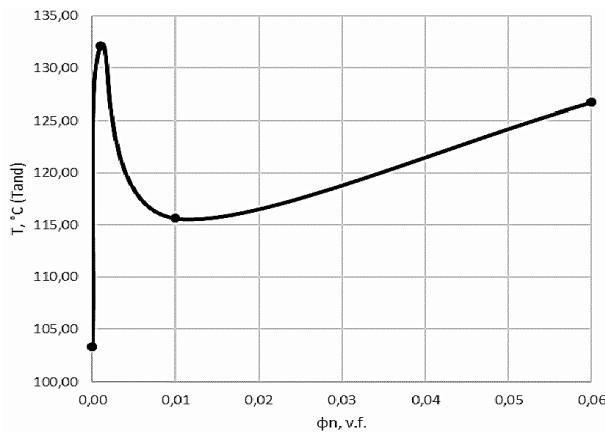


Fig. 8. Dependence of the tangent of the angle of mechanical losses on the volume content of the inorganic modifier Foskon-350

Fig. 9 shows the nonlinear dependence of the glass transition temperature on the volume content of the inorganic phosphorus-containing binder in the composite. This graph shows that there is an inflection point at a content of 0.01 modifying additive in the composite.

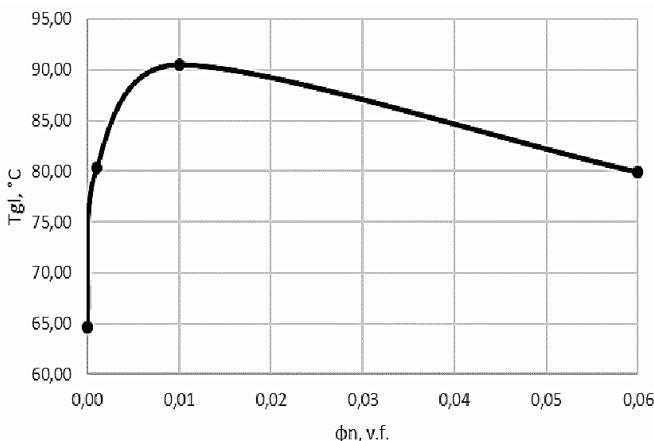


Fig. 9. Dependence of the glass transition temperature on the volume content of the inorganic modifier Foskon-350

Fig. 9 shows that the glass transition temperature of the composite increases with an increase in the proportion of filler in the composition. The thermophysical properties cease to increase with a content of more than 0.01 vol. d. of the modifier. It occurs due to the fact that these systems initially need a higher curing temperature.

Discussion and Conclusion

We have found that the introduction of 0.001 vol. d. of an inorganic phosphorus-containing binder of the Foskon-350 brand into an ED-20 epoxy resin leads to an increase in the bending strength of the matrix 2 times relatively to the unmodified one. This is because boron and aluminum molecules strengthen the internal structure of the epoxy resin and give it a new set of properties.

According to the conducted DMA studies, the introduction of inorganic phosphorus-containing additives to the epoxy resin increases the glass transition and operation temperatures by 50 % at the same heat treatment temperatures.

We have found that all the studied thermo-physical, operational and technological properties are improved due to the introduction of a certain proportion of an inorganic phosphorus-containing modifier. For the Foskon-350 brand, the optimal concentration is $\phi_n = 0.001$ vol. f.

In the future, we are going to study the curing process of modified epoxy resins using differential scanning calorimetry and to study the optimal temperature range for processing in detail, since the properties of modified resins exceed the properties of unmodified ones.

It is also necessary to determine a set of rheological properties of liquid binders separately and when they are mixed together. A set of new operational properties of modified epoxy resins makes it possible to study materials based on them for new industrial applications.

The author expresses his gratitude to FC Corporation for providing the research with the inorganic binders.

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УДК 629.02

Технологические решения по модернизации передвижного заправочного оборудования для ракетных топлив

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Представлен обзор перспективных автоцистерн для транспортировки, временного хранения и заправки высококипящих специальных жидкостей. Проведен анализ существующих схемно-конструктивных решений оснащения передвижного заправочного оборудования теплообменными и силовыми элементами. Рассмотрены преимущества и недостатки встроенных и внешних теплообменников, предложен оптимальный вариант использования универсального теплообменного модуля. Кластеризация рекомендована как инструмент по созданию типоразмерного ряда передвижного емкостного оборудования для заправки баков различных объемов. Обоснованы направления совершенствования автоцистерн, внедрение которых позволит существенно сократить сроки и затраты на создание и программу длительной эксплуатации заправочного оборудования.

Ключевые слова: компоненты ракетного топлива, автоцистерны, теплообменники, диафрагмы, колебания жидкости, кластеризация

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Review of Technological Solutions for Modernization of Mobile Refueling Equipment

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This work presents a review of promising tank trucks for transportation, temporary storage and refueling of high-boiling special liquids. There is an analysis of existing schematic and constructive solutions of refueling equipment equipping with heat-exchange and power elements. The advantages and disadvantages of built-in and external heat exchangers are considered, the optimal variant of using a universal heat exchanger module is proposed. Clustering is recommended as a tool for creating a size range of mobile tank equipment for filling tanks of different volumes. The directions of tanker trucks improvement are proved. Their introduction will significantly reduce the time and cost of the creation and the program of long-term operation of the refueling equipment.

Keywords: Rocket fuel components, tank truck, heat exchangers, diaphragms, fluid fluctuations, clustering

Introduction

At present as a part of mobile refueling means of rocket-space complexes (RSC) are used tank-trucks with tanks of various capacities, transport-fueling containers, tank semi-trailers and small portable tanks [1], which shape is shown in Fig 1.



a) Tank semi-trailer



b) Tank truck



c) Transport-fueling container



d) Small portable tank

Figure 1: Types of mobiles refueling equipment

Mobile tank refueling equipment is used for transportation, storage and preparation of high boiling special liquids by temperature and gas saturation, as well as for refueling the tanks of launch vehicles, upper stages and spacecraft [2].

The main disadvantages of the existing mobile rocket fuel tank equipment and directions of improvement are presented in Table 1.

Directions for tanker trucks improvement

Table 1

Disadvantages of existing equipment	Methods of improvement
Occurrence of an emergency situation in the refueling room	Installation of heat-exchange equipment
Occurrence of temperature gradients outside the refueling room	Effective passive thermostatting
Transportation without road class limits	Optimal number and geometry of diaphragms for vibration damping
The long-term process of preparing a tank truck for fuel dispensing in the fueling hall	Development of methods to estimate the quality of fuel components without laboratory analysis
The necessity of fuel component selection for chemical analysis in the laboratory	
Time-consuming process of tank certification	Vessel clustering for series applications

Overview of promising tanker trucks

The basic configuration of the domestic tank truck (Fig. 2) includes a filler neck with cup, service platform, pens for pressure-suction hoses, foot valve, ladder, folding rail and other [3]. The leading domestic enterprises developing and manufacturing samples of tank trucks for light petroleum products, which include rocket fuel, are JSC «Grabovsky Plant of Special Vehicles» and JSC «Neftekamsk Automobile Plant».

Depending on the equipment, tank trucks can perform various functions according to the classification in Table 2.

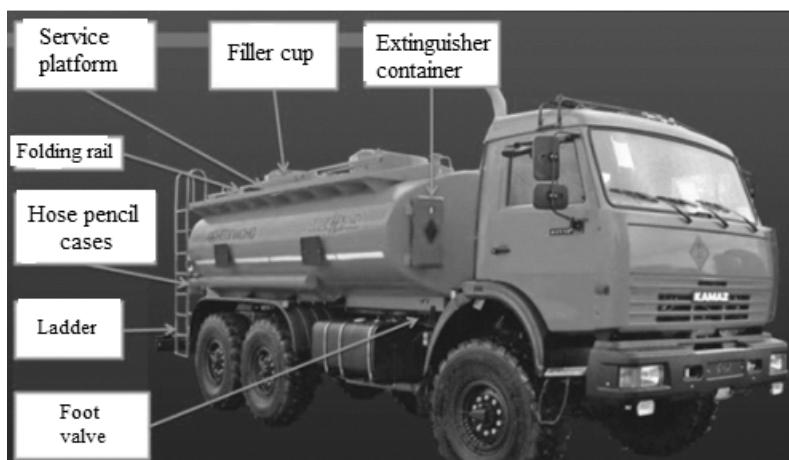


Figure 2: General view of the domestic tanker truck

Table 2
Functions of tank trucks

Complete set	Function	Distinctive feature
Without pump	Transportation receipt and dispensing of fuel	in the consumer's tank
With pump		in the consumer's tank and back
With pump and liquid counter		in the consumer's tank and back according with the set dose

Heat exchanging elements

Temperature preparation of fuel is carried out by organizing the processes of heating and cooling of fuel in the tanks of tank trucks [4]. Heat-exchange equipment by its design can be both built into the internal space of the tank and be outside in relation to the tank truck [5]. Implementation schemes are shown in Fig. 3.

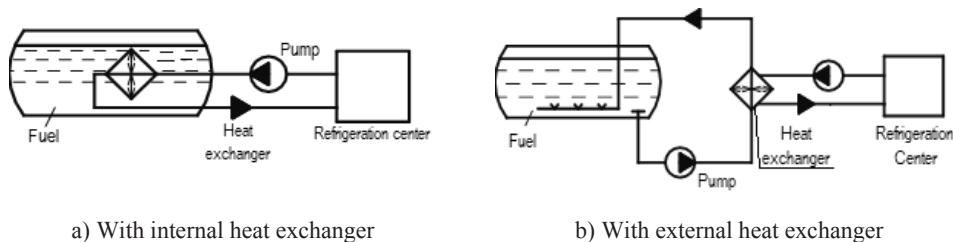


Figure 3: Variants of heat-exchange equipment design

The use of internal heat exchangers leads to the complexity of installation and service of the tank and heat exchangers, while their efficiency is low.

If the heat exchangers are located externally on another unit, it is necessary to carry out operations to connect and press the lines, to fill the cavity with product, providing fuel circulation by the regular fuel pump and after the temperature preparation of fuel it is necessary to neutralize the mass of the component.

The most promising is the variant of fuel and coolant circulation by means of a universal heat exchange module for thermostatting. It is proposed to include in the module circuit an effective small-sized plate heat exchanger and a low-capacity circulation pump, mounted on the tank bottom [6]. Passive thermostatting is provided by selection of optimal thermal insulation of the tank shell.

Power components

Transportation of the component without road class restrictions is dangerous due to the emergence of fluctuations of the liquid component, which can change the dynamics of the system, reduce the controllability of the tanker truck and a significant decrease in stability [7].

Operating experience shows that the best dynamic properties have tank trucks, in the volume of which a system of internal baffles (diaphragms) for damping of vibrations is installed. The diaphragms provide the reduction of pressure on the tank bottom during acceleration and braking while meeting the strength conditions. In terms of geometry the diaphragms differ in their installation (fig. 4), for example, horizontal, vertical or perpendicular to the longitudinal axis of the tank [8].



a) Curved vertical, $n = 2$

b) Flat slants, n = 3

Figure 4: Variants of diaphragm design

Increasing the number of diaphragms complicates the installation of internal elements and the operation of the tank, therefor the number of additional elements needed should be the smallest according to calculations.

Cluster analysis will allow to divide the huge number of mobiles refueling units with tank equipment according to the main characteristics into similar groups or clusters to simplify the procedure of their certification.

In work [9] a clustering was carried out for 76 refueling tanker trucks. As a result, a categorization into 5 main groups according to the main characteristics was obtained. Fig. 5 shows a diagram of the density distribution of tank trucks for different wall thicknesses depending on the volume and number of sections.

Clustering will provide the creation of a standard-size range of mobile tank equipment for refueling consumers' tanks of different volumes at rocket complexes and will reduce the cost of development of tank trucks.

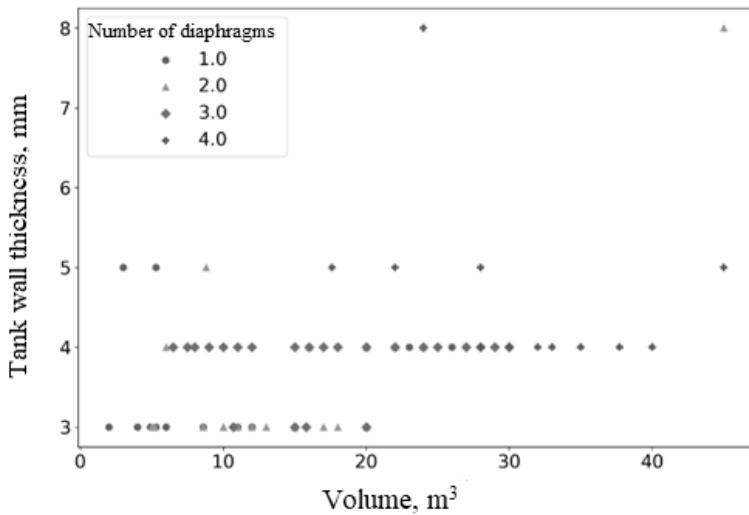


Figure 5: Cluster tanker distribution density

Methodology for determining the parameters of equilibrium and locally non-equilibrium states of the vapor-gas mixture in the tank to establish the acceptable range of component pressure variation depending on the temperature will reduce the time of preparing the tank racks for dispensing of rocket fuel in the refueling hall [10]. Practical recommendations of the method will make it possible to assess the quality of the product

delivered to the space launching site and to draw conclusions about its readiness for refueling operations without laboratory analysis.

Concluding Remarks

The recommendations formulated as a result of the analysis of existing schematic and structural solutions for equipping tank tracks with heat-exchange and power elements will make it possible to modernize the technical appearance of mobile refueling equipment. Application of the improved solutions is technologically significant to carry out at the stage of technical proposal and conceptual design of launch complexes for advanced launch vehicles.

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Создание модуля внутрисхемной отладки для RISC-V процессора

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Описан разработанный модуль внутрисхемной отладки для RISC-V процессоров. Для интеграции данного модуля в различные цифровые микросхемы требуется незначительные изменения системы. Это обеспечивается за счет реализации взаимодействия процессора с отладчиком в основном программными методами. В процессор должна быть добавлена лишь поддержка переходов в специальную область памяти для проведения отладки при получении запроса от отладчика, а также несколько регистров статуса и управления. Кроме изменения процессора, в систему также должна быть добавлена специальная область памяти, содержащая программу взаимодействия с отладчиком и memory-mapped регистры для передачи данных между процессором и отладчиком. Разработанный модуль совместим с доступными программными средствами отладки для RISC-V, тем самым предоставляя разработчикам удобные инструменты взаимодействия с микропроцессорной системой и ее тестирования. Данный модуль можно использовать для загрузки программы в микропроцессорную систему и предоставляет функции защиты программы от считывания и изменения.

Ключевые слова: RISC-V, отладка программного обеспечения, удаленная отладка, внутрисхемная отладка, внутрисхемный отладчик, отладчик, JTAG, процессор, отладка на кристалле, отладчик на кристалле

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Development of On-Chip Debugging Module for RISC-V Processor

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The developed on-chip debugging module for RISC-V processors is described. To integrate this module into various digital circuits, minor system changes are required. This is ensured through the implementation of the processor's interaction with the debugger, mainly by software methods. The only thing that needs to be added to the processor is support for switching to a special memory area for debugging when a request is received from the debugger, as well as several control and status registers. In addition to the change to the processor, a special memory area must also be added to the system, containing a program for interacting with the debugger and memory-mapped registers for transferring data between the processor and the debugger. The developed module is compatible with available debugging software for RISC-V (OpenOCD and GDB), thereby providing developers with convenient tools for interacting with the microprocessor system and testing it. Also, this module can be used to load the program to the microprocessor system and provides functions to protect the program from reading and changing.

Keywords: RISC-V, software debugging, remote debugging, on-chip debugging, on-chip debugger, debugger, JTAG, processor, CPU

Introduction

The rapid development of microelectronics has made it possible to create more and more complex and high-performance systems, including those operating under various critical impacts [1–4]. However, as the complexity of digital integrated circuits (IC) increases, so does the risk of errors and the difficulty in detecting them. Therefore, the creation of convenient and functional debugging tools that allow detecting defects and software errors is becoming an increasingly important and necessary task for any complex digital devices. The presence of a debugger allows not only to detect defects in the production of ICs, but no less important, it facilitates the search for software errors by programmers, thereby increasing the popularity and availability of microprocessors and systems based on them [5–6].

On-chip debugging on the device makes it possible to control the operation of the processor and analyze the parameters of the system during its interaction with real peripherals and signals, instead of conducting complex and often more time- and resource-intensive software simulations [7]. This debugging allows you to take into account all the features of the device being developed and greatly simplify the process of its development and testing.

This paper describes the developed on-chip debugger for an RISC-V processor (RISC-V CPU), which allows access to all processor registers and peripherals devices without making major changes to the design of the microprocessor system.

Description of the Developed Microprocessor

The proposed on-chip debugging unit is designed for the developed configurable microprocessor [8] based on the RISC-V architecture, which has the following characteristics:

- basic set of 32-bit integer instructions RV32I or RV32E (identical to RV32I, but has a smaller register file);
- 5-stage instruction pipeline;
- the ability to add a branch prediction block and bypass to speed up the processing of instructions;
- support for adding instruction cache;
- it is possible to add a Prefetch Buffer as an alternative or addition to the instruction cache;
- register file with 32 or 16 32-bit wide integer general purpose registers (GPRs), for the basic instruction sets RV32I and RV32E respectively;
- Optional ability to process compressed 16-bit instructions (extension C) — allows you to save the memory required to store the control program by an average of 25-30 % [9, 10];
- support for hardware integer multiplication and division (extension M), allows you to get a 64-bit integer multiplication result of 32-bit signed and unsigned numbers, as well as an incomplete quotient and a remainder from division;
- machine-level control and status registers (CSRs), used to manage interrupts, timers, get information about available modules, and control various processor parameters, are available in the Zicsr module;
- the Zifencei extension used to interact with the instruction cache;
- support for unaligned data memory access;
- support for the AMBA AHB bus for interacting with memory and peripheral units;

- two privilege levels — user-mode (U-mode) and machine mode (M-mode);
- support for 3 machine-mode interrupts required by the RISC-V standard, as well as 16 additional machine-mode interrupts;
- direct and vector modes of interrupt processing with the ability to set the starting address of the interrupt vector table;
- the presence of one non-maskable interrupt (NMI);
- support for Wait For Interrupt (WFI) instruction.

The block diagram of this processor core in the maximum configuration with all available modules is shown in Fig. 1.

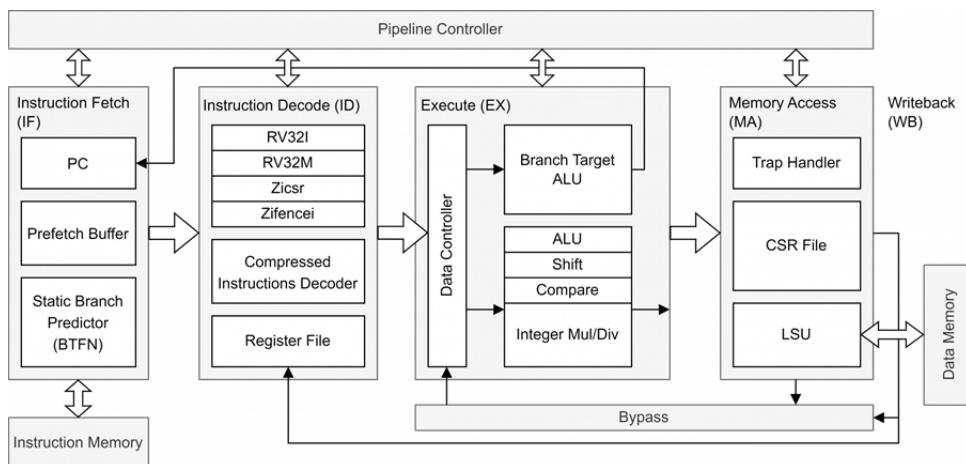


Fig. 1. Block diagram of the instruction pipeline of the developed microprocessor in a configuration with all available modules and architecture extensions

The mechanism of interaction with the debugger deserves special attention. To simplify the design of the processor, the signal for switching to debug mode is perceived as an interrupt, for its processing the processor goes to a certain address, where the program for interacting with the debugger is located. Thus, all debugging functions are implemented in software and the only change in the design of the processor is the complication of the Trap Handler block, as well as the addition of CSR that control the debugging process.

This processor implements the required minimum of CSRs, which allow you to configure the switching to debug mode when executing the ebreak instruction, step-by-step execution (step mode) of the program, as well as switching to debug mode when executing an instruction at a specific address.

Structure of the On-chip Debugger

The developed on-chip debugger for RISC-V processors uses a modular structure that makes it easy to add new interfaces to interact with the system. The basic blocks of such a system are the Debug Module and the Debug Transport Module.

The Debug Module directly interacts with the processor core and the system bus, while the Debug Transport Module is a layer that converts signals from various interfaces (JTAG, SPI, USB, etc.) into commands understandable by the Debug Module.

A system can have multiple Debug Transport Modules if it supports different debugging interfaces, and multiple Debug Modules, for example, if a processor with multiple cores is used.

At the moment, for the developed RISC-V processor, only the Debug Transport Module with support for the JTAG interface is implemented.

Debug Transport Module. The developed Debug Transport Module is used to convert JTAG interface signals to Debug Module parallel bus commands and vice versa.

It includes the TAP (Test Access Port) controller, as well as the data registers *IDCODE* (address 0x01), *BYPASS*, *dmc* (0x10) and *dmi* (0x11). The instruction register is 5 bits wide.

The 32-bit *IDCODE* register contains the device identifier and complies with the IEEE Std 1149.1-2013 standard [11]. The 1-bit *BYPASS* register also conforms to the JTAG and TAP specification, and is used to push data when connecting multiple devices in a JTAG chain. The remaining registers are not part of the standard TAP specification and are used to interact with the debugger.

Thus, the 32-bit *dmc* (DTM Control and Status) register is used to determine the version and parameters of the debugger, control its status, and reset it. The *dmi* (Debug Module Interface Access) register is 41 bits wide and is used to access the Debug Module. When accessing the Debug Module, the following is written to it: the address of the Debug Module control register (bits 40-34) to which the transaction is made, 32-bit data (bits 33-2) and the type of transaction (bits 1-0). In response, the register gives the data of the previous transaction (bits 33-2) and the status of its execution (bits 1-0).

The TAP block uses standard JTAG interface signals (TDI, TDO, TCLK, TMS and an optional TRST signal) to communicate with external devices.

Interactions with the Debug Module are performed via a parallel bus with the following structure (Table).

Description of bus signals between Debug Transport Module and Debug Module

Name	Type	Width	Description
REQ_VALID	O	1	Indicates that a new request is pending
REQ_READY	I	1	Specifies that the Debug Module can process the request
REQ_ADDRESS	O	7	The address of the register to which the request is made
REQ_DATA	O	32	Request Data
REQ_OP	O	2	Request type (read/write)
RSP_VALID	I	1	Indicates that a response to a request is pending confirmation
RSP_READY	O	1	Indicates that the Debug Transport Module can process the response to the request
RSP_DATA	I	32	Data received
RSP_OP	I	2	Response type (whether the command was successful)

Note: O – Output, I – Input.

The parallel bus signal type (Table 1) is specified relative to the Debug Transport Module. Parallel bus inputs to the Debug Transport Module are outputs to the Debug Module and vice versa.

Debug Module

Debug Module (Fig. 2) provides direct interaction with the processor and processing of debug commands. It has the following features:

- Switching the processor to halt mode, as well as exiting it with the resumption of normal processor operation (run mode).
- Reset of the entire system or just the processor.
- Abstract Commands of reading/writing data to general purpose registers (GPRs). Data is read from or written to a special register available to both the processor and the debugger.
- Execution of up to two arbitrary instructions from a program buffer.
- Direct access to memory, bypassing the processor, through a separate port for interacting with the system bus.

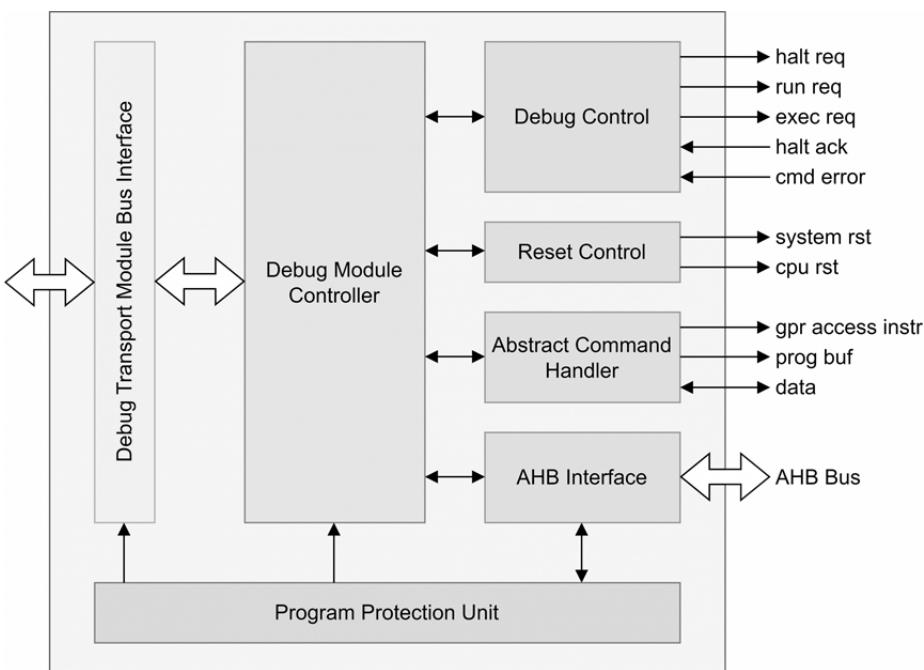


Fig. 2. Block diagram of the developed Debug Module that provides the execution of debug commands and interaction with the processor

These functions provide a sufficient set of ways to interact with the processor. So, for example, although direct access to CSRs is not supported, it can be done by writing the necessary instructions to the program buffer and then executing them. Thus, the presence of a buffer for transmitting arbitrary instructions to the processor allows access to all processor parameters without increasing the complexity of the debug block.

By executing arbitrary commands (instructions) through the program buffer, step mode or switching to debugging mode by CSR trigger can also be enabled on the processor. In this case, only the trigger for matching the address of the instruction being executed with the address in the CSR of the trigger is available. Another way to enter debug mode is to use *ebreak* instructions and/or breakpoints.

To put the processor into halt mode, the Debug Module sets the debug interrupt flag. After its processing, the CPU goes to the address of debugging interrupt handler program, and starts executing instructions from a special non-volatile read-only memory area (Debug ROM). It contains a small program that cyclically checks the signals from the Debug Module (using the memory-mapped registers of Debug RAM) and executes the corresponding commands, it also implements feedback from the processor (acknowledging the execution of commands and transmitting the processor status).

The program buffer and data transferred between the processor and the Debug Module is located in Debug RAM. The status register is also located in this memory area, with the help of which the processor can signal the Debug Module about the status of the execution of debug commands.

This implementation of the debug mode allows you to make minimal changes to the processor design, although it requires the allocation of special memory blocks (Debug ROM and Debug RAM) to interact with the Debug Module.

Although access to the system bus can also be implemented through a program buffer, having a separate interface for accessing it, bypassing the processor, has a number of advantages. Such as the ability to write a control program to the processor, even if there is no program in memory yet and switching to debug mode is impossible. Also, with direct access to the system bus, it is possible to control peripheral devices and data in memory without stopping the execution of the control program. Direct access to the system bus has a number of limitations, so only reading and writing 32-bit data to 32-bit aligned addresses is available.

The debug block has a number of functions that speed up the execution of commands and make life easier for the debugger user. For example, commands for accessing GPRs can be configured so that after their execution, instructions from the program buffer are automatically executed. The following functions are available to speed up direct system bus access:

- Automatic increment of the address register by 4 after each memory transaction.
- Automatic data reading after changing the debugger register containing the memory access address.
- Performing automatic reading of data from memory, after reading the data register by the debugger. This function can be useful for reading large amounts of data from memory, when address auto-incrementing is enabled.

In addition to the standard functions required by the RISC-V specification, this debugger also has the function of protecting the executable program from reading and rewriting (Program Protection Unit). After reset, the debugger reads data at a special address in non-volatile memory, which contains the debugger settings. Until this configuration structure (debugger settings) is read from memory, the debugger will not be available.

If the executable program protection flag is set in the settings, then the debugger will not execute any commands, except for the command to completely erase data. Also, when trying to read any registers of the Debug Module, except for the register indicating the protection status of the program, the Debug Module will return zero data. The Complete Erase command deletes all data from non-volatile memory and resets the program's protection flag.

Compliance with the RISC-V Specification and Available Programs

This implementation of the on-chip debugger is fully compatible with RISC-V Debug Specification Version 1.0 [12], which makes it possible to use a wide range of software tools developed for the RISC-V architecture to interact with the debugger.

Direct interaction with the JTAG interface of the debugger is performed using the OpenOCD program [13-14]. This program provides low-level interaction with the on-chip debugger and has a wide range of drivers for various interfaces and devices. While debugging directly with OpenOCD is possible, a more convenient way is to use OpenOCD as an interface between the device being debugged and higher-level debugging tools.

For example, OpenOCD can interact with the GDB debugger (GNU Debugger), which in turn provides much more convenient debugging methods and a larger set of functions.

The big advantage is the ability to run OpenOCD and GDB on different computers, using a network connection between them to ensure their interaction.

A diagram showing the IC with on-chip debugger and connected with external software debuggers, as well as the internal structure of such IC, is shown in Fig. 3.

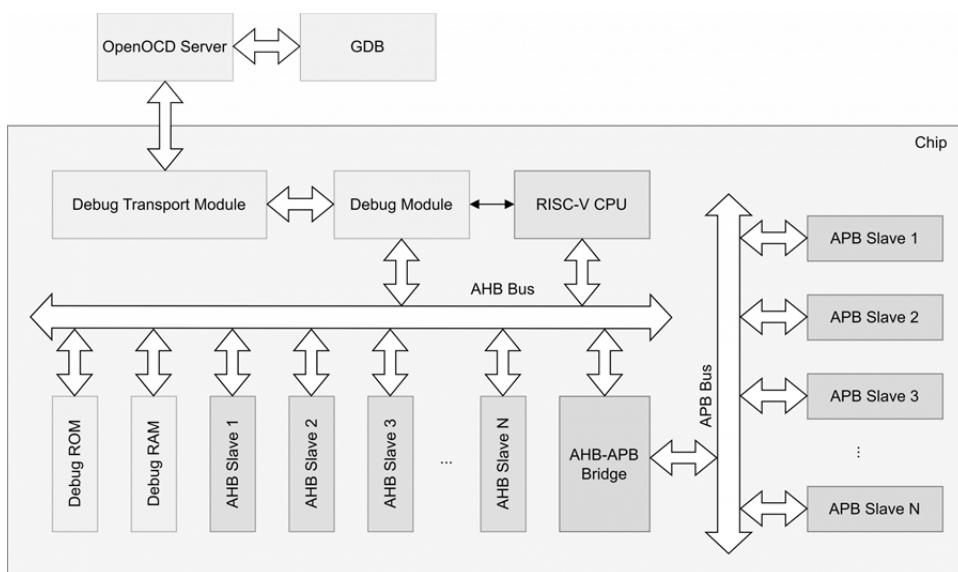


Fig. 3. Block diagram of the system with an RISC-V processor and an on-chip debugger, as well as external software debuggers connected to it based on OpenOCD and GDB

Since the developed processor is compatible with the RISC-V GNU Compiler Toolchain [15], the programmer can use the tools included in it to compile, load and debug the program. To compile a program written in C or assembly language, GCC (GNU Compiler Collection) is used, and the program is loaded and debugged using GDB. This software package is freely distributed and available for Linux-based operating systems.

The compatibility of the developed processor and debugging interface with the RISC-V specification and development tools available for the RISC-V architecture makes it possible to reduce the cost of developing software for this microchip and make it easier for programmers to master the development tools and write programs for this processor.

Conclusion

The developed on-chip debugger for RISC-V microprocessors allows access to all processor parameters and the system bus without making major changes to the design of the

device being developed. This is possible due to the implementation of most of the interaction of the debugger with the processor in software, using special memory areas containing the program for interacting with the debugger and registers for data exchange.

This approach significantly reduces the complexity of integrating the debugger into the developed IC and at the same time significantly improves the quality of its testing. The disadvantage of this architecture of the on-chip debugger is the lower speed of command processing, compared to debuggers with a fully hardware implementation of all functions.

Another advantage of this block is the ability to access the system bus bypassing the processor, which allows it to be used as a tool for loading a control program onto a device. It also provides protection for the control program from reading and rewriting, completely prohibiting any interaction with the debugger, except for the complete erasure of the program, when the appropriate setting is set during the device configuration.

The compatibility of the developed debugging module with various RISC-V debugging programs such as OpenOCD and GDB provides programmers with a convenient interface for finding software errors and testing developed programs in the real environment where the device will be used.

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УДК 004.056.53

Формирование детерминированного подхода к описанию технических каналов утечки информации

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Предложен детерминированный подход к описанию технических каналов утечки информации. Приведена демонстрация использования данного подхода. Предложен собранный авторами перечень элементов технических каналов утечки информации. С помощью определенных принципов проанализированы существующие исследования по данной теме. Приведенный перечень позволит в дальнейшем проводить классификацию данных каналов в зависимости от решаемых задач.

Ключевые слова: технические каналы утечки информации, несанкционированный доступ, побочные электромагнитные излучения и наводки, программное управление

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DOI: <https://doi.org/10.1109/CSF.2015.26>

Deterministic Approach to the Description of Information Leakage Channels

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The article describes a deterministic approach to the description of information leakage channels. The demonstration of the use of this approach is given. The preliminary list of information leakage channel elements is shown. The analysis of software-initiated information leakage channels is made. The approach described allows to carry out a further classification of information leakage channels depending on the task being solved.

Keywords: information leakage channels, unauthorized access protection, TEMPEST, software management

Introduction

The information leakage channel is traditionally understood as the combination of the intelligence object, a technical means of intelligence with which information about this object is extracted, and the physical environment in which the information signal is distributed [1].

The fundamental papers [1–3] in modern classification of information leakage channels rely on classification according to one of the three elements listed above. At the same time, only the result of classification is given in these papers and the opportunity to study all the channels that have been classified is not provided. As a result, the classification is deprived of one of the necessary criteria — verifiability, and, as a result, extensibility. Newly emerging channels are usually attributed to one of the classes considered in fundamental papers. However, there is no relationship between this inclusion and strengthening protection measures against channels of such class.

The purpose of this article is to propose the discussion of a deterministic approach to the description of information leakage channels, which will allow to obtain a complete list

of currently known channels. Channels from this list can later be classified depending on the tasks being solved. The following tasks will be solved for this purpose:

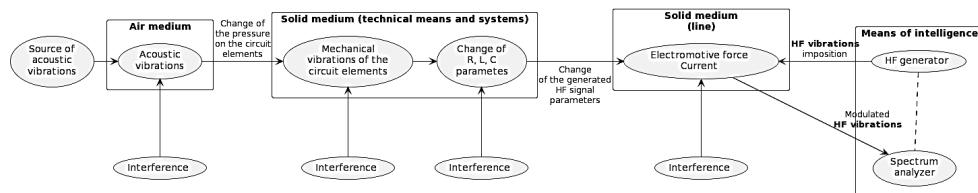
1. Modernization of the existing definition of information leakage channel.
2. Demonstration of proposed definition application.
3. Determination of the list of information sources, principles of formation and methods of reception.

Modernization of the existing definition of information leakage channel

In order to form a three-element structure of the information leakage channel it is proposed to expand the existing definition, previously given above, as follows:

- expand the concept of “intelligence object” to “source of information”;
- expand the concept of “physical environment” to “the principle of formation”;
- expand the concept of “a technical means of intelligence” to “reception method”.

It is proposed to use a combination of the elements described above for the name of the information leakage channel. For example, for the channel shown in Figure, one could use the name “Leakage channel of acoustic speech information due to high-frequency imposition with the reception of information contact / contactless on the line”.



Leakage channel of acoustic speech information due to high-frequency imposition
with the reception of information contact/contactless through the line

Determination of the list of information sources, principles of formation and reception methods

In order to form a complete list of information leakage channels, it is necessary to determine the list of elements that make up the channel. The following lists are proposed for consideration:

Sources of information:

- visual information;
- telecommunication information;
- acoustic speech information.

Principles of formation:

- acoustoelectric conversion;
- high-frequency acoustoelectric conversion;
- high-frequency imposition;
- high-frequency irradiation;
- high-frequency pumping;
- parasitic generation;
- solid medium vibrations;
- leakage in the power supply and grounding circuits;
- TEMPEST;

- software management of the components of the main technical means and systems;
- software management of the components of auxiliary technical means and systems.

Reception methods for receiving information:

- contactless from a dielectric air medium;
- from an optically transparent medium in the visible range;
- from the air medium;
- from the thermal medium;
- from a solid medium.

Analysis of existing software-initiated information leakage channels

Proposed approach was applied to the description of software-initiated information leakage channels described in modern research papers. The results of the correlation of the proposed channel name and research on this topic are shown in Table.

The results of the correlation of the proposed channel name and research on this topic

Channel name	Link to the research
Leakage channel of telecommunication information due to software management of the components of the main technical means and systems and TEMPEST with the reception of information contactless from a dielectric air medium	[4–7]
Leakage channel of telecommunication information due to software management of the components of the main technical means and systems with the reception of information from an optically transparent medium in the visible range	[8–11]
Leakage channel of telecommunication information due to software management of the components of the main technical means and systems with the reception of information from the air medium	[12, 13]
Leakage channel of telecommunication information due to software management of the components of the main technical means and systems and solid medium vibrations with the reception of information from a solid medium	[14]
Leakage channel of telecommunication information due to software management of the components of the main technical means and systems with the reception of information from the thermal medium	[15, 16]

Conclusion

The deterministic approach to the description of information leakage channels has been proposed. Based on this approach, an example of the description has been given and a list of deterministic elements collected by author has been shown. The direction of further work is the expansion of the list and formation of the list of protection measures based on the proposed descriptions.

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УДК 623

ПД-14 — прорыв в истории российского авиационного двигателестроения

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БГАА

Рассмотрен новый российский авиационный двигатель ПД-14. Исследованы основные его характеристики, рассказано о его истории, перспективах в будущем и также подробно разобрано его строение и принцип работы. Обсудили проблемы, с которыми столкнулись конструкторы, рассмотрены найденные решения. Проанализированы способы решения этой ситуации. Изучены испытания, проводимые над двигателем, упомянуты трудности, которые возникают перед работниками, разрабатывающим ПД-14. Сделан вывод о перспективах развития, планах корпорации «Объединенная двигателестроительная корпорация», которая создала данный двигатель, по дальнейшему применению и усовершенствованию данной конструкции.

Ключевые слова: сила тяги, компрессор, лопатки, вентиляторы, эффективность, камеры сгорания, Объединенная двигателестроительная корпорация, авиационный двигатель

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PD-14 — a Breakthrough in the History of Russian Aviation Engine Building

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The new Russian aircraft engine PD-14 is considered. Its main characteristics were studied, its history, future prospects were told and its structure and operating principle were also analysed in detail. Discussed the problems faced by the designers, considered the solutions found. The ways of solving this situation were analysed. The tests carried out on the engine were studied, the difficulties faced by the workers developing PD-14 were mentioned. The conclusion is made about the prospects of development, plans of the corporation "United Engine Corporation", which created this engine, for further application and improvement of this design.

Keywords: thrust force, compressor, blades, fans, efficiency, combustion chambers, United Engine Corporation, aircraft engine

The MS-21 310 aircraft took off at the airfield of the aircraft factory in Irkutsk on December 15, 2020. Like nothing special, but this flight can be considered one of the most important, because for the first time the plane was raised by engines that were considered impossible for a long time. Today WE will show a new Russian civil aircraft engine PD-14. We will tell you what new technologies it included itself and how it gave development not only to the aircraft, but to the entire industry. I present to you the PD-14 [1–4].

PD-14 flies recently, but its history is long and full of adventures. The MS-21 liner was supposed to be a huge leap(скачком) and the issue of the engine in it was one of the most important. The power plant must be at least at the level of competitors.

The first decision was to supply the same engine as the competitors (pratt & whitney engine is one of the leaders), but the UEC United Engine Construction Corporation decided to create a new engine. They needed to make the engine no worse than analogues. The analogues were the most powerful engines in the world. But the project was approved, given that the engines were primarily created for the MS-21 line, which includes several liners of different sizes, the engine thrust for them is from about 12 to 15 tons of forces. The task was set clear — the PD-14 should be a modern, efficient, environmentally friendly and competitive engine. The UEC became the chief designer, work was deployed throughout the country, including both university laboratories and giant aviation centers. The main place where finished engines will be born was the UEC plant in Perm.

The work was fast already in 2012, the first version was assembled for ground tests. In 2015, the engine saw the sky on the wing of the IL-76. On the IL-76, the main stage of testing was carried out, which ended in 2018 with the receipt of a certificate from the aviation authorities of Russia. In 2020, the PD-14 was delivered to the MS-21 310 liner in the basic assembly. PD-14 performed well. MS-21 310 conducts dozens of tests, participate in demonstration flights and flies long distances, including outside of Russia. There were no issues with the engine. The tests are still going on.

PD-14 is a classic modern turbojet engine. The air flow in it moves along the engine bypass; in the internal circuit, the air is compressed by the compressor, ignited, rotates the turbine and is exhausted through the nozzle, creating thrust. The engine bypass begins with a large fan, which we see from the outside. The fan rotates, driving air through the bypass, creating additional thrust and increasing engine efficiency. The inner core is the heart of the engine, its core and hot part. One of the main parameters is the temperature of the gas in the hot part, the efficiency depends on it. At the front is a compressor that compresses the air passing through it forward. He is driven by steps with blades around the circumference and fans. They are 11:3 low pressure and 8 high pressure. This motor with discs rotating at high speeds inside which air turns from cold air into hot gas in seconds, the pressure of which increases by 40 times.

The compressor is followed by a low-emission combustion chamber where the gas is injected and ignites the fuel. The chamber is includes 48 nozzles.

Some details are printed from metal by 3D printers. In the turbine, hot compressed air passes through the mechanism, first through two stages of high pressure, and then through six stages of low pressure. The gas rotates the stages and part of its energy is transferred through the turbine to the shaft, which rotates the fan and compressor stages, which in turn compress the gas. The hot gas passing through the turbine breaks out, creating jet thrust.

Problems faced by engineers. The blades must withstand enormous loads: not to melt, not to collapse. For this, heat-resistant steel was used. After many experiments, titanium was chosen.

Specific fuel consumption. Solved the problem by improving the aerodynamics of the aircraft. It can maintain a set airspeed with less thrust, which reduces fuel consumption.

PD-14 surpasses its predecessors in specific fuel consumption by 12...16 %, and in harmful emissions by about 30 %.

Finally, we can look at the engine in the form in which it appears to ordinary passengers. Mechanisms around the engine provide aerodynamic flow. An error here can seriously degrade the engine parameters, so there is a special device, the mechanism of which, at the time of landing, turns the air flow and slows down the aircraft. Another element of the appearance of the chevron engine is the toothed limb of the circuit, which ensures smooth mixing of air flows, which reduces the level of noise arising from this. The engine was originally designed to minimize noise.

Now the PD-14s have actively entered production, but we want to say that testing and modifications have not been stopped. The PD-35 has a thrust of about 35 tons of force, which is created for heavy aircraft in the first place with a wide fuselage of magnum opus odeco airliners. Nothing like this has been created before in Russia or in the USSR.

Enzo Ferrari said “I don't sell a car — I sell an engine. I give away cars for free, because these engines need to be put somewhere”

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УДК 539.3

Решение задачи контакта тела и двухслойного покрытия с использованием программного комплекса Salome-Meca

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Рассмотрена контактная задача о вдавливании жесткого полого цилиндра в деформируемое цилиндрическое тело с покрытием на верхнем основании без учета трения. Покрытие состоит из двух материалов с различными характеристиками. Геометрическая модель и конечноэлементное приближение строятся по упрощенной математической модели. Особое внимание уделено решению задачи с использованием модуля AsterStudy программного комплекса Salome-Meca.

Ключевые слова: математическое моделирование, механика контактного взаимодействия, метод конечных элементов, теория упругости, свободное программное обеспечение, Salome-Meca

Информация о гранте

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Solution of a Contact Problem for a Body with a Two-piece Coating Using Salome-Meca Software

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The paper deals with the study of a frictionless contact problem of pressing a rigid hollow cylinder into a deformable cylindrical body with a coating on the upper base. The coating consists of two materials with different characteristics. Geometry and mesh are built according to a simplified mathematical model. Particular attention is paid to solving the problem using the AsterStudy module of Salome-Meca software package.

Keywords: contact mechanics, mathematical modeling, finite-element method, elasticity theory, free software, Salome-Meca

Introduction

Frictional contact between deformable bodies can be frequently found in industry and everyday life such as train wheels with the rails, tectonic plates, the car's braking system, etc. Calculations related to contact interaction and wear must be made when manufacturing the products such as brakes, fasteners, hinges, gears, valves, and tires.

A variety of technical devices containing elements subjected to contact interaction and their real operating modes give rise to a wide range of problems in the mechanics of contact interaction and physics of friction, in particular, the problem of pressing an absolutely rigid stamp into a body protected by a coating [1, 2]. Nowadays, methods of coating the interacting surfaces of parts are widely used. To assess their strength and predict mutual behavior of bodies in the process of their joint work, it is necessary to analyze the distribution of stresses and strains of coatings. Such studies will allow the engineers to take necessary measures to change the design or the conditions of its work, which will lead to economic benefits in the future, at the design stage [3, 4].

The modeling and solution of contact problems in various software packages is of particular interest. Significant progress has been made in the modeling and analysis of static contact problems. However, quasi-static and dynamic problems, due to surface phenomena occurring in the contact zone, remain one of the most difficult types of problems in the framework of computational mechanics. Industrial needs have stimulated the numerical simulation of mechanical contacts which has drawn a lot of attention over the last years. Many algorithms have been proposed in order to solve problems of growing complexity: contacts between rigid or (visco-)elastic bodies, submitted to small or finite deformations, with or without friction, adhesion or wear. In this work, attention is focused on the use of free Salome-Meca software and the Code_Aster solver for calculating frictionless contact problems.

Modelling and problem solving in the Salome-Meca software package

This section presents a step-by-step modeling process of a contact problem, including creation of geometry and mesh as well as brief discussion of concepts used in solver AsterStudy (name of the Code_Aster solver module integrated into the software package Salome-Meca).

Geometry and mesh creation

The contact problem of indentation of a hollow rigid cylinder into a cylindrical body with a coating on the upper base is considered. Half of the section shown in Fig. 1 is selected as a model. Material of the body 1 is steel, Young's modulus of which is $E = 200000$ MPa, and a Poisson's ratio is $\nu = 0.3$. Body 2 is a coating with the following characteristics: $E = 8000$ MPa, $\nu = 0.3$, Body 3 is also a coating, but with different characteristics from body 2, namely $E = 16000$ MPa, $\nu = 0.3$. Body 4 is absolutely rigid, and the following material characteristics were chosen to simulate this property: $E = 1000000000$ MPa, $\nu = 0.3$.

Fragment of finite element approximation is shown in the Fig. 2.

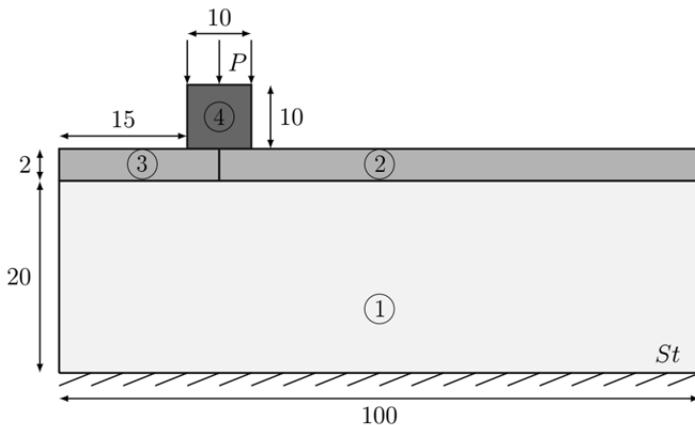


Fig. 1. Geometric model of the problem (dimensions are given in mm)

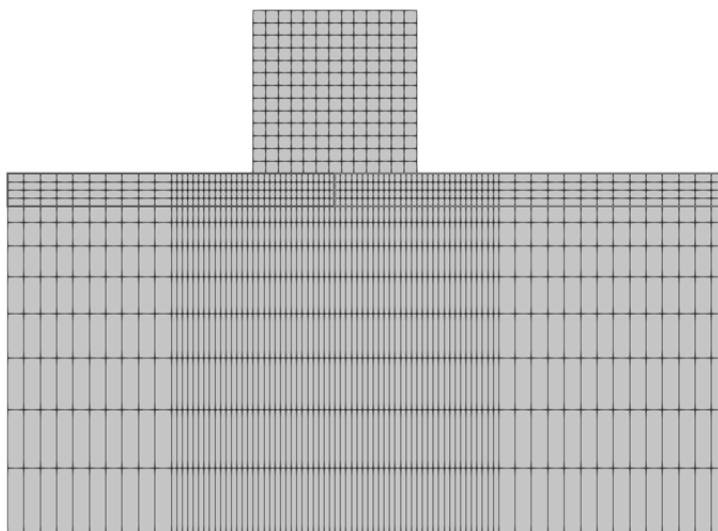


Fig. 2. Fragment of finite element approximation

The boundary conditions on the bottom edge of the body **1** prohibit displacements along the Oy axis. On the axis of symmetry, coinciding with the Oy axis, the boundary conditions will be determined by the type of simulation. The top edge of the body **4** is acted upon by the distributed force P . However, for simulation it is necessary to replace distributed force with pressure equal to 100 MPa.

In accordance with the Fig. 1 the geometry of the contact problem was built in the Geometry module of the Salome-Meca package. Groups of edges for boundary conditions application in further modelling are selected from the solid elements. At the same stage groups of faces, to which the properties of materials will be assigned, are selected.

The generated geometry is passed to the Mesh module to create a finite element approximation. In this case quadrangular finite elements were selected [5]. The hypothesis of equidistant splitting of edges, with the number of elements equal to 30, is set as the main hypothesis for the body **1**. Additionally, with the help of the hypothesis FIXED_POINTS, condensation of mesh is made to the part of the body under the stamp. That allows us to obtain more accurate results for the contact zone. The division of the bodies **2** and **3** into finite elements was carried out using the command to project nodes from the bottom edge to the top, four elements were selected along the smaller edge of the bodies. Edges of the body **4** were divided equidistantly into 13 segments [6, 7].

The Creategroupsfromgeometry command defines the groups of mesh elements based on the previously created geometry. For this problem elements on contact zone and on faces, on which degrees of freedom will be constrained, are selected. Mesh elements for bodies with numbers **2** and **3**, acting as contact zone, are selected manually.

Solving the problem in the AsterStudy module

Modeling the problem begins with reading the generated meshes, combining them into one model, and checking the direction of the normals in the zones of application of forces and contact. The normals must be externally oriented. This is programmatically implemented by the command ORIE_PEAU_2D, which takes as input the groups of edges, the normals to which need to be rebuilt [7].

Further step is to choose the right type of modeling according to formulated problem. In this case the simulation type MODELISATION='AXIS' needed to be chosen because the axisymmetric problem of contact interaction of several bodies is considered. On this stage materials are described, that is, the variables expressing the characteristics of the material are assigned the corresponding numerical values. The generated concepts are associated with the specified parts of the model.

To carry out the calculation, a list of fictitious time steps needed to be created. A list of values is pre-created, the start and end values and the step are set. This list is passed to the DEFI_LIST_INST command, which additionally specifies the method of automatic step division METHODE='AUTO' if there is no convergence. A function that scales the load applied to the body number **4** at each time step is defined by using the DEFI_FONCTION keyword.

The order of modeling in the AsterStudy module in the next step involves the definition of loads. In this problem, the displacements of the bottom edge of the body **1** were completely blocked along the Oy axis. On the axis of symmetry, the boundary conditions are determined by the type of simulation and were chosen on the previous step. A pressure of 100 MPa is applied to the top edge of the body **4** by setting AFFE_CHAR_MECA,PRES=100.

The contact area is determined in the same section, by choosing the DEFI_CONTACT concept. The contacting surfaces are selected, and the formulation CONTINUE is accepted. This contact interaction is considered without taking into account the friction force, that means FROTTEMENT='SANS'.

When determining the parameters of the algorithm for solving a quasi-static nonlinear problem, the user specifies the keyword STAT_NON_LINE, which contains a list of time steps, the created concept of loads applied to the model, and also increased the number of iterations for the CONVERGENCE parameter. During the test calculations, it was shown that 30 iterations at each step are sufficient for convergence.

The final step in modeling is the selection of keywords, such as stress fields, deformations, equivalent stresses, etc. that correspond to the required results. The path and name of the file to which the result will be written is set. In addition, the results are output to a third-party program for the previously selected nodes of the contact zone, which allows us to plot graphs of stresses σ_{yy} .

Numerical results

The distribution of stresses along the line of contact Fig. 3, as well as equivalent von Mises stresses Fig. 4, are given as the simulation results. As it can be seen from the Fig. 3, stress values are changed when going from one type of coating to another. Values on vertical axis of Fig. 3 are given in MPa, while numbers on horizontal axis means the number of a node on a selected contact zone. The nodes are assigned new, sequential numbers, and the internal numbering obtained when creating the mesh is not used. Values of horizontal bar on Fig. 4 are also given in MPa.

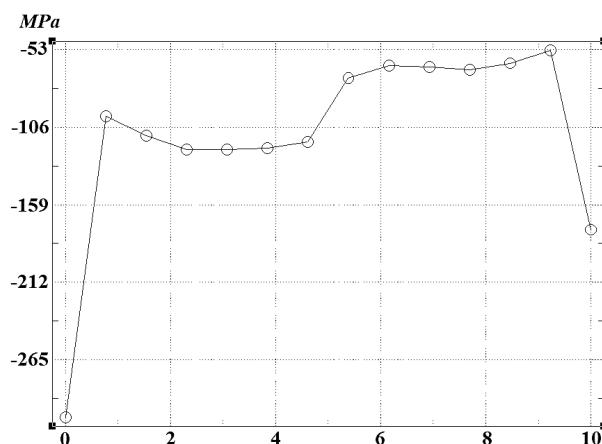


Fig. 3. Stress distribution along the contact zone

Conclusion

The possibility of modeling and solving contact interaction problems using free software package Salome-Meca was investigated. A sequence of actions for the correct description of contact zones is described, recommendations are given on the use of formulations and solution algorithms.

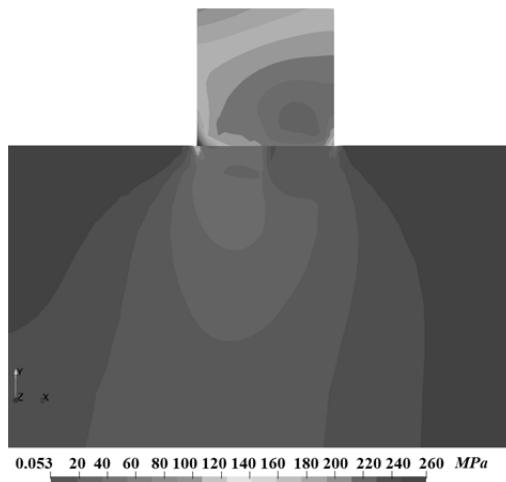


Fig. 4. Equivalent von Mises stresses (fragment)

A geometric model and a finite element approximation of the problem of pressing a stamp into a coated body are constructed. With the use of the Code-Aster solver, the modeling and solution of this problem have been carried out. The ParaVis module provides a graphical interpretation of the calculation results.

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УДК 62-503.55

Устройство автономной регистрации напряжения для испытания ампульного источника тока

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Представлено устройство автономной регистрации напряжения для испытаний ампульных источников тока. Основным источником для испытаний является СДС-ЗМ (электрохимическая система свинец-диоксид свинца). Разработанное устройство позволяет фиксировать время выхода на режим с момента активации и напряжение шумов. Своевременное выявление просадок напряжения ампульного источника тока позволит быстрее совершенствовать их конструкцию и в итоге повысить стабильность работы систем ближней радиолокации.

Ключевые слова: ампульный источник тока, регистрация напряжения, центрифуга, микроконтроллер, система ближней радиолокации (СБРЛ), помеховая обстановка

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Autonomous Voltage Registration Device for Testing an Ampoule Current Source

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The paper presents an autonomous voltage recording device for testing ampoule current sources. The main source for tests is LLD-3M (electrochemical lead-lead dioxide). The developed device enables recording the response time from the moment of activation and the noise voltage. On time detection of voltage slumps of the ampoule current source facilitates faster improvement of their design and eventually improve stability of short-range radiolocation systems.

Keywords: ampoule current source, voltage registration, centrifuge, microcontroller, short-range radiolocation systems (SRLS), jamming environment

The main requirement for modern short-range radiolocation systems (SRLS) is to ensure highly effective operation with the specified types of targets in the challenging natural and intentionally created jamming environment.

The constant development of jamming stations makes it necessary to solve the urgent problem of creating new SRLS for ammunition supplies of wide use: improvement of SRLS backup power sources that combine long storage life, high reliability, short response time, low noise level and energy security sufficient for state-of-the-art smart products.

Ampoule batteries were developed as a response to the need for current sources that would combine longs of storage life with constant readiness for forced discharge. They use active electrochemical systems capable of providing high power density and energy. As the discharge is short (a few minutes), self-discharge can be neglected after the source cells are filled with electrolyte [1].

Ampoule batteries have much in common with water-activated current sources. The electrode units are dry-charged; before activation, they retain electrical energy for a long time, that is, for years; they are activated by filling the cells with electrolyte and have a limited-service life when filled [2].

The characteristic feature of modern ampoule batteries is that they use aggressive electrolytes (usually concentrated acids or alkalis) with high electrical conductivity. The cells are filled with electrolyte under pressure. This results in significant change in technical and operational characteristics: the battery is activated fast, sometimes within fractions of a second, and the maximum discharge power is immediately achieved [3].

Remotely activated ampoule battery is a complex unit, which, along with the cell block, includes systems for keeping the electrolyte and feeding it at the right time to the cells, discharging gaseous products of side reactions, heating or thermostating electrolyte at low ambient temperatures.

Design of silver-zinc ampoule battery produced by Eagle-Picher is shown schematically in Fig. 1 [4]. Unit 3 cells have a common electrolyte supply line (shown with an arrow), which ends with sump 2 that has safety valve 1. The metal ampoule in the form

of coil 4 is overlapped on both sides by thin metal diaphragms 5. The ampoule of this shape (ampoules can also be cylindrical) withstands high pressure and has a well-developed surface, so the electrolyte can be quickly heated if necessary.

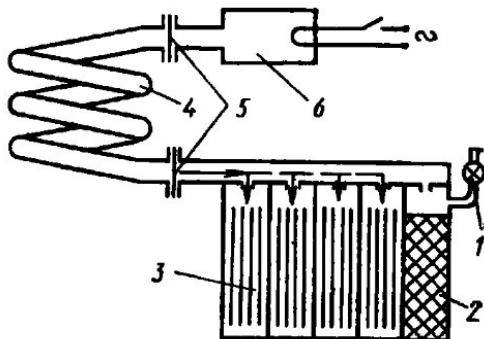


Fig. 1. Design of silver-zinc ampoule battery produced by Eagle-Picher:
1 - valve; 2 - sump; 3 - cells unit; 4 - ampoule; 5 - diaphragm; 6 - pressure generator

Pressure generator 6 is a metal cylinder in which an ignition cylinder with an electric spark igniter is placed.

Closing the circuit of the electric spark igniter is enough to activate the battery. The ignited pyrolytic mixture generates gas, the pressure in generator 6 sharply goes up, breaks diaphragms 5, and the electrolyte moves from the ampoule to the cells along the supply line. The excessive electrolyte ends up in the sump filled with porous absorbent.

The battery cannot be activated merely by ensuring contact of the electrolyte with the electrodes. It takes some time to impregnate the cages and withdraw the electrodes from the semi-passive state. But unlike water-activated cells, ampoule cells are activated very fast, within a period from fractions of a second to several tens of seconds. The activation time depends on the nature of the active masses and electrolyte, electrodes and cell design, cage material, method of filling the cell unit with electrolyte, etc [5].

The main area of application of ampoule current sources with high rate of discharge is aerospace and military equipment, while batteries with low rate of discharge are used in portable radios, location beacons and other communication equipment.

Ampoule backup current sources LLD-3M (hereinafter referred to as «ampoule current sources») are designed to supply DC to portable radio equipment and disposable electronic devices in mobile rotating systems (for example, in the shells of rifled artillery systems).

The reference designation of LLD-3M ampoule current source is decoded as follows:

- LLD is an electrochemical lead-lead dioxide system;
- 3M is a variant.

The ampoule current sources description according to UCIA (Universal Codifier of Issue Article) is as follows: primary cells and batteries based on them, including backup batteries.

To check the electrical characteristics of the ampoule current source, the centrifuge (Fig. 2) rotation speed can be set to 20,000 rpm when tested after exposure to elevated temperature corresponding to the operating conditions.



Fig. 2. Centrifuge design

When the ampoule current source is tested using the device, the following parameters are to be monitored:

- response time from the moment of activation;
- voltage stability (noises, overshoots and undershoots caused by electrolyte movement) [6].

The autonomous voltage recording device includes the following components:

- the electronic ADC unit (see Fig. 3);
- batteries holder;
- housing.

The scheme of the developed electronic ADC module includes units listed below (Fig. 4). Each of them performs certain inherent functions.

The in-circuit programming interface provides initial programming and periodic calibration of the microcontroller timing frequency, which is necessary because, due to design restrictions, the quartz resonator is hard to use under harsh operating conditions, namely due to the centrifuge high rotation speed. The output interface is used to transfer data from the flash memory via the programmer to the computer, then the data is analyzed and the test report is prepared. The autonomous power supply and voltage regulator provide power to the microcontroller and the flash memory.

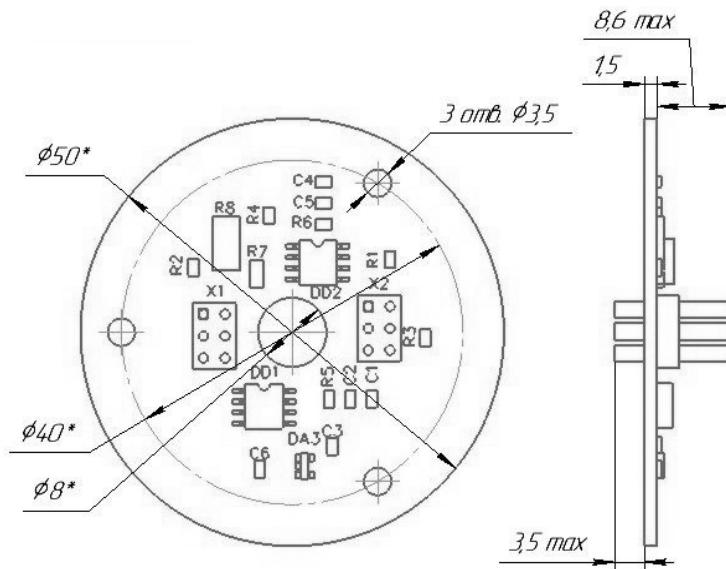


Fig. 3. Assembly diagram of the autonomous voltage registration device

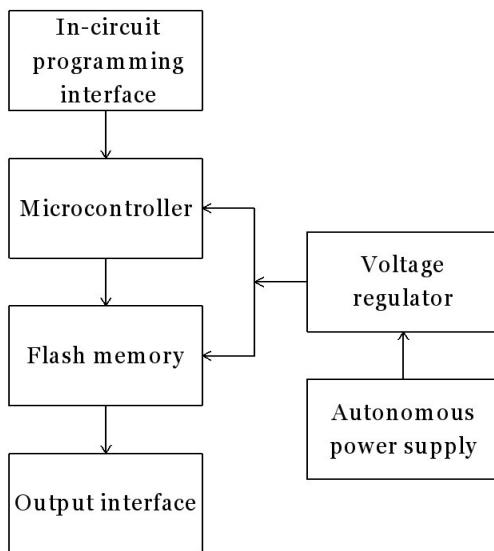


Fig. 4. Functional diagram of the autonomous voltage registration device

Microcontroller ATtiny85 records the analog voltage level and converts it into the digital value to record it to the external flash memory W25Q64 (64Mbit). The microcircuits are chosen as they are available, technologically easy to install and have small the housings. The current voltage value is recorded at a frequency of 1 kHz.

For taking measurements, we developed an algorithm for recording the analog voltage level. The block diagrams of the algorithm of embedded software main cycle and interrupt handling subroutines are shown in the Fig. 5–7 below. The algorithm is implemented in Assembler as it ensures fast operations [7].

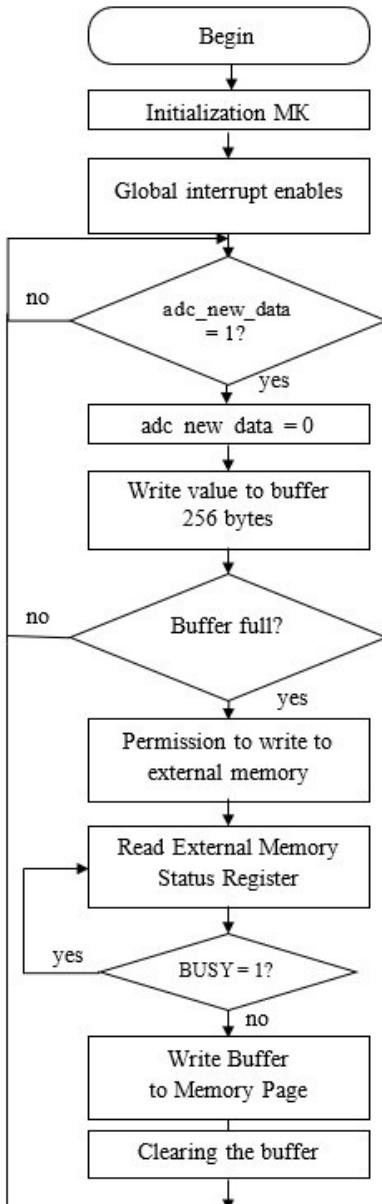


Fig. 5. Scheme to the algorithm of the main program

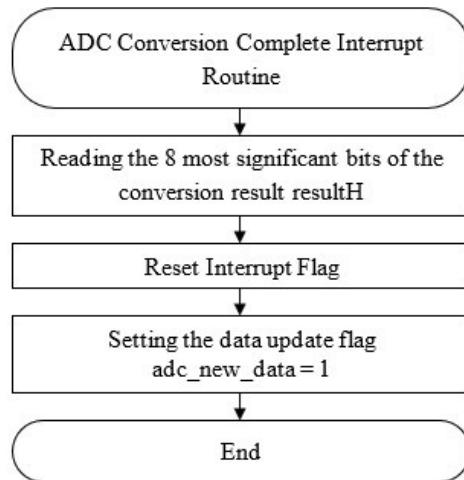


Fig. 6. Scheme of the algorithm of the interrupt handling subroutine coincidence of channel A of timer T0 and on completion of the ADC conversion

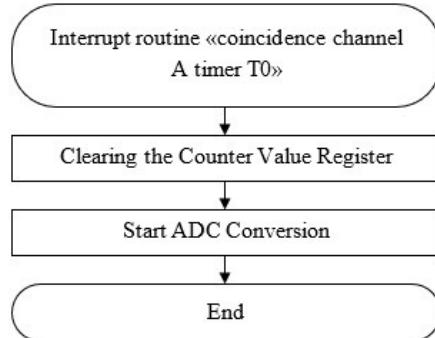


Fig. 7. Scheme of the algorithm of the interrupt handling subroutine coincidence of channel A of timer T0 and on completion of the ADC conversion

The developed device enables to record the response time from the moment of activation and the noise voltage. On time detection of voltage slumps of the ampoule current source will facilitate faster improvement of their design and eventually improve stability of short-range radiolocation systems.

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УДК 629.7.071

Сравнительный анализ динамических режимов работы компоновочных вариантов системы вертикализации для перспективной ракеты космического назначения сверхтяжелого класса

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В последние годы в России прорабатывался вариант создания ракеты-носителя «Енисей» сверхтяжелого класса, предназначенной для реализации перспективных программ освоения Луны и дальнего космоса. На текущий момент проект приостановлен, однако задача создания сверхтяжелой ракеты-носителя продолжает быть актуальной. Приведен сравнительный анализ динамических процессов, протекающих на определенных этапах функционирования установочного агрегата в процессе вертикализации ракеты космического назначения «Енисей» сверхтяжелого класса. Рассмотрено несколько конструктивных исполнений определенных узлов и элементов системы вертикализации ракеты в целях выбора их оптимальной конструкции. Приведенная конфигурация ракеты-носителя использовалась для оценки функционирования установочного агрегата, конструкция которого в дальнейшем может быть доработана под новое изделие. Актуальность исследования заключается в анализе специфичных режимов работы принципиально нового типа установочных агрегатов, который ранее не применялся в России и СССР. На основании проведенных расчетов установлена наиболее подходящая конфигурация интересующих узлов и элементов системы вертикализации. Предложены конструктивные решения, позволяющие снизить динамические нагрузки на ракету в процессе подъема и установки на пусковой стол.

Ключевые слова: наземная космическая инфраструктура, стартовый комплекс, ракета космического назначения сверхтяжелого класса, подъемно-установочный агрегат, вертикализация

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The Dynamic Operating Modes Comparative Analysis of the Verticalization System Layout Solutions for the Promising Super-Heavy Class Space Vehicle

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In recent years, Russia has been working on the option of creating the Yenisei super-heavy class launch vehicle, designed to implement promising programs for the exploration of the Moon and deep space. At the moment, the project has been suspended, but the task of creating a super-heavy launch vehicle continues to be relevant. The paper is devoted to a comparative analysis of the dynamic processes occurring at certain stages of the operation of the erector during the verticalization of the Yenisei super-heavy class space vehicle. At the same time, several design versions of certain units and elements of the space vehicle verticalization system were considered in order to select their optimal design. The launch vehicle configuration given in this paper was used to evaluate the functioning of the erector, the design of which can later be finalized for a new product. Research relevance lies in the analysis of operation specific modes of a fundamentally new type of erectors, which has not previously been used in Russia and the USSR. Based on the calculations, the most suitable configuration of the interesting nodes and elements of the verticalization system was established. Design solutions were proposed to reduce the dynamic loads on the space vehicle in the process of lifting and installation on the launch pad.

Keywords: ground-based infrastructure, launch complex, super-heavy class space vehicle, erector, verticalization

Introduction

Nowdays, in many countries of the world it is relevant the task of creating a superheavy class launch complex (LC) with a launch vehicle (LV) in its composition, allowing to launch payload weighing up to 100 t and more into a low Earth orbit [1]. During 2017–2021 Russia was developing a LC for the Yenisei super-heavy class LV capable of launching payload weighing more than 100 t into low Earth orbit [2]. In January 2021, Russian Academy of Sciences' Space Council recommended postponing the technical design of the super-heavy class LV because of the necessity to correct its shape. This was due to the fact that the currently existing oxygenkerosene liquid-propellant rocket engines do not allow the payload of the required mass to be launched into lunar orbit. Therefore, in February 2021 it was decided to suspend and revise the project in order to use promising technologies: methane as a fuel instead of oxygen and kerosene [3].

The general view of the Yenisei space vehicle (SV) of the last stage of technical design is shown in Fig. 1. The package of six oxygen-kerosene side blocks (SB) with RD-171MV liquid-propellant rocket engines makes up the first (4 SB) and the second (2 SB) stages of the launch vehicle. The central oxygen and kerosene block (CB) with the RD-180MV liquid-propellant rocket engines is the third stage. The SV also includes the accelerating-breaking block (ABB). As a space head module (SHM) is supposed to use a manned transport vehicle (MTV) or an unmanned spacecraft.

Varies types of erectors for a super-heavy class SV were studied in the published scientific papers [4–6]. However, an original erector with two axes of tilting was chosen for the design. The erector allows to abandon the mechanism of lowering the Yenisei SV on the launch pad (LP).

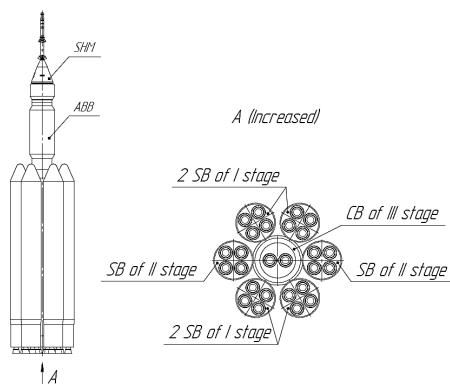


Fig. 1. General view of the Yenisei SV

Description of the layout schemes under consideration

In the course of the study considered in this paper, several variants of the verticalization system of the Yenisei SV were considered. They differ from each other only in variations of docking units and support elements.

The first type of verticalization system design, depicted on Fig. 2, was considered during sketch project on the super-heavy class LC at Vostochny cosmodrome. The layout of the Yenisei SV slightly differs from the variant of technical project. However, it is insignificant for the dynamic operating modes comparative analysis.

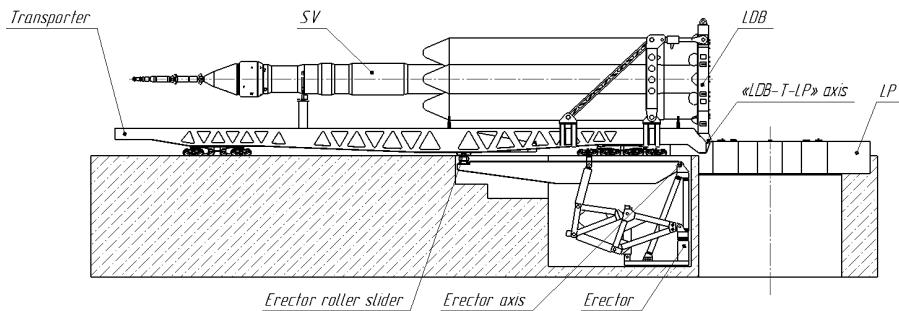


Fig. 2. General view of the verticalization system layout solution #1 (LS #1) for the Yenisei SV

The kinematic scheme of the verticalization system is a crank-and-slot mechanism. It has two tilting axes: the erector axis and the axis of the articulated connection of the transporter, the launch and docking block (LDB) and the LP [«LDB-T-LP» axis]. The system rotation of units with two tilting axes is provided by using a roller slider in the transporter and erector junction (Fig. 3). Technological gap Δ is provided to ensure guaranteed docking of the erector roller slider with the transporter guide elements.

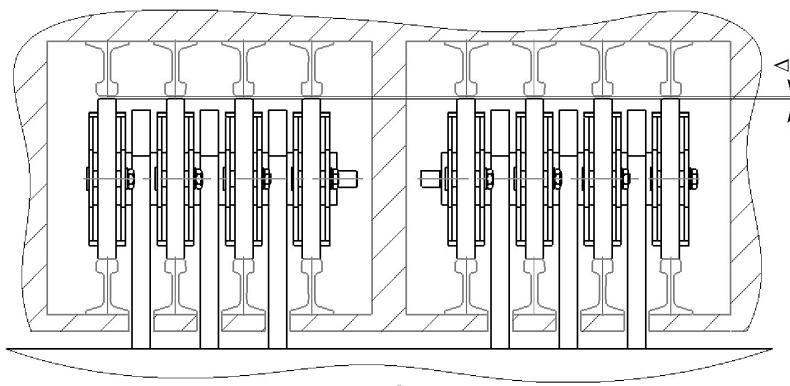


Fig. 3. General view of the roller slider in the transporter and erector junction

The verticalization system layout solution, shown in Fig. 4, was considered during the technical project development for the super-heavy class LV at the Vostochny cosmodrome.

The kinematic scheme of the verticalization system is an articulated four-link mechanism. In order to ensure joint rotation of the system with two tilting axes, a pair of clevises is provided in the erector boom design.

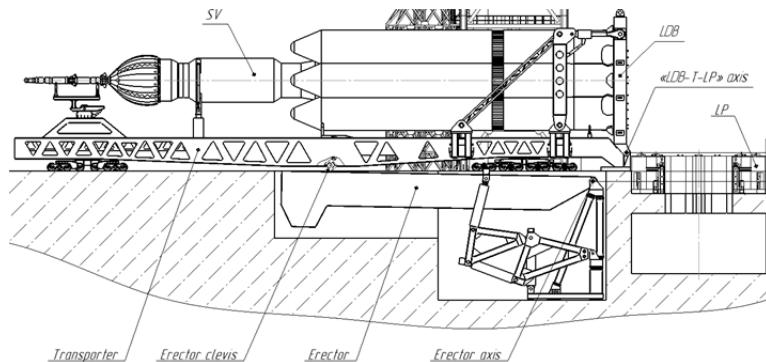


Fig. 4. General view of the verticalization system layout solution #2 (LS #2) for the Yenisei SV

Docking of the transporter with erector clevises is carried out with guaranteed gap Δ by means of an automatic couplers pair, respectively located on the transporter and the erector clevises (Fig. 5).

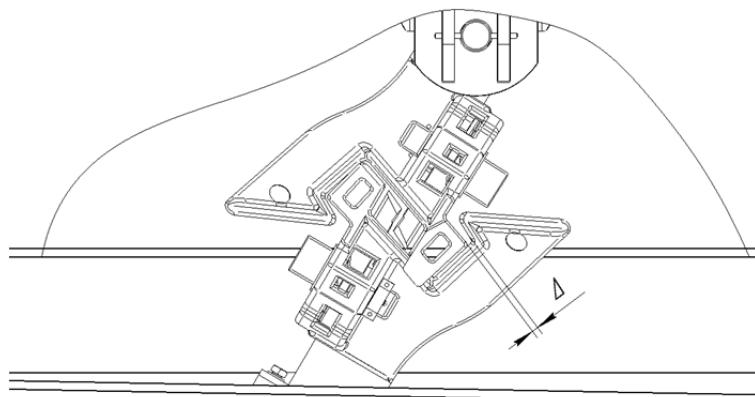


Fig. 5. General view of the transporter and erector junction

The erector clevis is a metal tube, at the end of which there is an erector automatic coupler (Fig. 6). Erector automatic coupler is designed on the basis of domestic railroad coupler model CA-3 GOST 32885-2014 and equipped with a drive of automatic uncoupling of transporter with erector on completion of operation with the SV.

Due to the specific kinematic schemes of the considered layout solutions and the mass-size characteristics of the SV, there are operating modes with high dynamic loading in the docking units and supporting elements of the verticalization system.

The first specific mode is «outweighing» mode. It is carried out when the boom is lifted at the moment of transition, caused by the center of mass (CM) displacement of the transporter — SV — LDB system beyond the axis of the transporter rotation. As a result, there is a one-step change in the sign of the tilting moment and, as a consequence, a shock in the transporter and erector junction due to a free choice of gap Δ .



Fig. 6. General view of the erector clevis

The second specific mode is the «weight transfer» mode. The installation of the SV with the LDB on the LP was considered for LS #2 in three variants:

1. Weight transfer of the SV with the LDB to the retractable supports of the LP. It is similar to the method of weight transfer on LC of light class LV, and on the LC of the N1 LV [7, 8].

2. Tilting and transferring the weight of the SV with the LDB to the fixed supports of the LP. Installation on stationary supports by lowering was used on the LC of the Energia LV [9]. SV tilting on fixed supports was not used on the domestic LC.

3. Tilting the SV with the LDB on special technological supports (STS) of the LDB with further weight transfer of the SV with the LDB to the retractable supports of the LP — an original combined variant of the installation.

The third variant of tilting required modification of the LDB design in order to equip it with STS (Fig. 7).

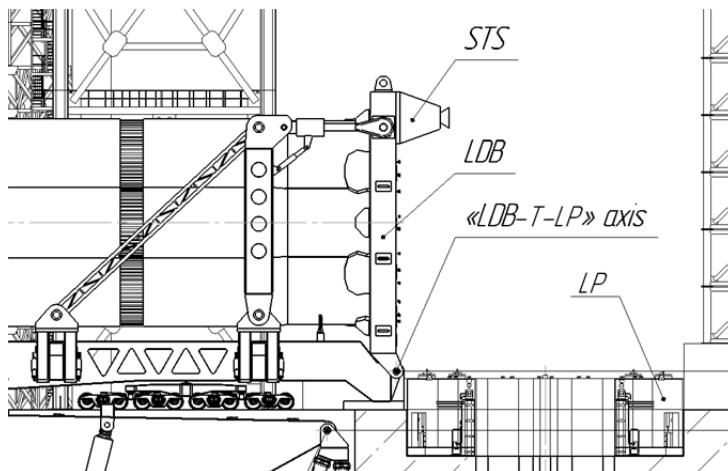


Fig. 7. Variant of equipping the LDB with STS

Results of the research

As a result of model calculations for the «outweighing», we obtained the values of forces in the movable support between the transporter and the erector, made in the form of a roller slider (LS #1) or automatic coupler (LS #2).

The graph of forces in nonlinear couplings (Fig. 8, 9) show their changes in direction. The moment of zeroing of forces is the beginning of «outweighing». A sharp increase in the value of forces in nonlinear connections is a shock with subsequent oscillations of the system and the end of «outweighing».

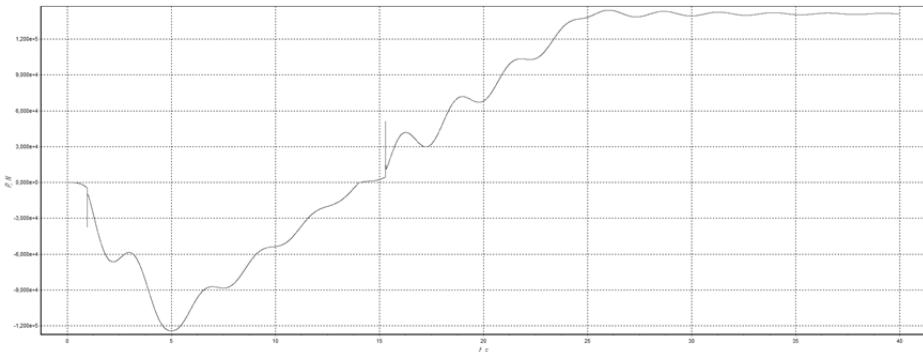


Fig. 8. Dependences of forces P in nonlinear connections on time t for LS #1

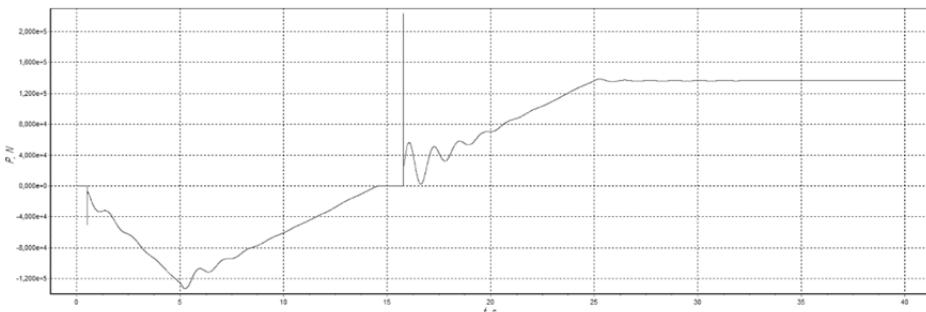


Fig. 9. Dependences of forces P in nonlinear connections on time t for LS #2

The maximum displacements q and accelerations q'' of the CM of the MTV at the moment of «outweighing» for the layout solutions under consideration are presented in Table 1. The obtained values do not exceed the permissible values.

Table 1

The maximum displacements q and accelerations q'' of the CM of the MTV at the moment of «outweighing» for the layout solutions under consideration

LS #1		LS #2	
q , m	q'' , m/s^2	q , m	q'' , m/s^2
0,025	0,15	0,007	0,6

The forces in the LP supports for the three considered variants of LS #2 for the «weight transfer» mode, are shown in Fig. 10–12. In Table 2 it is presented the maximum displacements q and accelerations q'' of the CM of the MTV in the process of transferring the weight of the SV with the LDB to the LP for the three variants under consideration. The obtained values do not exceed the permissible values.

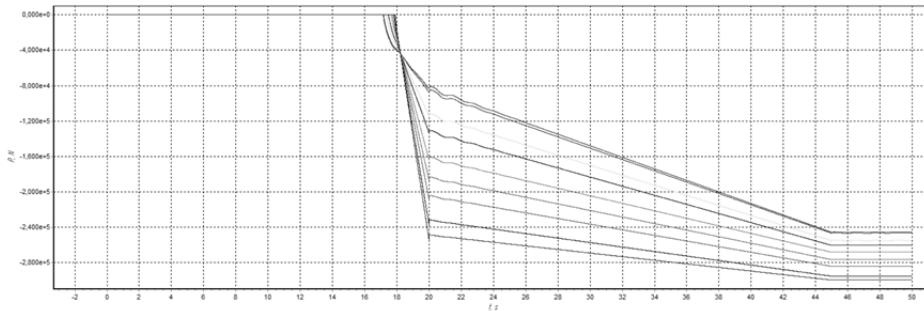


Fig. 10. Dependence of forces P in the LP supports on time t . Weight transfer of the SV with the LDB to the retractable supports of the LP (Variant #1)

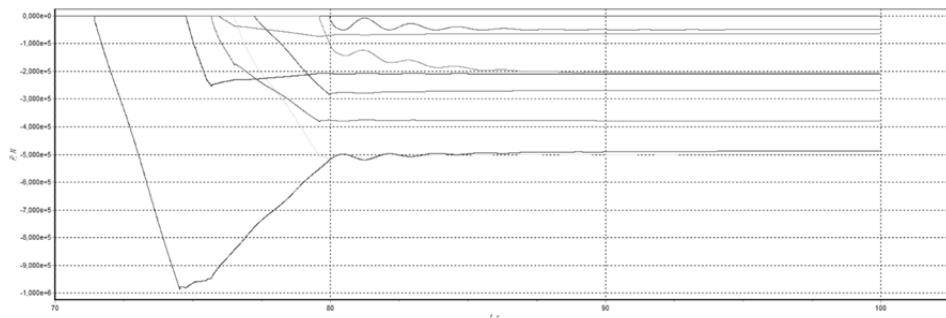


Fig. 11. Dependence of forces P in the LP supports on time t . Tilting and transferring the weight of the SV with the LDB to the fixed supports of the LP (Variant #2)

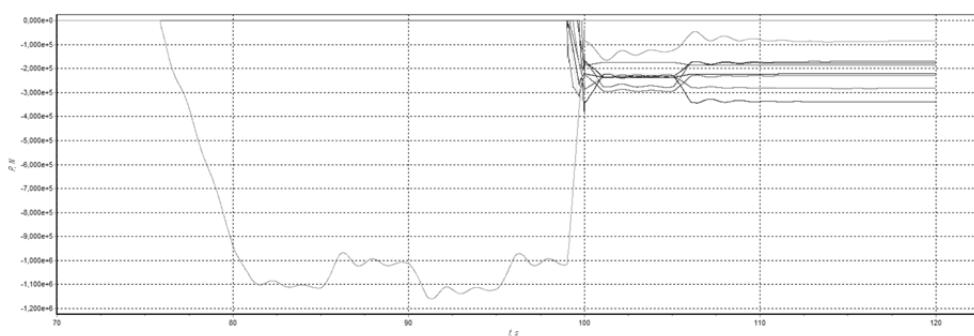


Fig. 12. Dependence of forces P in the LP supports on time t . Combined variant of the installation (Variant #3)

Table 2

**The maximum displacements q and accelerations q'' of the CM of the MTV
in the process of transferring the weight of the SV with the LDB to the LP
for the three variants under consideration**

Variant #1		Variant #2		Variant #3	
q, m	$q'', \text{m/s}^2$	q, m	$q'', \text{m/s}^2$	q, m	$q'', \text{m/s}^2$
0,005	0,085	0,020	0,15	0,030	0,181

Conclusion

Based on the calculations, the most suitable configuration of the interesting nodes and elements of the Yenisei SV verticalization system was established and the following conclusions were made:

1. The loads arising during outweighing in the junction of cast automatic couplers do not cause significant fluctuations of the payload. In addition, they are less dangerous for the junction than the loads in the «roller slider» docking unit, where hinged elements and guides are used. However, in order to completely eliminate shock loads at the moment of outweighing, it is desirable to create a docking unit with gapless contact.
2. Installation of the SV by tilting simultaneously on a large number of fixed supports is not promising. This is due to the fact that in the process of weight transfer the supports of the LP are not triggered simultaneously and are loaded extremely unevenly.
3. The combined variant of installation the SV on the LP supports showed the best results.
4. It is necessary to create a hydraulically looped system of LP supports to distribute the load evenly between them during installation.

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УДК 62.67

Малогабаритный возвращаемый аппарат для доставки научных грузов с орбитальных станций

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Рассмотрены вопросы проектирования спускаемого аппарата, пригодного для доставки биологических полезных грузов с орбитальных космических станций. Предлагаемый малый спускаемый аппарат предназначен для сокращения времени ожидания за счет облегчения доступа к нему путем выбора посадочных площадок в районах, недоступных для полноразмерных спускаемых аппаратов по соображениям безопасности. Отличительной особенностью аппарата является многороторная компоновка, в которой вместо парашюта для торможения используетсяautorотация.

Ключевые слова: капсула, МКС, autorотация, возвращаемый аппарат

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Small Re-Rntry Vehicle for Delivering Scientific Cargoes from Orbital Stations

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This paper refers to issues about the design of a re-entry vehicle which is suitable for the delivery of biological payloads from orbital space stations. The proposed small re-entry vehicle is designed to reduce waiting time through easier access by choosing landing sites in areas that are not available for full-sized descent vehicles for safety reasons. A distinctive feature of the lander is a multi-rotor assembly which operates through autorotation instead of a parachute for deceleration.

Keywords: capsule, ISS, autorotation, re-entry vehicle

In modern world, space research includes a significant number of diverse biological experiments. The unique microgravity environment on the space stations makes it possible to explore biological materials that cannot be produced on the Earth [1–4].

However, the existing methods of payload delivery from orbit do not allow scientists to take full advantage of these researches. It becomes important to create a vehicle that is capable of delivering scientific cargo independently from the existing cargo with high landing accuracy.

The main advantage of the vehicle being developed is the improvement of landing accuracy due to the autorotation effect. Such ability will allow scientists not only to reduce the time spent searching for the capsule, but also to meet the operational requirements for preserving the integrity of the biological cargo inside the capsule.

The flight of the small re-entry vehicle (SRV) starts with separation from the space station via a deployer pod. The vehicle performs deorbiting burn. After entering the atmosphere and decelerating to subsonic speeds, the cap of the descent capsule is decoupled and the parachute is deployed for the subsequent separation of the landing vehicle and the thermal protection shell. The arms of propellers on the landing vehicle extend under the influence of the oncoming airflow, the propeller blades are introduced into the flow.

Landing takes place at a speed of up to 5 m/s, which guarantees the successful release of the landing gear and shock damping while landing. Just before that, the rotor system changes to the landing mode and adjusts the trajectory by reversing blades (Fig. 1).

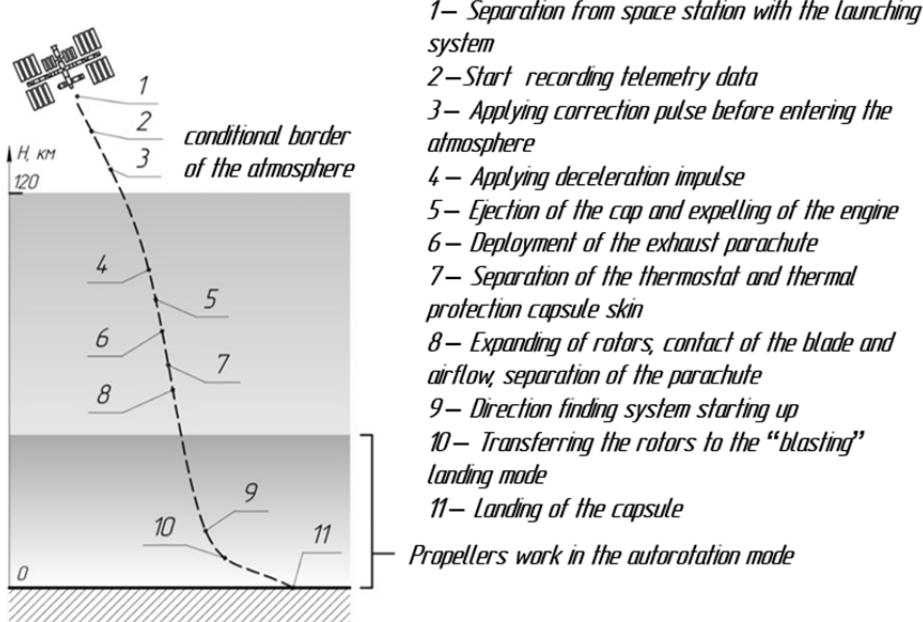


Fig. 1. Diagram of the flight profile

The descent capsule is a part of the SRV, which is necessary to deliver the container with the thermostat and the rotor system to a certain height for separation, as well as to protect against thermal and aerodynamic loads that can damage the container with biological material.

According to the several factors that were taken into account during the analysis, such as, temperature during atmosphere reentry and dynamic forces, acting on the vehicle, the optimal option in terms of aerodynamic and weight characteristics was found to be the Soyuz-type capsule.

The internal compartment of the capsule is designed taking into account the payload of 4 kg and the packages currently used for the delivery of biological cargo from space (Fig. 2).

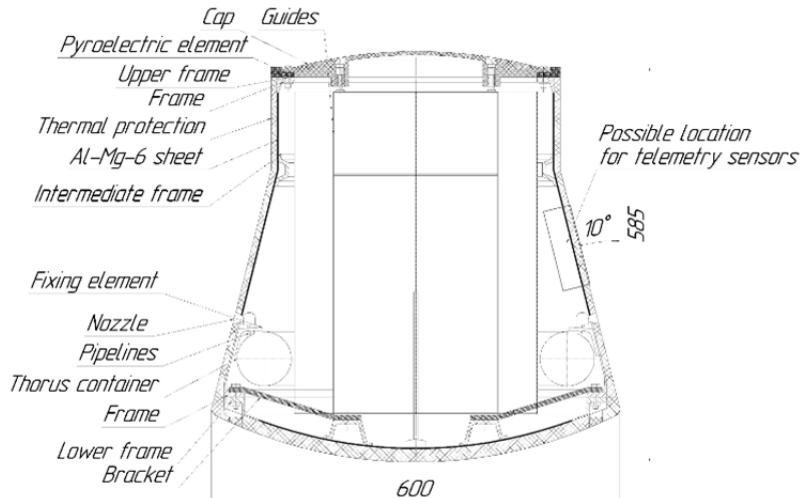


Fig. 2. Detailed drawing of capsule

The parachute for the landing of the capsule is located in the lower part of the vehicle and is packed under the container with biological materials. A balancing load will also be installed in this part of the vehicle.

When it is necessary to release the thermostatic container, the cap of the capsule is decoupled by pyrobolts, which receive an automatic signal from the the vehicle's telemetry sensors. A spring pusher is also provided to separate the cap.

To increase the accuracy of landing, autorotating propellers will be used. The propellers are attached to 4 arms of the landing vehicle. When lander is stored in the descent capsule, the arms and propellers of the vehicle are in the retracted position to minimize volume occupied inside the capsule (Fig. 3).

While in the subsonic period of the flight, the effect of autorotation is used as the principle for braking, further autorotation was examined from the aerodynamics point of view. Taking into account the influence of the flow on the rotor-blade unit, it can be concluded that the safest way to introduce propellers in the airflow is during the subsonic section of the trajectory since the resulting aerodynamic force acting on the blades decreases. It is also important to remember the occurrence of a flow stall on the rotor blades, which usually arises from the violent increase in the lander vibration and the loads acting on the elements of the control circuit. During the transition to the stable autorotation mode — special mode of rotation of the propeller, when the flow is asymmetric, the stall comes in the form of periodic torsional oscillations of the blades, which is called stall flutter (Fig. 4).

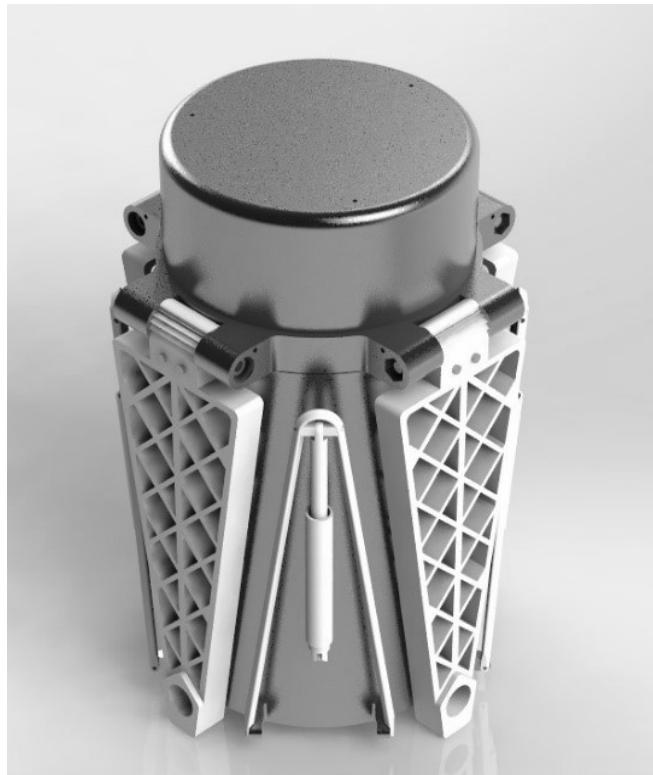


Fig. 3. Landing vehicle

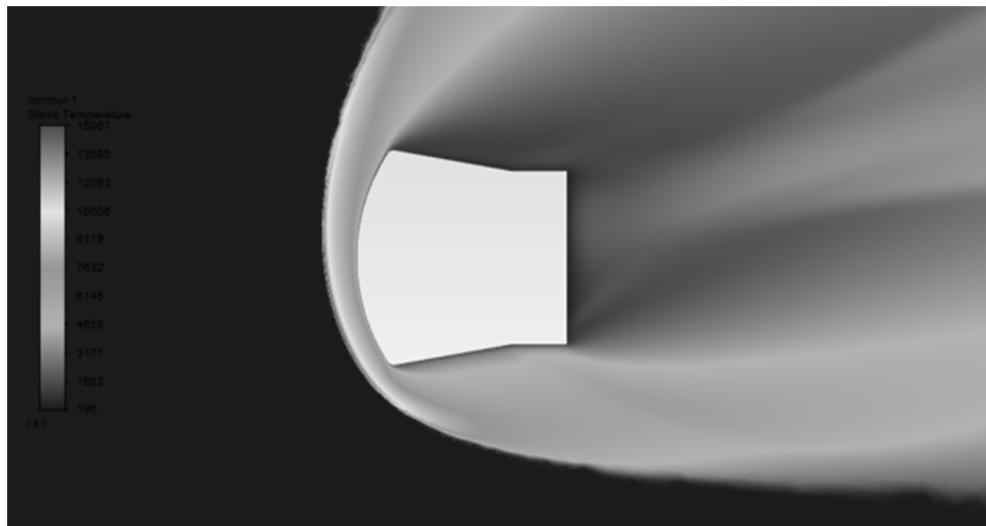


Fig. 4. Simulation in ANSYS Fluent

The ablative shield and lateral surface of the capsule is a glass-fiber laminate based on KT-11 silica fabric as a matrix impregnated with phenol-formaldehyde resin with a high emissivity coefficient.

To maintain the permissible temperature inside the capsule, thermal insulation materials like Fibrous Thermal Insulation Material (FTIM) and Ultra-Thin Thermal Insulation Material (UTTIM) are used. UTTIM is a glass block attached to the glass wool through the adhesive bond. FTIM is placed on top of the glass wool. FTIM is an alkali-free aluminoborosilicate fiber impregnated with organosilicon resin. Such composition of thermal insulation is necessary in order to minimize the mass of TPS while maintaining its thermal protection characteristics within the specified limits (Fig. 5).

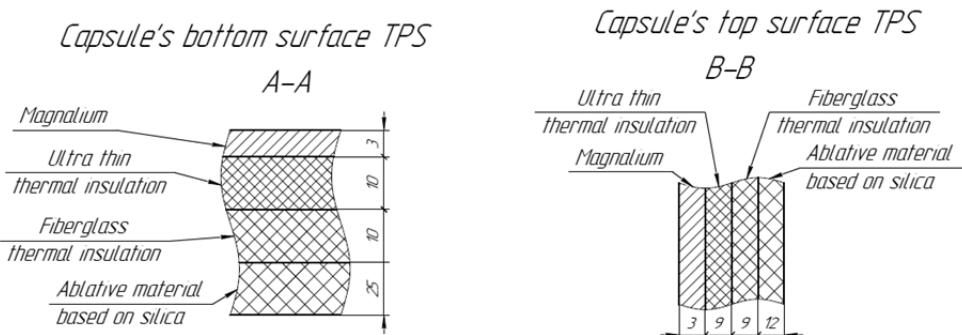


Fig. 5. Schemes of the thermal protection slayers

The focus of the work will be on the development of the electronic part of vehicle, as well as on the development of an experimental layout in order to obtain refined aerodynamic data using the autorotation effect.

The work proved the relevance and technological feasibility of developing a small lander designed to deliver scientific cargo from the space station.

In future, the developed model can claim large-scale use in the field of scientific cargo delivery, as well as improve the quality of scientific research and experiments conducted with the help of biological material from the space station.

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УДК 658.5.011

Анализ возможностей использования в производственных процессах современных материалов с добавками натуральных волокон и биоразлагаемых смол

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Проанализированы возможности использования натуральных волокон и биоразлагаемых смол в производстве, в частности, для аддитивного производства и армирования композиционных материалов. В качестве альтернативы предлагается использовать волокна Ичу — травы, произрастающей в перуанско-боливийских Андах. Выделены основные технологические процессы и проведен анализ достоинств, недостатков и ограничений в производстве для использования материалов, состоящих из натуральных волокон и биоразлагаемых смол.

Ключевые слова: композиционные материалы, натуральные волокна, биоразлагаемые смолы, трава ичу, аддитивное производство

Введение

Аддитивные технологии позволяют кратко уменьшить время и затраты на серийное производство изделий. При этом акцент в производстве беспилотных летательных аппаратов делается на снижение веса конструкции для максимального увеличения времени полета, дальности и полезной нагрузки. Компоненты с несколькими роторами представляют собой ключевую проблему для 3D-моделирования, оптимизации и аддитивного производства: они в основном состоят из сложных форм, где наиболее важными характеристиками являются надежность и легкий вес. Использование различных композитных материалов, натуральных волокон, полимеров, аддитивных материалов, методов оптимизации топологии играют ключевую роль в минимизации веса компонентов и повышении производительности машин. Более того, аддитивное производство позволяет производить больше деталей за меньшее время, повышая экономическую эффективность проектов. Целью статьи является анализ перспектив различных технологических процессов с использованием натуральных волокон для производства беспилотных летательных аппаратов.

Применение натуральных волокон для армирования композиционных материалов

Натуральные и синтетические волокна используются при производстве армированных волокном композитов (FRC) для дронов [1]. Синтетические волокна включают углеродные, стеклянные и арамидные материалы, в то время как натуральные волокна включают койру, пальмовое волокно, коноплю, люффу, хлопок, лен, шелк и шерсть [2], и в настоящее время изучаются свойства и применение травы Ичу [3, 4]. Натуральные волокна, используемые в настоящее время в производстве дронов, включают PLA и льняные композиты, PLA и композиты волокна кенафа [5, 6], полимерные композиты, такие как углеродное волокно, нейлон и стекловолокно [7],

материалы Нуретех, такие как саржа, полотняное переплетение, расправленный жгут и однодиапазонные ткани и термопласти с длинным волокном Xencor [8].

Недавно композиты, армированные натуральными волокнами, вызвали большой интерес в качестве альтернативного материала для нескольких конструкционных применений. Эти материалы обладают рядом преимуществ, таких как снижение загрязнения окружающей среды, поскольку легко перерабатываются и разлагаются. Они также обладают превосходными механическими характеристиками, низкой плотностью, умеренным соотношением веса к прочности/жесткости и высокой ударной вязкостью. Кроме того, они легко доступны по низким ценам. Эти композитные материалы из натуральных волокон в основном используются в строительной, текстильной, спортивной, транспортной отраслях [9].

Ранее для армирования использовались стекловолокна, за которыми следовали волокна бора и углерода. Но они очень дороги и к тому же загрязняют окружающую среду. По этой причине было проведено огромное количество исследований натуральных волокон, которые не загрязняют окружающую среду и являются относительно дешевыми по сравнению с такими синтетическими волокнами, как стекловолокно и углеродные волокна; также натуральные волокна обладают хорошими механическими свойствами.

Использование экологически чистых материалов важно в связи с современными требованиями по реализации концепции устойчивого производства, предполагающей введение новых экологических норм, повышение экологической, социальной и экономической ответственности, а также ограничение использования углеводородов. Использование экологически чистых материалов позволяет не только уменьшить количество твердых бытовых отходов, но и снизить загрязнение окружающей среды. Эти материалы имеют низкую стоимость, хорошие механические свойства, низкую плотность и более низкое энергопотребление во время обработки, что приводит к увеличению их использования [10]. В табл. 1 приведены основные преимущества и недостатки натуральных волокон с точки зрения их использования в производстве.

**Таблица 1
Преимущества и недостатки натуральных волокон**

Преимущество	Недостаток
Возобновляемый/перерабатываемый ресурс	Фактор-зависимые свойства (урожайность)
Биоразлагаемый	Нетехнические волокна (кустарные)
Низкая стоимость сырья	Отсутствие надежных исследований
Низкая плотность	Адгезия к матрице с низким содержанием волокон
СО ₂ нейтральный	Низкая огнестойкость
Хорошая прочность на растяжение	Поглощение влаги
Хороший модуль Юнга	Неструктурные приложения
Отсутствие отходов при сжигании	Высокая стоимость конечных материалов
Низкое потребление энергии	Отсутствие надежного производственного процесса
Нет раздражения кожи	Низкая рабочая температура
Неабразивный материал	Подвержен нападению живых организмов

Возможность использования волокон травы Ичу в качестве добавки к композиционным материалам

Натуральные волокна в Южной Америке, пригодные для использования в качестве армирующих в композитных материалах, разнообразны. В частности, в Андском регионе произрастает трава, которую обычно называют Ичу (Ichu-Stipa Obtusa). Вид Stipa Obtusa характерен для перуанско-боливийских Анд, он растет от пахотных земель до открытых пространств на высоте от 3 000 до 4 800 метров над уровнем моря. Волокно Ичу использовалось в Перу с древних времен для изготовления подвесных мостов, и строительства домов в качестве структурного и теплового армирования. Исследования, проведенные с использованием метода сегментации изображений, показали, что годовая добыча этого вида превышает 70 000 тонн в Андском регионе Перу [11]. Кроме того, учитывая, что Ичу является эндемичным растением, нет необходимости сажать его или ухаживать за ним во время его роста.

Ичу — грубое растение, имеет съемные волокна и демонстрирует выдающиеся характеристики, такие как высокая прочность и высокий модуль [3]. Кроме того, экстрагированные волокна обладают отличными характеристиками в качестве полимерного армирования (композитные ламинаты), демонстрируя результаты, сопоставимые с коммерческими натуральными волокнами по своим свойствам на изгиб. Для оптимизации обработки травы были представлены различные процессы (методы извлечения волокна) [5].

Другие производственные процессы, такие как вытягивание[12], были исследованы и имели хорошие результаты с механической точки зрения. Однако при такой технике геометрия ограничивается профилями. В литературе можно найти различные изделия, изготовленные с использованием методов закрытой формы и коротких волокон, аналогичных SMC [13]. В табл. 2 показаны преимущества, недостатки и ограничения процессов в области производства композиционных материалов из натуральных волокон.

Таблица 2

Преимущества, недостатки и ограничения производственных процессов с использованием материалов, состоящих из натуральных волокон и биоразлагаемых смол

Процесс	Преимущества	Недостатки
SMC	Сложная геометрия Низкая стоимость	Низкие механические свойства Стоимость напорного оборудования
Spray lay-up	Широко используется Низкая стоимость Свобода в размерах	Низкие механические и тепловые свойства Обработка поверхности Контроль размеров
Hand lay-up	Широко используется Низкая стоимость Непрерывное волокно	Пористость Накопление смолы Выброс летучих веществ
Vacuum Bagging	Больший объем волокна Лучшая пропитка Меньшее загрязнение, они летучие	Вспомогательные материальные затраты, затраты на рабочую силу Технические знания

Окончание табл. 2

Процесс	Преимущества	Недостатки
Filament winding	Автоматизированный регулятор громкости оптоволокна	Качество поверхности Стоимость оборудования Ограничение направления намотки на оси оправки Ограниченнная геометрия
RTM	Большой объем волокна Низкий уровень выбросов химических веществ Обработка поверхности Более низкие затраты на рабочую силу	Стоимость оборудования Небольшие компоненты Контроль впрыска Высокая стоимость энергии
Autoclave	Контролируемый материал Отличные механические и термические свойства	Очень высокая стоимость установок и оборудования Очень высокая стоимость энергии Ограничение по размеру Сложный процесс

Заключение

Предпринимаются попытки объединить два типа волокон вместе и смешать их с матричным материалом, чтобы сформировать гибридный материал. Для этого надо сравнить структурные характеристики сжатия натуральных и синтетических волокнисто-эпоксидных композитов. Исследование показало, что лен, джут, конопля, стекло и углеродные волокна могут использоваться в качестве армирующих материалов для FRC [14]. Имеющиеся в продаже эталонные препараты наиболее распространенных натуральных волокон — хлопка, льна, шелка и шерсти — являются неоценимой помощью в изучении их микроскопических свойств [2].

Таким образом, синтетические волокна обеспечивают большую жесткость, прочность и долговечность, в то время как натуральные волокна используются из-за их биоразлагаемых свойств, материалов из биомассы, композитных материалов, энергоэффективности [15], уменьшения количества естественных отходов, обеспечения возобновляемости, устойчивости, что делает их экологически чистыми, обладающими такими важными характеристиками, как низкая плотность, высокая ударная вязкость, хорошие удельные прочностные характеристики, сниженный износ инструментов и оборудования (неабразивные) и более низкая стоимость [16, 17].

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Analysis of the Possibilities of Using Modern Materials with the Addition of Natural Fibers and Biodegradable Resins in Production Processes

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This article analyzes the potential use of natural fibers and biodegradable resins in production, particularly for additive manufacturing and reinforcing composite materials. The use of Ichu fibers, a type of grass found in the Peruvian-Bolivian Andes, is proposed as an alternative. The main technological processes are identified, and an analysis of the advantages, disadvantages, and limitations of using materials made from natural fibers and biodegradable resins in production is conducted.

Keywords: composite materials, natural fibers, biodegradable resins, Ichu, additive manufacturing

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УДК 629.7

Бортовая система предупреждения столкновений

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Рассмотрен вопрос столкновений судов в воздухе всегда был важным для пилотов, диспетчеров и начальников авиации. Международная организация гражданской авиации настояла на внедрении системы предупреждения столкновений «Бортовая система предупреждения столкновений». Эта система обязательна должна быть установлена на воздушных судах с максимальной взлетной массой более чем 5 700 кг или имеющим разрешение перевозить более 19 пассажиров. Сделан вывод, что установка бортовой системы предупреждения столкновений добавила барьер безопасности для предотвращения столкновений в воздухе и улучшения ситуации в небе.

Ключевые слова: бортовая система, предупреждение столкновений, авиационная отрасль, технологии

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Traffic Collision Avoidance System

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The issue of mid-air collisions has always been an important one for pilots, air traffic controllers and aviation chiefs. The International Civil Aviation Organisation has insisted on the introduction of an Airborne Collision Warning System. The system is mandatory on aircraft with a maximum take-off weight of more than 5,700 kg or authorized to carry more than 19 passengers. It is concluded that the installation of the On-Board Collision Warning System has added a safety barrier to prevent airborne collisions and improve the situation in the sky.

Keywords: collision avoidance, system, ICAO standard, aviation technology

Introduction

No doubt, the question of midair collisions has always been the hot one for pilots, ATC controllers and aviation. International Civil Aviation Organization has also taken this problem into consideration authorities and insisted on implementation of collision avoidance system called T-CAS. This system is obligatory to be installed on aircraft with maximum take-off weight of more than 5700 kg or authorized to carry more than 19 passengers. This implementation added safety barrier for preventing midair collisions and improving the situation in the sky [1].

Tupolev and Boeing crash

On the night of Monday, 1 July 2002, a Tupolev Tu-154 passenger jet, and a Boeing 757 cargo jet, collided in midair over Überlingen, a southern German town on Lake Constance, near the Swiss border. All of the passengers and crew aboard both planes were killed, resulting in a total death toll of 71.

The official investigation by the German Federal Bureau of Aircraft Accident Investigation identified the main cause of the collision to be a number of shortcomings on the part of the Swiss air traffic controller (ATC) service in charge of the sector involved, as well as ambiguities in the procedures regarding the use of the traffic collision avoidance system (TCAS) on board.

Traffic Collision Avoidance System monitors airspace around the aircraft for other aircraft equipped with a corresponding active transponder and warns pilots of possible midair collision threat.

The accident raised questions as to how pilots must react when they receive conflicting orders from TCAS and ATC. TCAS was a relatively new technology at the time of the accident, having been mandatory in Europe since 2000.

The BFU recommended that this ambiguity should be resolved in favor of obeying TCAS advisories even when these were in conflict with ATC instructions [2].

How does it work

T-CAS is a very sophisticated system but generally it consists of three modes:

1. Traffic Advisory (TA);
2. Resolution Advisory (RA);
3. Clear of Conflict (CC) (but this one is not considered to be a full-fledged mode) [3].

Traffic Advisory provides pilots with information about traffic around the aircraft, while Resolution Advisory gives instructions how to avoid collision.

When Resolution Advisory mode is on, pilots should immediately comply with its instruction even if this instruction contradicts with ATC's one. In this situation ATCO is no longer responsible for separation of aircraft involved.

In responding to a TCAS RA that directs a deviation from assigned altitude, the flight crew should communicate with ATC as soon as practicable after responding to the RA. When the RA is removed, the flight crew should advise ATC that they are returning to their previously assigned clearance or should acknowledge any amended clearance issued [2].

Versions of TCAS

Since the time of its first implementation T-CAS has been modernized and up-graded several times. Nowadays we can talk about four generations of T-CAS: T-CAS 1, T-CAS 2, T-CAS 3 and T-CAS 4 (but the last one was abandoned). And each following version is better than the previous one.

Thus T-CAS 1 is able only to generate collision warnings in form of Traffic Advisory and does not offer any suggested remedy.

T-CAS 2 has all the benefits of T-CAS 1 but in addition it offers vertical maneuvering directives to avoid collision. (For example: whole world is currently uses TCAS 2 (ver. 7.1)) [4].

As for T-CAS 3, it has capability to offer both vertical and horizontal maneuvering directives, which is very useful when aircraft operates close to the ground have little vertical maneuvering space. But all work on TCAS III was suspended and there are no plans for its implementation.

TCAS 4 uses additional position information encoded on an air-to-air data link to generate the bearing information, so the accuracy of the directional antenna would not be a factor. But, the TCAS 4 concept was abandoned as ADS-B development started [2].

Main commands

The following Table describes the TCAS operation based on TCAS 2, since this is the version that has been adopted as an international standard (ACAS 2) by ICAO and aviation authorities worldwide [2].

TCAS operation

Type	Text	Meaning	Required action
TA	Traffic: traffic	Intruder near both horizontally and vertically	Attempt visual contact, and be prepared to maneuver if an RA occurs.
RA	Climb: climb	Intruder will pass below	Begin climbing at 1500–2000 ft/min
RA	Descend. Descend	Intruder will pass above	Begin descending at 1500-2000 ft/min
RA	Increase climb	Intruder will pass just below	Climb at 2500–3000 ft/min
RA	Increase descend	Intruder will pass just above	Descend at 2500–3000 ft/min
RA	Reduce climb	Intruder is probably well below	Climb at a slower rate
RA	Reduce descent	Intruder is probably well above	Descend at a slower rate
RA	Climb: climb now	Intruder that was passing above, will now pass below	Change from a descent to a climb
RA	Descend: descend now	Intruder that was passing below, will now pass above	Change from a climb to a descent
RA	Maintain vertical speed: maintain	Intruder will be avoided if vertical rate is maintained	Maintain current vertical rate
RA	Level off. level off	Intruder considerably away, or weakening of initial RA	Begin to level off

End of Table

Type	Text	Meaning	Required action
RA	Monitor vertical speed	Intruder ahead in level flight, above or below	Remain in level flight
RA	Crossing	Passing through the intruder's level. Usually added to any other RA	Proceed according to the associated RA
CC	Clear of conflict	Intruder is no longer a threat	Return promptly to previous ATC clearance

Conclusion

T-CAS has much better knowledge of surrounding traffic than any ground radar system as its traffic information is up-grated every second. In contrast, ATCs see the traffic picture on their radar screens up-grated every 5...12 seconds. So, T-CAS owns much more current and precise information than is available to ATC and is better positioned to provide effective last-resort collision avoidance.

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Экспериментальная проверка ультраструктурной диагностики поверхностного слоя материала детали сложного профиля

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При изготовлении изделий современной техники успешно применяются такие технологии гидроабразивной обработки, как гидроабразивная резка материалов. Однако физическая и энергетическая основа ультраджетной техники предопределяет гораздо более широкую сферу ее практического применения. Предложена методика проведения диагностики с помощью высоконапорной струи жидкости. В основе данной методики лежит процесс гидроэррозионного разрушения в процессе воздействия высокозергетической струи на поверхность диагностируемого материала. Ультраструктурная диагностика (УСД) основана на анализе зависимости характеристик локальной гидроэррозии диагностируемого участка поверхности анализируемого объекта от параметров его качества. К параметрам качества поверхности относятся физико-механические и эксплуатационные свойства. Разработан формализованный подход, численно определяющий главный информационный параметр ультраструктурной диагностики – глубину гидрокаверны. С помощью сравнения расчетной глубины с экспериментальной можно судить о качестве диагностируемой поверхности. Экспериментальная проверка предложенного метода показала свою эффективность и достоверность.

Ключевые слова: ультраструктурная диагностика, гидроэррозия, нестационарность условий, оценка качества

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Ultra-Jet Diagnostics Experimental Verification of the Material Surface Layer as a Part of Object's Complex Profile

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When manufacturing products of modern technology, such technologies of waterjet processing as water jet cutting are successfully used for cutting materials. However, the physical and energy basis of ultrajet technology predetermines a much broader scope of its practical applications. This paper proposes an innovative method for determining diagnosis information using a high-pressure jet fluid. This technique is based on the process of hydro-erosive destruction in the process of ultrajet exposure to a high-energy jet on the surface of the material being diagnosed. Ultra-jet diagnostics (UJD) is based on the analysis of the dependence between the local hydro-erosion characteristics of the diagnosed area and the parameters of its quality. Surface quality parameters include physical and mechanical properties and operational properties. In this paper a formalized approach has been developed. It determines the value of the main informative parameter of ultrajet diagnostics - the hydrocavern's depth. By comparing the calculated depth with experimental data, one can judge the quality of the diagnosed surface. Experimental verification of the proposed method has shown its effectiveness and confirms its reliability.

Keywords: ultrajet diagnostics, hydroerosion, nonstationary conditions, quality assessment

Introduction

Nowadays the development of new models for assessing the Physical and Mechanical Properties (PMP) and operational properties of modern engineering components is one of the most urgent problems of mechanical engineering [1–3]. The additional informational and physical parameters may be required for estimation of the operational properties, primarily related to surface layer of products made of new materials. It was shown in [3,4] that express determination of changes in PMP and parameters of the surface layer is possible when analyzing the results of exposure to the surface of the investigated material with high-speed Ultra-Jet (UJ). This estimation is carried out on the basis of comparison of informative signs related to local hydro-erosive destruction: the depth of the formed UJ hydro-cavern, the micro-relief of the surface structure, the mass-geometric parameters of eroded particles, etc. [3–5].

Ultra-Jet Diagnostics' essence

Ultra-Jet Diagnostics (UJD) is a set of methods and means for creating the implementation of such parameters of a high-energy compact liquid jet. When it interacts with a diagnosed medium, for example, during shock-dynamic braking on a solid target, can lead to fixed purposeful changes in the processed material and/or in the liquid itself. In this case, a high-energy compact jet of liquid will be called *Ultra-Jet*. And the resulting depression in the surface of the material as a result of UJD is *hydro-cavern* (or just *cavern*) [6]. Fig. 1, 2 depict hydro-caverns of polymer material. Photos were taken with an electronic magnifier at 60x magnification. In other words, the hydro-cavern is like a scratch on the surface of the material made by high speed water jet and is referred to as “Ultra-Jet”.

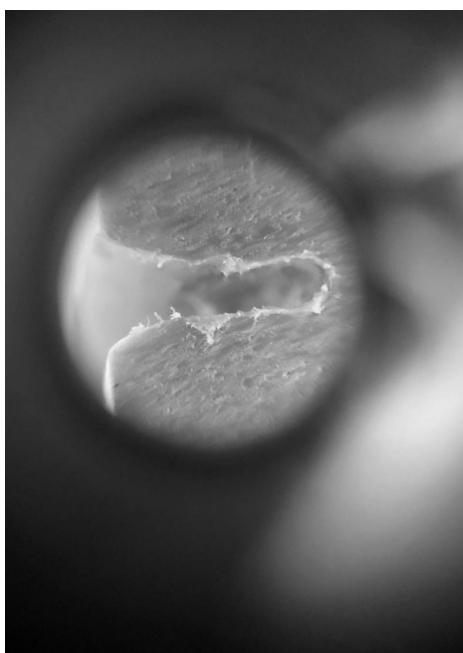


Fig. 1. Illustrations of hydro-caverns for polymer material: (a) – front view of a hydro-cavern



Fig. 2. Illustrations of hydro-caverns for polymer material: (b) – back view of a hydro-cavern

Basic UJD Algorithm

The classic UJD algorithm, according to [6], includes the following steps:

1. The diagnosed surface is exposed to a hydro-jetting effect, which causes hydro-erosion of the surface under certain conditions (working pressure of the jet, its diameter, motion kinematics, etc.).
2. Then the parameters of hydro-erosion (particle size of the material, the structure of the material in the place of the cut, depth of the cut, etc.) are investigated and compared with the reference characteristics or with each other on different parts of the surface.
3. The obtained difference in the results of comparisons (absolute or relative) is used to judge the quality of the controlled area of the surface and the current state as a whole.

Suggested diagnostic technique

For the most part modern mechanical engineering objects have a complex internal and external configuration. The non-planar diagnostic surface makes it difficult to obtain reliable diagnostic information. Fig. 3 shows a general view of a complex profile surface for diagnostics. From this view, it follows that in the case of complex-profile object UJD, the parameters of local hydroerosion (the main informative parameter of diagnosis) are significantly negatively affected by changes in $L(x)$ and $\alpha(x)$, which distort the result of determining the PMP and other characteristics of the surface layer. It is possible to formalize these functionally latent dependences by constructing a model of the influence of these deviations in the conditions of the UJD on its informative and technological effectiveness.

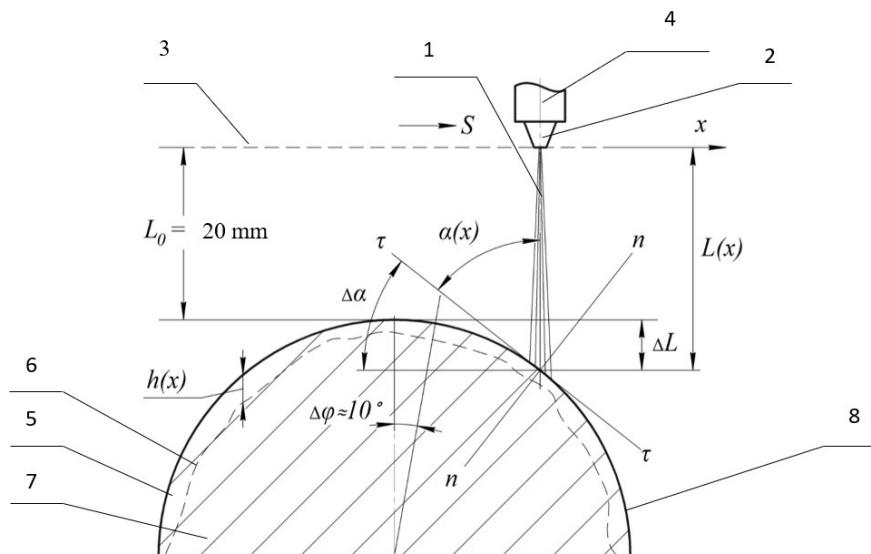


Fig. 3. Scheme for the UJD implementation under non-stationary conditions of interaction between the UJ and complex-profile surface of the object

In the Fig. 3 it is accepted: 1 — diagnostic ultrajet (UJ); 2 — jet forming nozzle head; 3 — rectilinear trajectory of movement 2; 4 — intermediate positions of the UJ relative to the object; 5 — hydrocavern formed by UJ with depth $h(x)$; 6 — contour of the future hydrocavern from the action of the UJ; 7 — material of the object; 8 — contour of complex-profile;

$L(x)$ — current distance between the cut of the jet-forming head and the action point of the UJ on the diagnosed section of the surface of object

$\alpha(x)$ — current value of the angle of interaction between UJ and the surface of the object in the zone of diagnosis;

$n - n$ and $\tau - \tau$ — respectively, the direction of the normal and the tangent to the surface of the object in the place of UJD.

S — direction of movement of the UJ on the surface;

$\alpha_0 = \pi/2$ — conditionally nominal angle of influence of the UJ on the flat surface.

Based on the physico-technological essence of the problem being solved of a formalized description of the UJD operation in non-stationary conditions, the generalized dependence between the studied parameters and their deviations from the nominal value in this case will have the form:

$$h + \delta h = F(S_i + \delta S_i, L_i + \delta L_i, \alpha_i + \delta \alpha_i) \quad (1)$$

where: h and δh — characterize the depth of the hydrocavern and its current relatively small changes respectively; S_i and δS_i — set of parameters characterizing the state of the surface layer ($i = 1, 2, \dots, N$ — total number of considered parameters) respectively; L and δL — distance and its change in the process of UJD between the cut of the jet-forming head and the zone of influence of the UJ on the studied area of the surface respectively.

Following the logic of the problem under consideration, in the first approximation, with small deviations of the stationary characteristic parameters δL and $\delta \alpha$ from (1), we obtain a linear mathematical model describing their interconnection of the following form:

$$\delta h = \xi_s \delta S + \xi_L \delta L + \xi_\alpha \delta \alpha \quad (2)$$

where: $\xi_s = \frac{\partial F}{\partial S}$, $\xi_L = \frac{\partial F}{\partial L}$, $\xi_\alpha = \frac{\partial F}{\partial \alpha}$ — coefficients of the influence of deviations of the analyzed parameters on the change in the depth of the hydrocavern, and in the general case, the informative parameters of the local erosion of the surface layer in the zone of the UJD.

Experimental testing

For the experimental verification of the proposed UJD method, experiments were carried out to determine the effect of the curvature radius of the detail (Fig. 4, 5) on the depth of the formed hydrocavern by UJ.

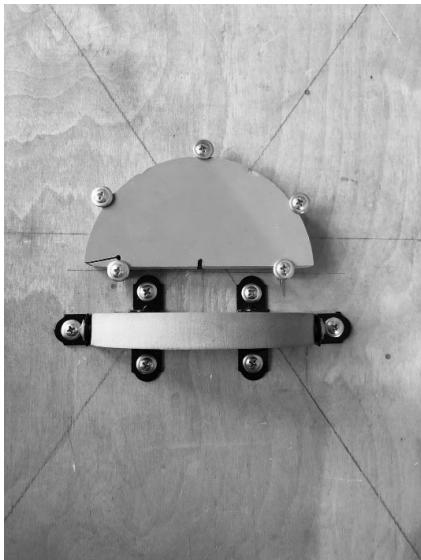


Fig. 4. Illustrations of the analysed detail made of polymer material: (a) – before UJD

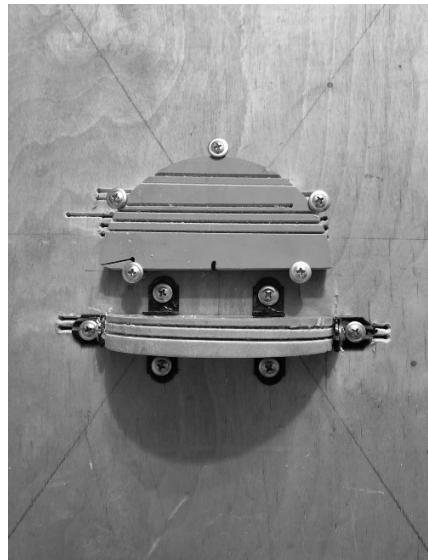


Fig. 5. Illustrations of the analysed detail made of polymer material: (a) – after UJD

The obtained results of experiments to determine the degree of influence of deviations during UJD are presented in Table 1.

Table 1
The experimental results to determine the degree of influence of UJD conditions

Scheme parameters	Parameter change level			Analyzed deviations parameters			Coefficients of influence deviations	
	max	mid	min					
$\alpha = \text{const} \left(\alpha = \alpha_0 = \frac{\pi}{2} \right)$ $\left(\alpha = \alpha_0 = \frac{\pi}{2} \right) L \rightarrow \text{var}$	L – UJ length, mm			δL , mm			$\xi_L \frac{\text{micron}}{\text{mm}}$	
	40	20	10	+20	0	-10		
	depth h , mm			δh , micron				
	4,85	4,90	4,92	-50	0	+20	-2,25	
$L = \text{const}$ $(L_0 = 20 \text{ mm})\alpha \rightarrow \text{var}$	α — angle of UJ slope, degree			$\delta\alpha$, degree			$\chi, \xi_\alpha \frac{\text{micron}}{\text{degree}}$	
	90	80	70	0	-10	-20		
	Depth h , mm			δh , micron				
	4,90	4,92	4,93	0	+20	+30	-1,75	

Table 2 shows the results of comparison for direct experiments with calculated values for different levels of change in L and α .

The precision was determined by the ratio of the difference between the calculated and experimental values of h , referred to the experimental depth of the hydrocavern.

Table 2
Comparison of experimental and calculated values of depth of the hydro-cavern

No.	Cavern's depth, mm	Angle ϕ for hydrocavern depth measurement h , mm						
		-15	-10	-5	0	+5	+10	+15
1	Experiment	3,86	4,02	4,58	4,92	4,15	3,80	3,48
2	Calculation	2,46	3,14	4,28	4,91	4,3	3,18	2,51
3	Precision, %	36	28	2,4	0,2	3,6	16	28

Discussion

Analysing the results in table 2, it's obvious that the zone close to the ϕ angle's value of 90° has the smallest precision. As the ϕ angle increases, the information content begins to decrease. This is due to the fact that when angle ϕ changes, the deviation of the distance between the jet head and the diagnostic surface also greatly increases. In the future research, it is planned to introduce additional coefficients to increase the effectiveness of the UJD for complex-shaped products with a strong curvature.

Conclusion

Thus, the experimental approbation of the proposed technique allows to reasonably assert that the analysis of the functional non-stationarity of the UJD process itself significantly expands not only the technological, but also the information capabilities of this research and control technique of quality indicators for various materials. Therefore, the full-scale implementation of this problem-promising approach significantly complements the innovative and technical potential of UJD as a way to quickly obtain the necessary information about the physical and technological parameters for the state of the surface layer of the objects at almost all stages of their life cycle.

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Машиностроение

Mechanical Engineering

УДК 629.7.015.3

История развития и основные принципы вихревых методов

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Рассмотрены вихревые методы вычислительной гидродинамики. Кратко изложен процесс развития и разветвления вихревых методов как от зарождения в работах Н.Е. Жуковского и С.М. Белоцерковского до наших дней. Приведены основные достоинства и недостатки вихревых методов по сравнению с широко используемыми в настоящее время сеточными методами. Кратко приведена информация об алгоритме реализации двумерного панельного метода и трехмерного метода замкнутых вихревых рамок. Представлены и проанализированы результаты написания программного обеспечения в соответствии с описанными алгоритмами.

Ключевые слова: вихревые методы, малый спускаемый аппарат, авторотация, парашютная система, Python

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Evolution and Basic Principles of Vortex Methods

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In this article the vortex methods of computational fluid dynamics are considered. The history and evolution of vortex methods is briefly described from its origin in the works of N.E. Zhukovsky and S.M. Belotserkovsky to the present day. The main advantages and disadvantages of vortex methods in comparison to conventional methods are presented. The algorithm for the implementation of the two-dimensional panel method and the three-dimensional vortex frame method are briefly described. The results of implementing the aforementioned algorithms in software are presented and analyzed.

Keywords: *vortex methods, small lander vehicle, autorotation, parachute system, Python*

Nowadays there is a tendency to conduct scientific and technical research on the basis of orbital complexes, spacecraft, individual scientific modules and laboratories. Development in this direction depends on the successful performance of many biological and physical experiments in microgravity conditions and applications of the results in different areas of science and technology.

One of the approaches to solve the problem of returning small cargoes of different purposes from the Earth orbit is the use of small-sized capsule-type landers. In order to properly shape the design of a small descent vehicle (SDV), it is necessary to select its landing system in the initial stages of its design. Requirements imposed on the landing system are defined by the tasks and size of the return vehicle. The problem is that such calculations for small vehicles have not been widely performed.

It is also worth mentioning the fact that calculations with the help of conventional fluid dynamics numerical methods for problems often can't provide any conclusions within the design stage, and the high machine time consumption makes this approach unfeasible.

One probable solution may be the formation of a mathematical model and software built on less demanding computational gridless methods, in particular, vortex methods, followed by evaluation and validation of the results using experimental data and computational experiments [1, 2].

Vortex methods modelling capabilities (throughout all methods) include:

- one-phase isothermal incompressible flows (some programs mentioned in [3] can also predict aerodynamic characteristics of bodies in supersonic, i.e. compressible flows);
 - inviscid/Viscous (through stochastic or deterministic “viscous speed”) flows;
 - linear (most methods) to quadratic (some cases for T-model [4]) accuracy gain.

Being gridless, vortex methods usually require user to model the surface of the scoped body and its vortex trail shed from the body. As such, vortex methods have the following advantages:

- ease of forming a calculation scheme and writing a program;
- low cost of computational resources;
- growing popularity in new software packages, a lot of algorithms were programmed and verified in the 20th century.

However, relative efficiency comes at a cost. Because of their structure vortex methods are best at solving one-phase isothermal incompressible flows (viscous or inviscid). Usually vortex methods' disadvantages are:

- limited use without additional modifications;

- low order of accuracy in basic methods. (Usually, you get two times more accurate solution with using twice the elements.)

Vortex methods are quite vast. The name «vortex methods» has become a term for methods where modelling flow around a body is achieved by replacing the real surface of the body with a system of vortices. Because of their diversity, these methods do not lend themselves to a precise classification, but rather represent a set of approaches and techniques for describing particular flow phenomena.

Historically the origin of vortex methods can be traced to research papers of famous Russian scientist Nikolay Yegorovich Zhukovsky. His pioneering vision on the theory of wing lift and propeller thrust was published in 1905 in an article called “On attached vortices”. In the paper he established the possibility of replacing the aerodynamic profile with a system of vortices. This system of vortices has the same effect on the flow of the medium as the profile, thus establishing the inherent vortex nature of lift.

The first implementations and modifications of vortex methods appeared as early as the 1950s, almost simultaneously with the appearance of a computer. N.E. Zhukovsky, S.A. Chaplygin, L. Prandtl, M.V. Kutta, and a large number of domestic and foreign scientists made invaluable contributions to the theory behind vortex methods [4].

S.M. Belotserkovsky is considered to be the founder of the Soviet and Russian scientific school of vortex methods as a branch of computational aerohydrodynamics. In the 1950s he developed the method of discrete vortices for solving aerodynamics problems, which is based on reducing the problem of calculating the flow around a contour or surface to the solution of the singular boundary integral equation [5]. He and his students have developed numerous modifications of the method of discrete vortices and closed vortex frames. Methods proposed by Belotserkovsky were gridless purely Lagrangian methods of modeling plane and spatial flows. The Lagrangian character of vortex methods is determined by the fundamental properties of the vorticity field, which were established by Helmholtz [4]. Lagrangian character of a method means that vortex lines are essentially “embedded” in an ideal incompressible medium. The introduction of these methods into the practice of calculations made it possible to solve the problems of calculating the characteristics of new types of aircraft and new structures, for example, the lattice wing.

In their initial formulation, the solutions provided by the vortex methods did not take into account viscosity of the flow. The first theory that described the process of vorticity diffusion in a viscous fluid was proposed in 1970s in works of A.J. Chorin [6]. A so-called “random walks” method is based on the possibility of describing the viscous flow with the help of probabilistic models. Then, in 1991 a deterministic (instead of a probabilistic) method was proposed to account for flow viscosity. It was called the diffusion velocity method by its inventors, Y. Ogami and T. Akamatsu.

The viscous medium model was further developed in the viscous vortex domain (VVD) method, first published in 2004. It proved to be a very effective tool for a wide class of problems, including the coupled flow problems. Since 2010 up to nowadays in the papers of A.V. Setukha, G.A. Scheglov, I.K. Marchevsky, S.A. Dergachev the methods of isolated vortex elements (vortex segments and vortex loops) have been actively developed.

Let us consider the steps taken in the basic versions of the vortex methods to obtain the solution of the flow around the profile with a non-viscous flow. There are several components to any vortex method:

- the discretization schemes. The surface of the body is divided into regions that vortex elements in some form — points, lines, frames, rings, or distributed over the surface;
- equations denoting the contribution of velocities to flow formation. Every region formed during discretization step contributes to resulting velocity of the flow;

- Boundary conditions on the streamlined surface. Usually, these conditions take two forms depending on the formulation. For inviscid flow Neumann or Dirichlet conditions are used. They denote that either normal velocity on the surface of the panel or velocity potential inside the body (for closed bodies problem) are zero. For viscous flow a no-slip condition is applied, denoting that velocity on the region surface is zero.

- a method to resolve the resulting system of equation to obtain the vortex intensity;
- a method for updating the vorticity in the flow area.

In order to verify the algorithms and methods given in this article, two programs were written to calculate two-dimensional and three-dimensional flow characteristics in Python. The three-dimensional flow calculation program is written with object-oriented programming (OOP), and includes a breakdown into classes represented by the geometry hierarchy (node, panel, mesh, panel set), methods applicable to panels and panel meshes, and separate child classes for dealing with vortex traces.

For two-dimensional steady-state flow the capabilities of standard libraries were mainly used, for calculating three-dimensional fairings the matrix multiplication algorithms provided as part of the Numpy module were used. Using certain syntactic constructions for matrix multiplication calculations in the package Numpy allows to carry out fast matrix multiplication with calls of functions from C++ and implementation of multithreading that has significantly reduced the time of matrix calculation (approximately by 900 times in comparison using of double loop for iteration over panels).

Visualization in two-dimensional case was performed using library Matplotlib for Python, for three-dimensional streamline mode PyVista was used.

In addition, the values of lifting force coefficients obtained as a result of the algorithm were validated. The results of plotting the change in the coefficient depending on the angle of attack are shown in Fig. 1. The experimental data for the analysis were taken from [7].

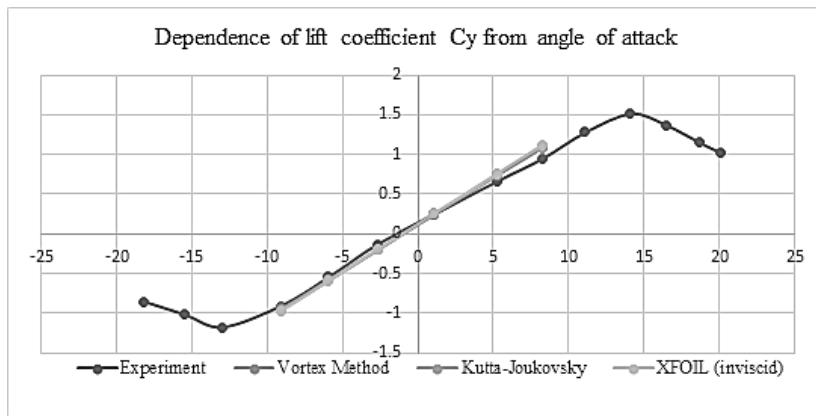


Fig. 1. Graph that shows the dependence for lift coefficient from attack angle

For the three-dimensional flow problem, the results were obtained in qualitative agreement with the results of [8]. An example of the flow pattern at an angle of attack of 30 degrees (without taking into account the vortex shedding from the leading edge) is shown in Fig. 2. Symmetric coagulation of vortices at the wing ends is observed, which corresponds to the flow patterns obtained in [5].

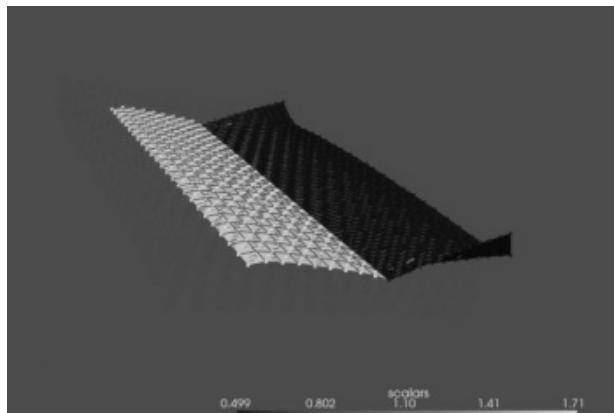


Fig. 2. Visualization of vortex trail behind the profile

To summarize, possible use of vortex methods for estimating aeroballistic and strength characteristics of aerodynamic configurations can significantly reduce the calculation time for simulating the flow around the bodies in comparison with the grid methods, which are widely used today. Nevertheless, vortex methods need to be properly incorporated into the design process: their limitations are to be disentangled. Moreover, their consistency with experimental data and sometimes methods themselves are to be verified.

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УДК 629.78

Управление движением спускаемым аппаратом

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Исследовано угловое движение спускаемого аппарата с надувным тормозным устройством, которое возникает при управлении его движением. Управление движением осуществляется методом смещения центра масс. Составлена математическая модель углового движения спускаемого аппарата. Решения уравнений математической модели выполнено методом Рунге — Кутта. По результатам моделирования сделан вывод о возможности управления рассмотренным методом.

Ключевые слова: спускаемый аппарат, управление движением, математическая модель, надувное тормозное устройство

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Descent Vehicle Movement Control

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The paper investigates the angular motion of a descent vehicle with an inflatable aeroshell, which occurs when controlling its motion. Motion control is carried out by the method of shifting the center of mass. A mathematical model of the angular motion of the descent vehicle has been compiled. The equations of the mathematical model are solved by the Runge-Kutta method. Based on the simulation results, a conclusion was made about the possibility of controlling the considered method.

Keywords: descent vehicle, inflatable aeroshell, mathematical model, movement control

Introduction

The Earth atmosphere makes the space flight challenging. The spacecraft launching is part of the space flight. Spacecraft reentry is a difficult objective. All kinetic and potential energy must be dissipated during the spacecraft landing. The movement of the descent vehicle in the atmosphere releases a large amount of heat. For the first time the problem of reentry was discussed by the Soviet and American scientists. In the Soviet Union, this problem was analyzed by the team headed by Konstantin Petrovich Feoktistov (Fig. 1). In America, the task of reentry was analyzed by the team of Wernher von Braun(Fig. 2).



Fig. 1. Feoktistov Konstantin Petrovich



Fig. 2. Wernher von Braun

The warhead design for ballistic missile was preceded by the development of a descent vehicle. The flight conditions of the warhead and the descent vehicle are similar. In the space race, a ready-made solution was used. Thus, the trajectory of the first descent vehicles was ballistic. The shape of the first descent vehicles(Fig. 3 and Fig. 4.) is explained by their trajectory.

At the moment, the descent vehicles equipped with inflatable aeroshells is a promising technology for reentry. Inflatable aeroshells offer several advantages over traditional rigid aeroshells for atmospheric entry [1, 2]. Inflatables offer the increased payload volume fraction under the launch vehicle shroud. This results in the ability to deliver more payload mass to the surface at the equivalent trajectory constraints. The inflatable's diameter is not limited by the launch vehicle shroud. The resultant larger drag area can provide deceleration equivalent to a rigid system at higher atmospheric altitudes, thus offering access to the mountain landing sites. When stowed for launch and cruise, the inflatable aeroshells allow access to the payload and offer direct access to the vehicle structure for the launch vehicle integration. They also give the opportunity to eliminate extra systems between the cruise stage and the reentry vehicle.

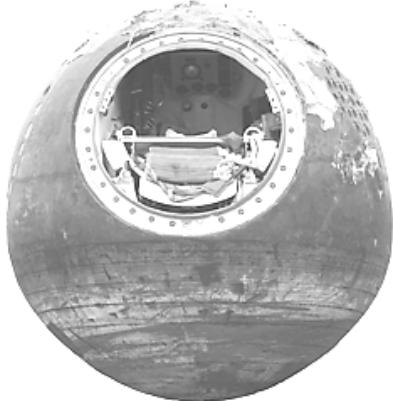


Fig. 3. The first soviet descent vehicle
(April 20, 1961)

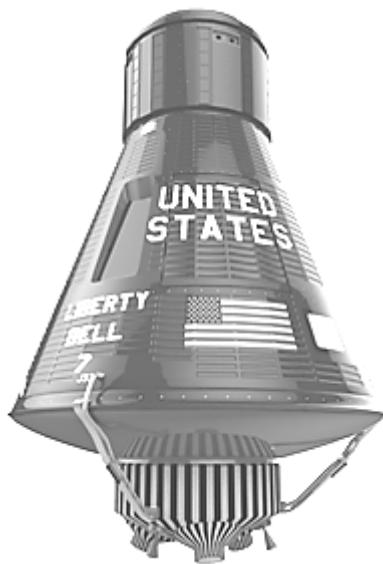


Fig. 4. The first american descent vehicle
(May 5, 1961)

There are engineering challenges for inflatable aeroshells. The aeroshell is flexible. This flexibility could result in unpredictable drag performance or to the aerostructural dynamic instability. In addition, durability of large inflatable structures may limit their application. They are susceptible to catastrophic puncture. Finally heating during planetary entry is a significant challenge to a thin membrane.

Problem of statement

Unpredictable drag performance and aerostructural dynamic instability could lead to the structural collapse of the descent vehicle and result in trajectory error. Thus the descent vehicle control would prevent the structural collapse of the descent vehicle and the trajectory error. Descent vehicle movement control is carried out by shifting the center of mass. The descent vehicle under investigation consist of three parts: 1 — inflatable decelerator; 2 — spacecraft; 3 — pivot mechanism (Fig. 5). The change in the position of the center of mass perform as follows: the pivot mechanism rotates the spacecraft (payload) relative to their connection point. Such a rotation of the payload leads to a shift in the center of mass of the descent vehicle relative to its initial position. The displacement of the center of mass leads to the rotation of the descent vehicle at a certain angle relative to the oncoming flow vector. After that, forces arise perpendicular to the direction of motion of the descent vehicle. Due to these forces, the movement of the descent vehicle is controlled [3].

Methods

Structural integrity and structural response of the inflatable aeroshells can be verified by flight tests. Aerodynamic stability as well as drag performance are verified with an on

board inertial measurements and ground radar tracking. Aerodynamic and trajectory modeling should be validated during the flight tests. The mathematical model was applied to trajectory simulation. The mathematical model based on the transformation matrix is intended to calculate the aircraft position according to the predetermined trajectory. Comparison of the modeled trajectory and the actual flight trajectory would provide the evaluation of the modeling inaccuracies.

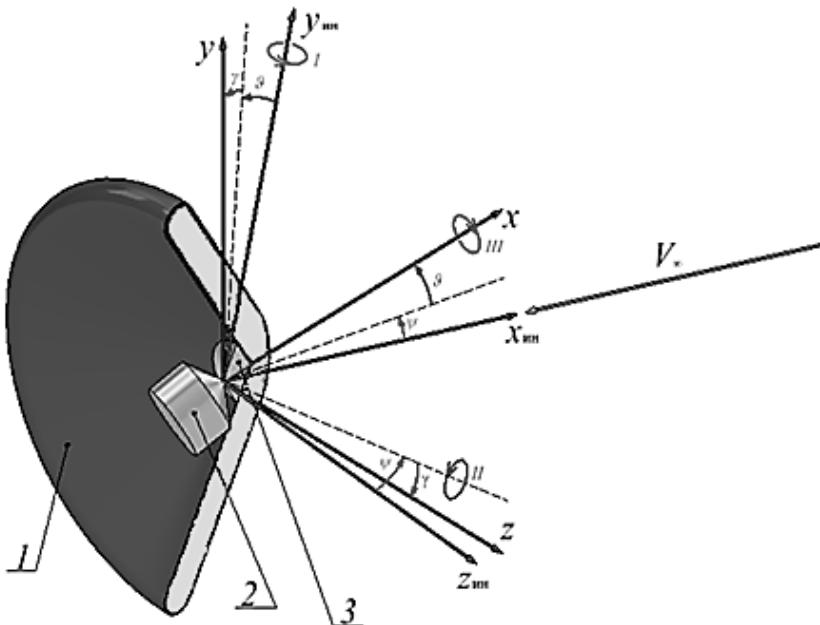


Fig. 5. A scheme of the descent vehicle under consideration
and the location of the coordinate systems:
1 — inflatable decelerator; 2 — spacecraft; 3 — pivot mechanism

Research algorithm

The following kinematic schemes were used to conduct theoretical research. The mathematical model of descent vehicle movement is compiled according to the above diagram (Fig. 5). The mathematical model is based on the following coordinate systems:

- inertial coordinate system;
- coordinate system connected with the descent vehicle;
- coordinate system connected with the payload;
- coordinate system connected with the oncoming flow vector.

The descent vehicle characteristics

The descent vehicle under investigation has the next mass characteristics:

- the total mass of the descent vehicle is 700 kilograms

- the spacecraft mass is 300 kilograms

The size characteristics of the descent vehicle are shown in Fig. 6.

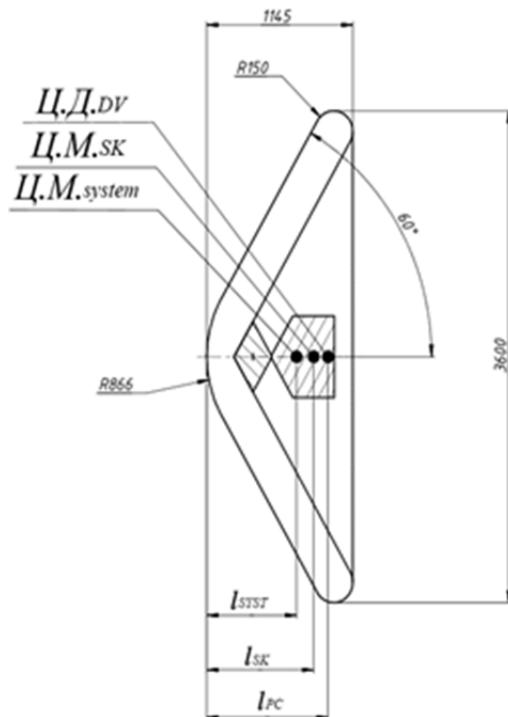


Fig. 6. Sectional view of descent vehicle

Mathematical model

The equations of mathematical model are:

$$\begin{cases} \frac{d\bar{K}}{dt} + \bar{\omega} \times \bar{K} = \bar{M} \\ \frac{dA}{dt} = \Omega \cdot A \end{cases}$$

• the first equation of mathematical model is based on the equation conservation kinematic momentum;

• the second equation is kinematic Poisson equation

$\bar{K} = J \cdot \bar{\omega}$ — kinematic momentum

J — inertia tensor of the descent vehicle

$\bar{\omega}$ — angular-velocity vector

$$\Omega = \begin{pmatrix} 0 & \omega_z & -\omega_y \\ -\omega_z & 0 & \omega_x \\ \omega_y & -\omega_x & 0 \end{pmatrix} \text{— attitude rate matrix}$$

A — direction cosine matrix

The solution of these equations is carried out by the Runge-Kutta method.

Preliminary research results

The results of the simulation are presented in the form of graphical dependencies (Fig. 7 and Fig. 8). These diagrams display the change in the position of descent vehicle during movement, as well as the changes in the angular velocity with time. The preliminary simulation results demonstrate that the motion of the descent vehicle is stable [4]. The theoretical calculation allows us to conclude that the control method under consideration is applicable in practice. To validate the theoretical calculations, it is necessary to conduct an experimental study.

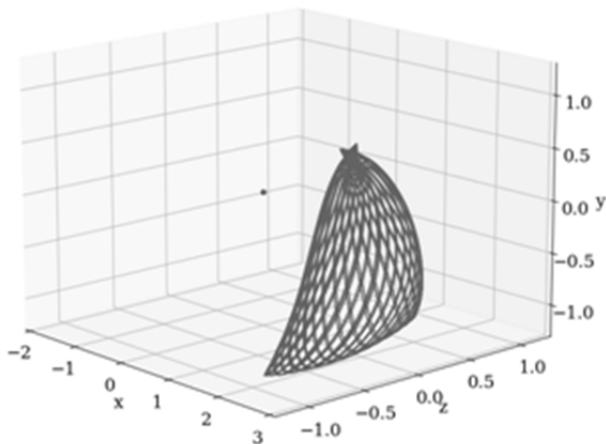


Fig. 7. The position change of the point descent vehicle during movement

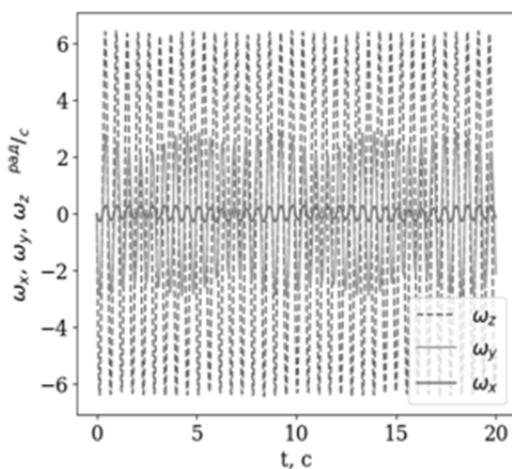


Fig. 8. Angular velocity change with time

Conclusion

The object of research is the descent vehicle with inflatable aeroshell. The descent vehicle control is the subject of research.

The descent vehicle with inflatable aeroshell has some advantages over the rigid braking devices. However, the inflatable braking devices also have disadvantages as they are flexible. To compensate disadvantages, a method for controlling the descent vehicles, is proposed. The preliminary results showed that the controlled motion of the descent vehicle is stable. Preliminary results have shown that the considered control method is applicable in practice with the condition of having a stabilization system too.

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Применение композиционных материалов в силовых элементах адаптивного крыла

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Рассмотрены методы изготовления силовых элементов адаптивного крыла из композиционных материалов, а также различные принципы изменения конфигурации адаптивного крыла. Приведено сравнение аэродинамических характеристик крыла с адаптивным профилем и крыла с традиционной механизацией. Приведено также сравнение характеристик полимерных композиционных материалов и металлических сплавов с памятью формы.

Ключевые слова: адаптивное крыло, композиционные материалы, мультистабильные материалы, морфинг, бистабильные ламинаты, аэродинамика адаптивного крыла, память формы

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Anwendung von Verbundwerkstoffen in Kraftelementen des adaptiven Fl^{ALS}gels

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Der Artikel untersucht die Verfahren zur Herstellung von Kraftelementen des adaptiven Flügels aus Verbundwerkstoffen sowie verschiedene Prinzipien zur Änderung der Konfiguration des adaptiven Flügels. Es wird ein Vergleich zwischen Legierungen und Formgedächtnisverbundwerkstoffen durchgeführt. Es wird ein Vergleich der aerodynamischen Eigenschaften des adaptiven Flügels und des Flügels mit der traditionellen Mechanisierung durchgeführt.

Keywords: adaptiver Flügel, Verbundwerkstoffen, multistabile Materialien, Formgedächtnis, aerodynamik des adaptiven Flügels

EINLEITUNG

Die Mechanisierung des Flügels, die viele Vorrichtungen wie Klappen, Vorflügel, Spoiler, Querruder, Scharniere und Führungsschienen umfasst, ermöglicht es, den Auftrieb und den Widerstand des Flugzeugflügels zu ändern. Gleichzeitig entstehen im Betrieb dieser Anlagen die Lücken, die die aerodynamischen Eigenschaften des Flügels verschlechtern. Außerdem haben diese Anlagen eine erhebliche Masse.

Als Alternative zu einem Flügel mit traditioneller Mechanisierung kann ein integraler adaptiver Flügel mit einer sich je nach Flugmodus ändernden Profilform eingesetzt werden. Die Verwendung eines adaptiven Flügels wird es ermöglichen, viele Vorrichtungen loszuwerden, die Auftrieb und Luftwiderstand ändern, wodurch die Masse und die Wahrscheinlichkeit eines Flügelversagens verringert werden. Das ermöglicht auch, Lücken zu beseitigen, die die aerodynamischen Eigenschaften des Flügels deutlich reduzieren.

Ein effizienter Flug in der Atmosphäre erfordert je nach Fluggeschwindigkeit und Flugmodus eine unterschiedliche Aerodynamik der Anlage. Die klassische Herangehensweise an die Projektierung neuer Flugzeuge erlaubt derzeit nur eine geringfügige (nicht mehr als 1-2%) Verbesserung der aerodynamischen Qualität und eine Verbesserung der Start- und Landeeigenschaften. Die Mechanisierung des Flügels in Form von einfachen ablenkbaren Nasen und Schwangen des Profils oder einer Änderung der Pfeilung erlaubt es nicht, hohe Werte des maximalen Auftriebskoeffizienten unter wechselnden Betriebsbedingungen zu erhalten.

Daher wird in den letzten Jahren im Zusammenhang mit der Entwicklung der technischen Basis und dem Entstehen neuer Luftfahrtmaterialien immer mehr Aufmerksamkeit der Möglichkeit geschenkt, die aerodynamischen Eigenschaften des Flugzeugs zu verbessern, indem die Geometrie des Flügels im Flugmodus geändert wird, das bedeutet die Verwendung eines adaptiven Flügels.

Die Verwendung von Verbundwerkstoffen bei der Konstruktion der tragenden Elemente des adaptiven Flügels wird ihn auch leichter machen. Die Eigenschaften von Verbundwerkstoffen lassen das Konzept eines adaptiven Flügels umsetzen.

Ein Problem für viele Arten von Verbundwerkstoffprodukten ist die geringe Automatisierung ihrer Produktion oder ihre völlige Abwesenheit. Darüber hinaus gibt es für die meisten Arten der Herstellung von Verbundwerkstoffprodukten keine Möglichkeit, optimierte Konstruktionen herzustellen. Auch Produkte aus Verbundwerkstoffen, die mit herkömmlichen Herstellungsverfahren produziert werden, verlieren häufig ihre mechanischen Eigenschaften neben den Bohrungen, die durch verschiedene Bearbeitungstypen hergestellt wurden, wegen einer Beschädigung des Armierungsmaterials. Diese Nachteile können durch den als Produktionsverfahren benutzten 3D-Druck eines mit kontinuierlichen Kohlenstofffasern verstärkten Verbundmaterials ausgeglichen werden.

Die Herstellung von mit Kohlenstoff-Endlosfasern verstärkten Verbundstrukturen mittels additiver Technologien eröffnet neue Möglichkeiten zur automatisierten und kostengünstigen Herstellung hochbelasteter Konstruktionen. Dies wird durch eine große Freiheit im Projektionsprozess erreicht, wodurch die Anordnung der Fasern angepasst werden kann und so die Anisotropie und Festigkeit des Verbundmaterials voll ausgenutzt werden.

Einen Beitrag zur Untersuchung adaptiver Strukturen leisteten I. K.-V. Kuder, U. Fasel, D. Keidel, L. Baumann, B. Vermes, T. Czigany, W. Hufenbach, M. Gude, L. Kroll, E. R. Abrahamson, M.S. See, N.A. Munshi. I.K.-V. Kuder, U. Fasel, D. Keidel, L. Baumann führten eine Erforschung zu adaptiven Strukturen im Kontext ihrer Anwendung in Flugkörpern durch. U. Fasel, D. Keidel, L. Baumann demonstrierten auch die Vorteile des Einsatzes von 3D-Druck in der Produktion von tragenden Elementen eines adaptiven Flügels. Zi Kan, Daochun Li, T. Shen untersuchten die Verbesserung der aerodynamischen Eigenschaften eines adaptiven Flügels im Vergleich zu einem herkömmlichen Flügel.

Das Anisoprint-Team leistete einen großen Beitrag zur Erforschung des 3D-Drucks von Verbundwerkstoffen und seiner Anwendung in der Praxis. Also in der Arbeit von A.V. Azarov (et al.) [1] werden der Herstellungsprozess eines Quadrocopter-Rahmenmusters

unter Verwendung von Composite-3D-Druck sowie das Testen des fertigen Produkts beschrieben. Gleichzeitig wurden die Tests mit dem resultierenden Produkt durchgeführt, die zeigten, dass es Belastungen von bis zu 30 kg ohne Anzeichen von Zerstörung oder Delaminierung des Materials bestehen kann. Mark G.T., Gozdz A.S. untersuchten auch die Technologie des 3D-Drucks eines Verbundmaterials.

WERKSTOFFE UND VERFAHREN

Prinzipien zum Ändern der Konfiguration eines adaptiven Flügels. Verschiedene Konzepte adaptiver Konstruktionen wurden in [2]–[15] betrachtet. Adaptive Mechanismen in solchen Konstruktionen werden ausführlich in [16]–[18] untersucht.

Es gibt mehrere Prinzipien zum Ändern des Profils eines adaptiven Flügels. Das ist der Einsatz von adaptiven Werkstoffen, speziellen Mechanismen, semiaktiven Verfahren und multistabilen Werkstoffen. Durch die Verwendung spezieller adaptiver Materialien kann man die Konfiguration der Struktur gezielt ändern.

Die Formgedächtniswerkstoffe sind somit von Bedeutung.

Sehr viele Forschungsarbeiten sind Werkstoffen gewidmet wie verschiedenen Legierungen, Keramiken und Polymeren, bei denen die Formgedächtniserscheinung beobachtet werden kann. Beispielsweise wurde die Erscheinung des Formgedächtnisses in [19] untersucht. Im Zusammenhang mit der Verwendung spezieller Materialien im Aufbau von tragenden Elementen eines adaptiven Flügels sind Formgedächtnispolymeren aufgrund ihrer erheblichen reversiblen Verformungsfähigkeit am interessantesten in Kombination mit der Möglichkeit einer zusätzlichen Verbesserung ihrer Eigenschaften durch Armieren und demzufolge der Bildung von Verbundwerkstoffen mit Formgedächtnis oder mit sogenannter Memory-Elastizität.

Durch den Vergleich von Legierungen und Polymeren mit dem Formgedächtnis hinsichtlich der Anwendbarkeit in adaptiven Konstruktionen können wir daraus schließen, dass die Polymere die mechanischen Eigenschaften der Legierungen übertreffen, da sie eine geringere Dichte, größere reversible Verformungen und eine bessere Anpassung der thermomechanischen Eigenschaften an einzelne Bedingungen aufweisen. Auch Polymerkonstruktionen sind in der Herstellung wirtschaftlicher, und die Bemühungen, sie zu betätigen, sind im Vergleich zu legierten Konstruktionen um eine Größenordnung geringer. Andererseits ist die Gefahr einer Beschädigung von Polymerkonstruktionen im Mikroskala bei unzureichender Betriebstemperatur und damit die Risiken einer Verringerung ihrer Zuverlässigkeit und Haltbarkeit zu berücksichtigen.

Wenn Polymere separat verwendet werden, haben die daraus resultierenden Konstruktionen ein signifikantes reversibles Verformungspotenzial von bis zu 200%. Die Polymere weisen jedoch eine Reihe von Nachteilen auf, z. B. eine hohe Temperaturrempfindlichkeit, wodurch die Konfiguration der adaptiven Projektierung, die geringe Steifigkeit bei erhöhten Temperaturen und der hohe Wert des linearen thermischen Ausdehnungskoeffizienten schwierig zu steuern sind.

Eine Verbesserung der Steifigkeit kann durch die Verwendung von Armierung erreicht werden, was zu einer 10-fachen Verringerung der reversiblen Verformung führt. Um diese Einschränkungen zu beseitigen, wurden Kompositionsmaterialien auf der Basis von Formgedächtnispolymeren entwickelt, die Formgedächtnispolymeren oder Elastizitätsgedächtnispolymeren genannt werden. Solche Werkstoffe ermöglichen es, eine ausreichende Steifigkeit mit einer kontrollierten hohen Verformungsfähigkeit zu kombinieren.

Man geht davon aus, dass der Begriff Verbundwerkstoff mit Gedächtnis der Elastizität mit der Verwendung einer duroplastischen Matrix verbunden ist, da sie dem Verbund bessere mechanische Eigenschaften, Haltbarkeit und Verarbeitbarkeit bietet.

Bei Experimenten mit dem duroplastischen Harz CTD-DP-5.1 fanden Abrahamson et al. heraus, dass der Effekt des Formgedächtnisses nicht nur im Standardprozess der Temperaturbelastung, sondern auch durch die Anwendung außergewöhnlich hoher mechanischer Belastungen verursacht werden kann, ohne dass eine Erwärmung erforderlich ist. Diese Tatsache zeigt, dass Verbundwerkstoffe mit einem Gedächtnis der Elastizität bei der Auswahl eines Werkstoffs für die Kraftstrukturen des adaptiven Flügels berücksichtigt werden sollten.

Das traditionelle Verfahren zum Ändern der Konfiguration eines Flügels besteht darin, Vorrichtungen zu verwenden, die auf Mechanismen mit separaten Steuerflächen basieren, wie z. B. Klappen, Vorflügel, Spoiler und Querruder. Variabler Flügelschwung ist auch ein ähnliches Verfahren. Aber die Nachteile solcher Systeme sind eine große Masse, eine erhebliche Anzahl von Teilen und ein erhöhter Konstruktionsaufwand.

Semiaktive Verfahren beinhalten die Verwendung von Elektrizität, um die Steifigkeit von Leistungselementen zu ändern, indem Elektroden in sie eingeführt und piezoelektrische Werkstoffe verwendet werden. Das Forschungsvolumen auf diesem Gebiet ist jedoch gering, was es nicht erlaubt, Vorhersagen über die notwendige Genauigkeit zu treffen, um die Realisierbarkeit der Anwendung dieser Technologien für die Kraftelemente eines adaptiven Flügels zu beurteilen.

Unter den multistabilen Werkstoffen sind die sogenannten bistabilen (zweistabilen) Lamine gesondert zu betrachten.

Ein bistabiles oder multistabiles Laminat ist eine Art Verbundstruktur, die viele stabile statische Konfigurationen aufweist. Das Vorhandensein einer Vielzahl von Konfigurationen mit stabilem Gleichgewicht macht bistabile Lamine zu äußerst attraktiven Mitteln für adaptive Flügel. Asymmetrische Verbundlamine weisen nach dem Aushärten bei erhöhter Temperatur zwei stabile Konfigurationen bei Raumtemperatur auf. Die Bistabilität von mehrschichtigen Laminaten mit Querschichten ist auf das Vorhandensein von Restverformungen zurückzuführen, die während des Aushärtungsprozesses auftreten. Der Verlust der Stabilität kann der Grund für den Übergang von einer stabilen Form zur anderen sein. Die Kraft, die benötigt wird, um eine andere stabile Form zu erreichen, hängt von der Gesamtverformungsenergie des Laminats in der ursprünglichen ausgehärterten Form ab. Durch die Auswahl der Energieniveaus von stabilen Formen, z. B. quadratischen Laminaten, kann die Kraft, die benötigt wird, um eine andere stabile Form zu erreichen, und die Rückkehrskraft variiert werden.

Verwendung von additiven Technologien bei der Herstellung von Kraftelementen des adaptiven Flügels. Die neuesten Entwicklungen in der additiven Herstellung von Verbundwerkstoffen, die mit kontinuierlicher Kohlefaser armiert sind, ermöglichen die Automatisierung des Herstellungsprozesses und die Herstellung sehr komplexer Verbundteile ohne spezielle Formen. Im Vergleich zur automatisierten Faserauslegung mit begrenzter maximaler Kabelkrümmung oder modernen, manuellen Prozessen können mit additiven Technologien komplexere geometrische Formen zu geringeren Kosten realisiert werden. Die erste Berechnung der Kosten für durchgehende faserverstärkte Verbundteile, die durch eine additive Methode hergestellt werden, setzt eine mögliche Reduzierung der Produktionskosten unter Verwendung der vorgestellten 3D-Drucktechnologie um das Zehnfache voraus.

Aerodynamik des adaptiven Flügels. In [20] Z. Kan (et al.) wurde die aerodynamische Berechnung des adaptiven Flügels durchgeführt und die erhaltenen aerodynamischen Eigenschaften mit den aerodynamischen Eigenschaften eines herkömmlichen Flügels verglichen. Für die numerische Modellierung wurde ein zweidimensionales NACA 0012-Profil mit einer flexiblen Vorderkante verwendet. Die Form der Verformung ist parabolisch, und der verformbare Bereich befindet sich im vorderen Viertel der Sehne des Profils. Eine einfache, starre Vorderkante und eine flexible Vorderkante sind auf Abbildung 1 dargestellt. Der Winkel der Abweichung der Vorderkante γ wird als der Winkel zwischen der Sehnenlinie und der Linie von der Abweichungsachse zur Vorderkante definiert, wobei die Richtung nach unten positiv ist. Der Anstellwinkel α ist definiert als der Winkel zwischen der Sehnenlinie und der Strömungsgeschwindigkeitsrichtung.

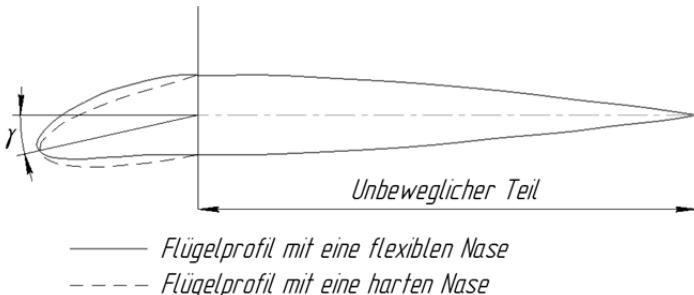


BILD 1. NACA-Flügelprofil 0012 mit normaler harten Nase und flexibler Nase

Die von Reynolds gemittelte Navier-Stokes-Gleichung mit dem Spalart-Allmaras-Turbulenzmodell wurde verwendet, um die aerodynamischen Eigenschaften der adaptiven Flügel zu modellieren. Die Grenze des Rechenbereichs wurde als Druckfeld festgelegt, und das Profil wurde als gleitfreie statische Wand festgelegt. Das Raster wurde mit der lokalen Zellenumlagerung und der federbasierten Glättungsmethode aktualisiert, da sich die Vorderkante mit großer Amplitude geändert hat. Um für dieses Verfahren anwendbar zu sein, wurden dreieckige Zelltypen angenommen, und das Gitter wurde in der Nähe des Profils verfeinert, um die Genauigkeit der Ergebnisse zu verbessern.

Die aerodynamischen Eigenschaften des adaptiven Flügels und die des normalen Flügels wurden numerisch untersucht. Die Machzahl und die Reynoldszahl des Flusses betrug jeweils 0,2 bzw. $4,6 \times 10^6$, und der Ablenkungswinkel γ betrug 16° .

ERGEBNISSE UND DISKUSSION

Auswahl des Werkstoffes für die Kraftelemente des adaptiven Flügels, deren Herstellungsverfahren. Adaptive oder sogenannte Morphingmechanismen, die die elastischen Eigenschaften des Werkstoffs verwenden, um die Form der Konstruktion zu verändern, zeigen ein großes Potenzial zur Verbesserung der Flugeigenschaften von Luft- und Raumfahrtkonstruktionen. Solche Konstruktionen haben eine komplexe interne Topologie, die sie für die Herstellung mit herkömmlichen Verfahren unerschwinglich teuer macht. Die Kombination von additiven Technologien zur Herstellung von Verbundwerkstoffen und Morphingmechanismen kann möglicherweise gleichzeitig die Produktionskosten senken und die Flugeigenschaften von Luft- und Raumfahrtkonstruktionen erheblich verbessern.

Daher sollten in weiteren Erforschungen Verbundwerkstoffe mit elastischem Speicher oder bistabile Laminate als Material für die Kraftelemente des adaptiven Flügels betrachtet werden.

Untersuchung der Aerodynamik des adaptiven Flügels. Bild 2(a) zeigt die Hebekraftkurven für normale und adaptive Flügel. Man kann sehen, dass die Steigung der Hubkraftkurve des adaptiven Flügels fast identisch mit der des normalen Flügels ist. Ein adaptiver Flügel hat einen höheren Hubkoeffizienten als ein normaler Flügel, insbesondere in der Nähe des kritischen Ablagewinkels. Darüber hinaus sind der Anstellwinkel und der maximale Hubkoeffizient des adaptiven Flügels größer als der eines normalen Flügels. Der maximale Hubkoeffizient eines adaptiven Flügels ist etwa 8% größer als der eines normalen Flügels.

Auf Bild 2(b) werden die Eigenschaften des Verhältnisses von Hubkraft zu Frontwiderstand (C_y/C_x) gezeigt. Das Verhältnis der Hebekraft zum Frontwiderstand der beiden Flügel erhöht sich zuerst auf das Maximum und nimmt dann ab, wenn der Anstellwinkel zunimmt. Der adaptive Flügel ist dem normalen Flügel in Bezug auf das Verhältnis von Hubkraft zu Frontwiderstand deutlich überlegen. Der adaptive Flügel erreicht ein maximales Verhältnis von Hubkraft zu Frontwiderstand — 75,2 bei $\alpha = 10^\circ$, was 10,3% mehr ist als bei einem normalen Flügel — 68,2 bei $\alpha = 12^\circ$. Darüber hinaus, wie auf Bild 2(b) dargestellt, zeigen die Drehmomentkoeffizientenkurven von etwa einem Viertel der Sehne, dass der adaptive Flügel einen niedrigeren Nasen-nach-Unten-Momentkoeffizienten aufweist als ein normaler Flügel, wodurch die Steueroberflächeneffizienz und die aerodynamischen Eigenschaften verbessert werden.

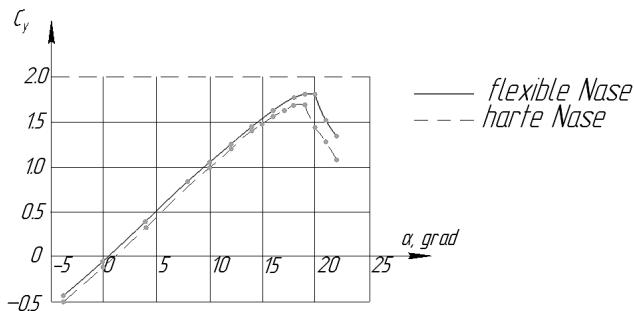


BILD 2a. Hebekraftkurven für Flügel mit einer flexiblen Nase und für Flügel mit einer harten Nase

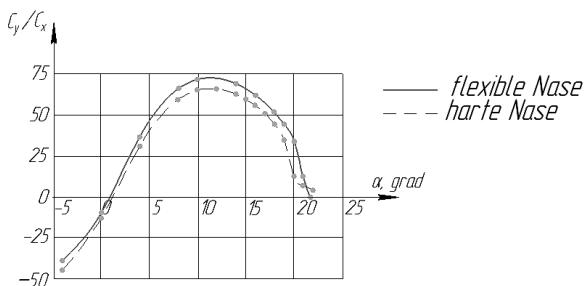


BILD 2b. Eigenschaften des Verhältnisses von Auftrieb zu Widerstand für Flügel mit einer flexiblen Nase und für Flügel mit einer harten Nase

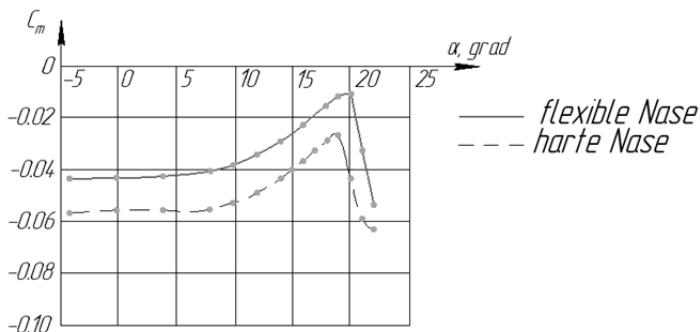


BILD 2c. Momentkoeffizientenkurven für Flügel mit einer flexiblen Nase und für Flügel mit einer harten Nase

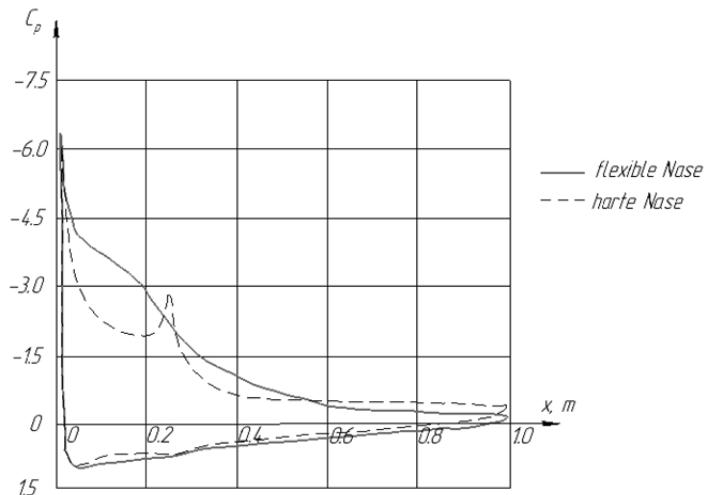


BILD 3. Druckkoeffizientenkurven auf Flügeloberflächen mit einer flexiblen Nase und auf Flügeloberflächen mit einer harten Nase beim Angriffswinkel $\alpha = 20^\circ$

SCHLUSS

1. Verbundwerkstoffe mit Gedächtnis der Elastizität oder bistabile Laminate sind die am besten für die Herstellung von Kraftelementen eines adaptiven Flügels geeigneten Werkstoffe.
2. Als ein Verfahren zur Herstellung von Kraftelementen eines adaptiven Flügels aus komplexen Topologien aus Verbundwerkstoffen sollte das Verfahren des dreidimensionalen Druckens eines mit kontinuierlicher Kohlefaser armierten Verbundmaterials in Betracht gezogen werden.
3. Der adaptive Flügel hat im Vergleich zu einem Flügel mit traditioneller Mechanisierung eine verbesserte aerodynamische Leistung.

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УДК 621.923.9

Сравнение используемых в аддитивном производстве технологий снижения шероховатости изделий из металлов и их сплавов, изготовленных с помощью селективного лазерного сплавления

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Рассмотрена повышенная шероховатость изделий как одна из ключевых проблем использования технологий послойного синтеза. Рассмотрены наиболее актуальные на сегодняшний день виды постобработки, которые активно внедряются в аддитивное производство. Проведен анализ и сделаны заключения о преимуществах и недостатках рассмотренных технологий снижения шероховатости, а также представлено их сравнение. Сделаны выводы о наиболее перспективных и эффективных способах постобработки.

Ключевые слова: аддитивные технологии, снижение шероховатости, селективное лазерное сплавление, постобработка, обработка резанием, абразивная обработка, галтовка, электрохимическая обработка, электролитно-плазменное полирование

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Comparison of Technologies Used in Additive Manufacturing to Reduce the Roughness of Metal and Alloy Products Made by the Selective Laser Melting

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The paper considers the high roughness of products as one of the main problems in the use of layer-by-layer synthesis technologies. The most relevant up-to-date types of processing actively implemented into additive manufacturing are considered. The article contains an analysis and conclusions on the advantages and disadvantages of the considered technologies for reducing roughness, as well as their comparison is given. The conclusions on the most promising and effective post-processing methods are made.

Keywords: additive technologies, roughness reduction, selective laser melting , post-processing, cutting, abrasive processing, tumbling, electrochemical processing, plasma electrolytic polishing

Introduction

Additive technologies (AT) are becoming an integral part of various areas of production: aircraft manufacturing, rocket and space industry [1–3], energy plants [4, 5], medicine [6, 7], jewelry production, and others. The main feature of AT is the method of forming an object by synthesis, and not by removing part of the material from the workpiece. Layer-by-layer synthesis is the main difference from casting welding and soldering. This feature allows creating objects of complex shape using AT.

One of the most popular technologies in additive manufacturing (AM) is a selective laser melting (SLM). The manufacturing process is based on the formation of an object from connected layers of powder particles fused by a laser beam. This method is quite universal, since it is applicable to a wide range of materials: metals, alloys, ceramics, plastics, rubbers. Modern SLM equipment is capable of creating products from several materials at once. This ability allows creating multilayer structures, such as bimetallic heat exchangers.

Despite the apparent superiority over other production technologies, SLM, like most AT, has a number of disadvantages: the high cost of equipment and consumables, low productivity, and high requirements for the qualifications of workers [8]. One of the main factors hindering the process of implemented AT into production is the high surface roughness [9, 10], which does not always allow the product to be put into operation because of the non-compliance of the product parameters with the technical requirements.

The roughness structure of objects synthesized using SLM has the dual nature. The first is the relief formed by the surfaces of particles randomly located in the sintered layer. The particles have different shapes and sizes (the characteristic size, as a rule, is in the range from 20 μm to 50 μm [11]). The second is the displacement of one layer relative to another that forms a stepped surface — the «step effect» [12], which is most common on surfaces that are placed at an angle to the desktop.

Polishing Technologies

The most common way to remove micro-roughness and reduce roughness is the use of cutting processing. This technological process is beneficial for its wide application, since there are practically no industries that do not use at least a lathe or milling machine. By adjusting the speed, direction of movement and the number of passes of a certain cutting tool, it is possible to bring the roughness of the product to Ra values of less than 0.05 μm . Despite these advantages, cutting processing in additive manufacturing is most often used only for finishing linear dimensions and removing supports, because due to the limitations of machine tools on the movement of the cutting tool, the shape of the machined object must be as primitive as possible (planes and surfaces formed by rotation). The dimensions of the cutting tool are also an obstacle for processing hard-to-reach surfaces: grooves, holes, channels, cavities.

AM often uses abrasive processing. The equipment for this is usually sold together with 3D printers. This is equipment for jet-abrasive treatment which process for reducing the roughness consists in the mechanical removal or deformation of irregularities with solid granules accelerated and transported to the place of treatment by a liquid or gaseous medium. This method has reduced restrictions on the shape of the product, since it is possible to process curved surfaces with its help. However, a sufficiently large abrasive grain size prevents a significant decrease in the overall roughness [13–15] and practically does not reduce the influence of the step effect [16]. As in case of cutting, abrasive blasting is applicable only to easily accessible surfaces, to which the flow of abrasive is able to reach unhindered.

Tumbling reduces roughness more effectively than abrasive blasting. The item is placed in a rolling stock containing abrasive granules. Tumbling can be categorized according to the way the filler moves relative to the product:

- rotary — the movement of the filler occurs due to the rotation of either the product or the filler;
- vibration — the movement of the filler occurs by vibratory bowl finishers.

Rotary finishing differs according to the type of equipment: a barrel, a centrifuge, a spinning spindle.

Each type has its own advantages and disadvantages, so the consistent use of certain tumbling methods is considered more advantageous. This technology compares favorably among all types of processing with its simple equipment and technological process, and

sufficiently high efficiency, which makes it possible to reduce the level of roughness Ra to values from $0.3 \mu\text{m}$ to $0.35 \mu\text{m}$ [17].

Compared to jet-abrasive processing, tumbling also has lower restrictions on the shape of the processed object, which are associated with the size of the abrasive grains (from 0.5 mm). Granules can become clogged in holes, channels, or not come into contact with hard-to-reach surfaces at all. Due to the possible deformation of the product, there are restrictions on the mechanical properties of the processing object, the material of which must be either sufficiently elastic or sufficiently rigid and hard.

The main disadvantage of tumbling when used in AM is the inefficient stepwise effect [18]. Abrasive flow finishing (AFF) is better suited to eliminate this problem. AFF is a flow under pressure along the treated surface of a viscous medium, due to the pressure created in which the mechanical contact of the abrasive with the material occurs [19]. This processing is applicable only for products having a smooth shape, which allows the mixture to be pumped freely and with minimal energy losses along the treated surface. Therefore, AFF is most often used for polishing channels and holes.

Chemical polishing methods have minimal restrictions on the shape of the workpiece: chemical polishing, electrochemical machining (ECM), plasma electrolytic polishing (PEP) and their various modifications.

Chemical polishing or etching is the dissolution of a substance with the help of acid. This is used in many areas of production, but its main function is removing a layer from the surface of the material, for example, removing oxides or degreasing. This type of treatment does not lead to a significant reduction in roughness, since the dissolution rate of the material is almost the same on all microroughnesses, due to which the surface relief remains unchanged.

In the case of ECM, the dissolution rate depends on the density of the electric current supplied to the workpiece (anode) placed in the electrolytic bath. The higher the microroughness, the higher the potential gradient near its surface is. This contributes to an increase in current density and material removal rate. However, the difference between the dissolution rates at the troughs and tops of the asperities is not sufficient for significant smoothing. Therefore, the product roughness Ra can be reduced only to $8 \mu\text{m}$ [20].

PEP technology is more efficient. Like ECM, it is based on the processes of anodic dissolution of the metal. It is possible to reduce the roughness Ra to $1.6 \mu\text{m}$ [20] using this type of polishing.

The main features of PEP from ECM are the use of a higher voltage (from 200 V and above), as well as the use of low-concentration electrolytes, which are a solution of salts and acids, the mass concentrations of which rarely exceed 5 %. These physical and chemical conditions of the polishing process lead to abundant gas formation in the anode zone, which is accompanied by a characteristic glow. Due to this light effect, this polishing is called «plasma». However, to date, there is no unified theory describing this physical phenomenon, and plasma generation near the surface of a workpiece has not been experimentally confirmed [21]. Due to the lack of a theoretical basis, the processing result is difficult to predict, and PEP can lead to material erosion [22] if polished for a long time.

Both ECM and PEP have a common problem of surface treatment of long holes, deep channels and grooves [23, 24]. This phenomenon is a consequence of the «Faraday cage» effect, which blocks the spread of an electric field, and, consequently, the formation of an electric charge on the surface of the product.

There are also more specific ways to reduce roughness, such as laser polishing [25], ion beam or electron beam polishing [26–28], but their use in AM is very rare due to very low

productivity, high complexity of equipment and technological process, high qualification requirements for workers. These processing technologies are usually used for very specific products that require a significant reduction in roughness ($R_a < 0.01 \mu\text{m}$), for example, parts of optical and electronic systems.

Conclusion

It can be concluded that today there is no universal technology that can effectively reduce the roughness of any products made of metal and their alloy by using SLM. Each processing method has its advantages and disadvantages, which make it applicable in specific practical situations. However, of all the above post-processing methods, it is worth highlighting tumbling and PEP, which most effectively smooth out microroughnesses, have high productivity and minimal restrictions on the shape of the product. The equipment and materials used in the tumbling and PEP process are relatively cheap and safe for humans and the environment. PEP can become a more efficient technology compared to tumbling, and its implementation in AP will make AT the most common production technology if a sufficient amount of experimental and theoretical data is obtained and an accurate physical and mathematical model of the polishing process is invented.

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Разработка последовательности многовариантного расчета механизма подъема лифта

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Приведены основные отличия разрабатываемой последовательности многовариантного расчета механизма подъема лифта от его классического расчета. Представлены основные этапы предлагаемой последовательности расчета, которая позволит получить множество возможных решений. Многовариантность достигается путем варьирования значений параметров элементов привода. Разработанную последовательность целесообразно реализовать с использованием ЭВМ. Это снизит трудозатраты расчета и проектирования, поможет выявить взаимосвязь параметров элементов механизма подъема лифта, которая может быть использована для оптимизации привода.

Ключевые слова: лифт, механизм подъема, последовательность расчета, привод лифта, стальной канат

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Multivariate Calculation Sequence Development for the Elevator Lifting Mechanism

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The main differences between the developed sequence of the multivariate calculation of the elevator lifting mechanism and its classical calculation are given. The main stages of the proposed calculation sequence are presented, which will allow to obtain many possible solutions. Multivariance is achieved by varying the values of the parameters of the drive elements. It is advisable to implement the developed sequence using a computer. This will

reduce the labor costs of calculation and design, will help to identify the relationship between the parameters of the elements of the elevator lifting mechanism, which can be used to optimize the drive.

Keywords: elevator, lifting mechanism, calculation sequence, elevator drive, steel rope

The lifting mechanism is an integral elevator mechanism that gives movement to its cabin, consisting of several elements (Fig. 1). The reliability and efficiency of the lifting mechanism and the elevator as a whole depend on their parameters.

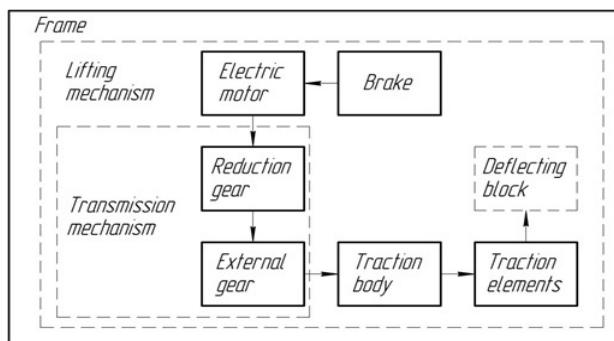


Fig. 1. Structural diagram of the lift mechanism

A number of requirements are imposed on the elevator lifting mechanism: durability, economic and energy efficiency and comfort of movement. All these criteria should be laid down at the design stage of the elevator drive. In this regard, the problem of determining the best combination of mutually influencing parameters of the elements that make up the elevator lifting mechanism arises. The choice of the most satisfying option of parameter combinations must be made from the set of all possible solutions obtained as a result of the drive calculation. All calculation methods set forth in well-known sources have a drawback — they do not have variability.

To find the best combination of parameters when calculating the drive, a sequence of multivariate calculation of all possible solutions that meet the requirements of regulatory and technical documentation is proposed, which contains the following steps:

1. Assignment of the source data depending on the parameters of the building.
2. Determination of cabin and counterweight weights. According to [1], approximate empirical dependences obtained for cabins of domestic production [2] depending on the type of elevator can be used to determine the weight of the cabin. The counterweight is calculated from the condition that it balances the weight of the cabin and part (usually 40...50 %) of the elevator's load capacity.
3. The choice of the kinematic scheme of the elevator. Two main tasks are solved: determining its layout, due to the design features of the building and the location of the elevator inside it; determination of the multiplicity of the polypast suspension, implying the introduction of the first criterion that ensures the variability of values. Therefore, in a multivariate calculation, it is advisable to simultaneously consider several multiplicity of the polypast, for example, and.

4. The choice of a traction rope. In elevators, round-strand double-lay steel ropes are most often used [2–4]. There are recommendations in [2, 5] to use 6-strand ropes for elevators according to national standards GOST 2688–80 of design $6 \times 19 (1+6+6/6) + \text{o.c.}$ and GOST 3077–80 designs $6 \times 19 (1+9+9) + \text{o.c.}$ According to the data on the operation of elevators in Kaluga (Russia) [6], 8-strand ropes according to GOST 3080-55 (not currently valid) of the design $8 \times 19 (1+9+9) + \text{o.c.}$ can also be recommended for use or their modern counterparts. In a foreign monograph [3], recommendations for elevators are given with similar rope designs.

5. Multivariable calculations of traction ropes. Traction ropes of elevators are preliminarily calculated by the value of the minimum breaking load attributable to all traction ropes, taking into account the minimum safety factor:

$$N_{min} = \left(\frac{Q+Q_K}{a} + Q_{TK} \right) * g * k_{min} * 10^{-3}, \text{ kN}, \quad (1)$$

where Q_{TK} — mass of traction ropes, kg (in preliminary calculations it is taken equal to zero); $g = 9,81 \text{ m/s}^2$ — acceleration of gravity; k_{min} — minimum safety factor.

From the catalogs, the technical parameters of the ropes are selected for breaking force, the value of which is not less than the minimum breaking load per one traction rope:

$$N_{min}^1 = \frac{N_{min}}{n}, \text{ kN},$$

when n — number of traction ropes. After that, the actual value of the safety factor of the traction rope is specified, taking into account the mass of the selected traction ropes from formula (1). In order to vary the parameters of the traction ropes, it is advisable to consider a different number of ropes, for example, $n = 3, 4, 5$. It is also necessary to consider the possibility of increasing the obtained diameter of the traction ropes by one or two standard sizes, since this can increase their durability [3], through the index $\xi = 0, +1, +2$.

Thus, we get an index consisting of parameters that have several options for values: $n; a; \xi$. This index will be assigned to all values that depend directly and indirectly on these three parameters. The resulting set of solutions for the calculation of traction ropes can be presented in the form of Table.

6. Calculations of friction losses arising from the movement of the elevator. The lifting mechanism of the elevator overcomes the friction forces that occur between the shoes of the cabin $F_{\Sigma K}$, counterweight F_{Π} and guides. All calculated dependences are given in [7]. Losses for resistance to rope movement are taken equal to 2% of the maximum tension of the traction rope branch in each design mode [4]. Friction losses on bypass blocks with a ratio of block diameter to rope diameter $D_B/d_{TK_{n;a;\xi}} \geq 30$ can be taken into account by the value of the efficiency of the block or polyspast suspension.

7. Calculations of tensions in traction ropes and their ratios for various modes of operation of the elevator. When developing an elevator, tensions are calculated for 11 different modes, depending on the load on the cabin, its position and direction of movement [7]. In general, the formulas for calculating tensions can be written as:

$$T_{1i_{n;a;\xi}} = \left(G_K + G + G_{\Pi K} + G_{K \Theta_{n;a;\xi}} \pm F_K \pm F_{\Gamma} \right) \frac{n_a}{a};$$

$$T_{2i_{n;a;\xi}} = \left(G_{\Pi} + G_{TK_{n;a;\xi}} + G_{K \Theta_{n;a;\xi}} \pm F_{\Pi} \right) \frac{n_a}{a}$$

when i — mode number; G ; G_K ; G_{Π} ; $G_{TK_{n;a;\xi}}$ — weight of cargo, cab, counterweight and traction ropes, respectively, N; $G_{\Pi K}$ — overhead cable weight, N; $G_{K\Theta_{n;a;\xi}}$ — weight of compensating elements, N.

An example of a summary table of a set of solutions for the calculation of traction ropes

Traction rope parameters		$n = 3$			$n = 4$...
Type	$a; \xi$	d_{TK} , mm	N^1 , kN	k	d_{TK} , mm	N^1 , kN	k	...
Rope 6×19 (1+6+6;Z6)+o.c.	2:0	13	89	12,1	И	68,8	12,7	...
	2;+1	14	108	12,6	13	89	13,6	...

	4;+2	13	89	13,8	12	78,6	14,5	...
Traction rope parameters		$n = 3$			$n = 4$...
Type	$a; \xi$	d_{TK} , mm	N^1 , kN	k	d_{TK} , mm	N^1 , kN	k	...
Rope 8×19 (1+9+9)+o.c.	2;0	10	64,9	11,3	И	54,5	11,4	...
	2;+1	13	76,1	13	12	64,	13,2	...

	4;+2	11	54,5	14,2	10	45,1	14,1	...
...

8. Multivariant calculations of the traction sheave. The smallest allowable diameter of the traction sheave is found from the condition of ensuring the minimum number of kinks in the rope when it bends around cylindrical surfaces:

$$D_{KBIII_{n;a;\xi}} \geq e d_{TK_{n;a;\xi}}$$

when e — envelope coefficient [7]. The frequent use in practice of traction sheaves with a diameter greater than the calculated one causes the introduction of a variation in diameters: $D_{KBIII_{n;a;\xi}}$ — calculated diameter; $D_{KBIII+25_{n;a;\xi}}$ — increase in diameter by 25%; $D_{KBIII+50_{n;a;\xi}}$ — increase in diameter by 50 %.

9. Calculations and selection of gearbox and electric motor. The choice of gearbox should be carried out taking into account the actual value of the duration of the drive, the equivalent torque on the low-speed shaft of the gearbox and the allowable cantilever load. The required motor power is determined by the following relationship:

$$N'_{\Theta\Delta B} = P_{Omax_{n;a;\xi}} * V_H * a * 10^{-3} / \eta$$

when $P_{Omax_{n;a;\xi}}$ — the largest value of the circumferential force according to paragraph 7 of the algorithm.; V_H — cabin speed, m/s; η — gearbox efficiency. Next, the rotational speed of the traction sheave and the gear ratio of the gearbox (required for the selected electric motor) are determined as the ratio of the rotational speeds of the electric motor and the pulley.

10. Calculations of the brake. The calculation of the brake is carried out according to the value of the static moment on the high-speed shaft of the gearbox, with restrictions imposed by the permissible value of the deceleration acceleration.

Thus, a sequence of multivariate calculations of the elevator lifting mechanism is proposed. Its difference lies in the fact that all the selected values of the parameters of the elevator drive elements that satisfy the conditions for ensuring the system's operability go through each stage of the calculation.

Based on the developed sequence, a multivariate calculation algorithm will be generated. Based on it, a computer program will be developed that will reduce the complexity of calculations and get the opportunity to analyze a large number of output data and subsequently implement the choice of the optimal solution from the generated set.

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Исследование операций для оценки эффективности гусеничных машин

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Для оценки эффективности гусеничных машин требуется создание различных теорий, которые будут отражать их характеристики. Разработка теоретической основы связана со сбором и анализом данных, которые получены в результате эксплуатации машин. Однако следует проводить сбор данных и их анализ на основе определенной методологии. Приведен обзор и анализ принципов, которые изложенные в книге «Методы исследования операций». Ее авторы, Ф.М. Морз и Дж.Е. Кимбелл, обобщили опыт исследовательских групп, которые занимались статистическим исследованием боевых действий времен Второй мировой войны, в частности действий авиации и морского флота. На основе проведенного обзора предложенные методы в области оценки эффективности военных гусеничных машин проанализированы и рассмотрены.

Ключевые слова: исследование операций, гусеничная техника, военные гусеничные машины, оценка эффективности, принятие решений в условиях неопределенности

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Operation Research for Tracked Vehicles Efficiency Evaluation

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In order to assess the tracked vehicles efficiency, it is necessary to build different theories which could reflect their characteristics. The development of a theoretical framework is associated with the collection and analysis of data which are obtained as a result of the

vehicles exploitation. However, data collection and analysis should be carried out on the basis of a certain methodology. The article reviews and reveals the principles mentioned in the book "Methods of Operations Research". The authors, F.M. Morse and J.E. Kimball, summarize the experience of research groups engaged in statistical study of World War II, especially in aviation and naval battles. As a result of the review, the proposed methods in the field of military tracked vehicles have been analyzed and examined.

Keywords: operations research, tracked vehicles, military tracked vehicles, effectiveness evaluation, decision making

Introduction

During the Second World War, the latest weaponry and technology began to appear on the battlefield and in support of combat operations. In order to increase the effectiveness of these technical innovations, a theory was needed that could mathematically justify certain control solutions. Among the many scientists who worked with the U.S. Department of Defense were Philip M. Morse, a physics professor at the Massachusetts Institute of Technology, and George E. Kimball, a chemistry professor at Columbia University [1]. The accumulated knowledge in warfare was sufficient to compile a book, Operations Research Methods, and make it available for wider study. As a result of the work done, by the middle of the XX century, operations research is being formed as a separate trend that affects not only military, but also civilian aspects of society life. The credit for this belongs to many teams of scientists in the UK and the USA.

The purpose of this article is to review the methodology from the above-mentioned work and provide examples of operations research in the field of military tracked vehicles. Many of the problems the authors refer to are within the domain of airpower and naval forces, yet the methodology is similar elsewhere.

The definition of «operation» in Morse and Kimball's work is defined as scientific method scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control [2]. This definition could be completed with the definition of operation by E. Ventcel, soviet mathematician. She defines operation like any activity (or system of activities) that has a common purpose and aims at achieving a certain goal [3]. This means that operation research could be applied to a very large field of scientific problems.

At first, authors notice, that operation research is an applied science, which exists only like mathematical methods for any events, not a branch of mathematics. Also, operation research could give a quantitative basis for making any decision but the operations research worker does not, and should not make the decision. That is the reason for separation of Operations Research from Executive Decision.

When the operation researcher becomes a person, who could make any decisions, he loses his scientific impersonality, that is why scientist should share his results to nonscientists. Such collaboration requires mutual respect.

Examples of operation research methods could be rearrangement of equipment application, changes in setting, rearrangement of unit size determination of dependence on operational parameters, the problem of finding the problem, finding the sensitive parameters.

Methods of operation research are divided into groups according to the process of data processing. Field assignments, collection of data are the ways of collecting necessary data

for research. Men in field should collect the certain data which are needed for the research. This work could be hazardous in military operations. After data collection it needs to be limited to choose important only for making easier the further processing. In any situations the data could be added by experimental methods. This is impossible for all situations, but could be less dangerous for researchers. Also, “Expert opinion” could be used for data collecting, but people could not estimate random events correctly [2]. Then the data should be evaluated for getting the desired result. Most useful methods in that case are statistical ones, which could be process the large number of reports. Analytical methods could transform rapidly data into generalized theories by mathematical methods. The last is the summary of methods, which could help to find the optimal way of finding the result.

Useful theories for operation research

The theory of probability is most useful for operation research. The main part of operations could be classified as a stochastic process moreover the probability takes a great part of its research. Chapter 2 focuses on fundamental concepts of probability theory.

Morse and Kimball give a definition of probability, distribution functions and expected values. Then they describe a principle of some simple distribution laws like binomial distribution, normal distribution and Poisson distribution. As a summary the authors give an example for using this law in shooting.

This part is very useful for researchers in the field of military tracked vehicles effectiveness evaluation. Many types of modern armament are subject to the laws of distribution.

Chapter 3 of «Methods of Operations Research» gives a definition about the using measures of effectiveness. Sweep rates are the measurement for reconnaissance efficiency. For example, the authors provide a standoff between submarines and airborne forces. The planes should find as many submarines in area as possible. This example could be very helpful for military vehicles too. In the age of unmanned aerial vehicles algorithms of finding enemy and protecting friendly vehicles are very actual.

Another efficiency measure is the exchange rate between enemy loss and own loss. Knowledge of this values could give an information about success and benefits of this operation. Examples were the air-to-air combat, convoys versus submarines as well as the tank duels from the field of ground vehicles.

Comparative effectiveness provides an efficiency measurement between two types of weapons or tactics. Methods of operation research could help the researchers find the most optimal method for enemy defeat. Marine operations evaluate the anti-ship weapons, U-boat bombing, anti-ship, etc. Ground military vehicles should be evaluated by their ability to resist anti-tank weapons.

There is an interesting remark about evaluating results of new equipment application. Authors gives a lot of examples regarding the results of using the experimental weapons and enemy countermeasures.

Chapters 4 and 5 are focused on strategical kinematics, and tactical analysis. Strategical kinematics gives an overview about army as a whole. Force requirements like requirement for air escort for navy (or fuel supply for ground tracked vehicles) makes commanders think about storage facility or airfield building. Operation research could help to find the best places and the shortest ways for their placing. These problems are also common to civilian tasks, what makes the operation research methods applicable to a wide range of human activities.

Lanchester equations are mathematical method for losses assessment. Authors give a main equation of this theory, like the linear law, the square law and its probability analysis. As the summary, the generalized Lanchester's law gives a theory of loss rate.

Lanchester's equations are widely used in the military operations research. For example, this law was used for evaluating Kursk battle between Soviet Union and Germany [4, 5]. In this battle both sides used a great number of tanks and artillery.

Tactical analysis is a very large part of Morse and Kimball work. All subchapters are about mathematical basis for finding and justifying the most effective tactics of using the military forces.

In the statistical solutions there were effects of maneuvering and an angle approach for airplane. Search theory could give the possible answers for covered area, probability of hit, area bombardment etc. examples. Tactics for torpedoes evading, situation analysis for all these problems were examples and mathematical equations.

The most useful chapter for evaluating the military tracked vehicles firing efficiency evaluation is the chapter 6, which are dedicated to Gunnery and bombardment problems. There are different problems which arise in the evaluation of such weapons as guns, bombs, and torpedoes, and in analyzing the best methods for their use [3].

Mathematical dependencies for pattern fire ballistic dispersion could be used for evaluating tank and another military tracked vehicles armament.

Chapters 7 and 8 are focused on the practical problems that arise in conducting an operational experiment with equipment and tactics as well as the organizational and procedural problems in the research teams.

The planning of the experiment includes the preliminary theory on which the experiment is to be conducted, the pre-recording, the plan for conducting the experiment. The experiment requires the collection of meaningful data, thus separating it from unnecessary information.

The most common type of test program is accuracy measurement. The calculation of the standard deviation as a function of the range enables to assess the effectiveness of the weapon. The survival problem for anti-aircraft artillery is interesting and is presented at the end of the chapter.

Chapter 8 describes the challenges and process of organizing operations research in military units. The nuances of fieldwork for research sub-teams, types of fieldwork are described. This method is universal for many types of military forces and could be very useful for operation researchers in the future.

Conclusion

Methods of operation research were written in the middle of XX century. Despite the age this work is still very useful, because of the practical experience of the working in the real military organizations. This book describes many problems the researchers will encounter in their future practical work.

Ground tracked vehicles could be analyzed by the operation research methods. Many theories which are described in this book could be very useful for statements of scientific objectives. Chapters about gunnery efficiency evaluation and strategical and tactical analysis might be very useful. Morse and Campbell's methods are recommended for consideration providing tracked vehicles efficiency evaluation.

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Критерий эффективности при проектировании твердотопливной ракеты космического назначения

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Приведен анализ возможных критериев эффективности применительно к твердотопливным ракетам космического назначения. Представлены обоснование выбора комплексного критерия эффективности, основные положения технико-экономического анализа, зависимости для оценки стоимости опытно-конструкторских работ по созданию ракеты космического назначения и стоимости оказания пусковых услуг. Полученная модель стоимости при ее включении в алгоритм оптимального баллистического проектирования позволяет делать обоснованное заключение о рациональном выборе проектных параметров ракеты.

Ключевые слова: ракета космического назначения, критерий эффективности, технико-экономический анализ, пусковые услуги

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Efficiency Criterion in the Design of a Solid-propellant Rocket for Space Purposes

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The paper provides an analysis of possible efficiency criteria in relation to solid-propellant rockets for space purposes. The rationale for the choice of a comprehensive efficiency criterion, the main provisions of a technical and economic analysis, dependencies for estimating the cost of research and development (R&D) for the creation of a space rocket and the cost of launch services are presented. The resulting cost model, included in the optimal ballistic design algorithm, allows making a reasonable conclusion on the rational choice of rocket design parameters.

Keywords: space rocket, efficiency criterion, feasibility study, launch services

In connection with the growing demand for operational launches of small spacecraft (SC), there is an increasing interest in the use of solid rockets as space carriers.

For newly developed space rockets (SR) of a light class, an urgent task is to choose its rational appearance, taking into account various factors.

As noted in [1], three types of criteria that influence the formation and selection of the most preferred SR among all those are considered:

- formalizable private and generalized criteria (payload mass, spacecraft compartment height, etc.) characterizing the energy and ballistic capabilities of the SR;
- poorly formalized private criteria (technological, environmental, operational);
- cost criteria (indicators of the cost of development, provision of spacecraft launch services, serial production, etc.).

Most often, the starting mass of the system is chosen as a quality criterion in the design of rocket and space technology, assuming its proportionality to the cost of the product [2]. However, this is often not the case.

In [3], attempts are made to present the desired criterion in the form of an integral technical and economic indicator. To this end, in the process of designing a complex technical system, the cost of the life cycle of the developed systems is estimated.

System life cycle cost estimates can be used in the following two main methods of system feasibility analysis:

1. The traditional method of comparative evaluation and selection of alternative systems or their subsystems using the cost criterion at various stages of decision making during the design.

2. Non-traditional management formation of rational cost characteristics within the framework of the design concept according to a given cost.

In the first method, the cost is taken as an equal, and not a dominant parameter. The equal impact of cost does not provide a firm guarantee of not exceeding the established directive cost, because there is always a desire to increase the level of technical sophistication of the system, which simultaneously leads to improved performance and unplanned increase in cost indicators.

In recent years, American designers of rocket and space systems have begun to use the second method, based on the concept of creating systems «Design to cost». Design according to the given cost criterion is understood as an approach in accordance with which the exact values of marginal costs are established during the development process, and the control of the cost of systems within the given limits is practically achieved on the basis of compromise values of the criteria that determine the flight performance of the system.

Design for a given cost is applied at the early design stage with accompanying procedures at subsequent stages. In the early stages of design, uncertainty is higher, and in the later stages, the cost of changing technical solutions is high.

Designing for a given cost consists in striving for the most accurate determination of the cost of a product based on a set of planned technical solutions and correlating the estimates obtained with the presented cost requirements.

Both in Russia and in world practice, three fundamental approaches to cost estimation are used: parametric, analog and costly.

The lack of the necessary initial data at the initial stages leads to the need for aggregated estimates, and in order for these estimates not to change radically at subsequent stages, it is necessary to ensure the integrity of the cost management process and the constant updating of models.

In many cases, a set of non-formalizable criteria can be transformed through a single cost criterion. For example, measures to meet operational requirements can be valued and included in the overall cost of the work. Then the choice of the preferred SR option can be carried out using only two groups of criteria: energy and cost.

The energy indicators can be represented as dependencies between the mass of the spacecraft being launched and the height of the circular near-Earth orbit for each SR variant $M_{SC}(H_{orb})$. For ease of comparative analysis, a fixed value of the orbit height is chosen. The spacecraft mass is determined by solving the direct ballistics problem for each vector of the SR design parameters, taking into account restrictions on the trajectory parameters.

The cost indicators are the cost of R&D and the cost of providing a launch service C_{launch} . The method for assessing the values of these indicators is presented in this paper. The value of the R&D cost is a constraint in the optimal design problem.

However, none of these groups of criteria can be considered as an objective criterion when choosing an SR option due to their obvious inconsistency: with an increase in the energy capabilities of the SR, the cost of services increases accordingly and vice versa.

Therefore, for a more objective assessment, as a comprehensive criterion, we can apply the ratio of the cost of launch services to the mass of the spacecraft that is launched into a given orbit or the unit cost of launch services.

$$\overline{C_{launch}} = C_{launch}/M_{SC}$$

The method proposed by the author for assessing the cost indicators of SR is based on the following provisions:

- SRs are created on the basis of a wide scientific and technical backlog of previously created analogues;
- in the manufacture of ground equipment units, units of analogue complexes with the necessary refinement are used;
- a set of ground equipment manufactured at the R&D stage after the completion of the flight tests is used to implement the SC launch program.

R&D costs are determined by the following relationship:

$$C_{RD} = K_{unc} \sum_{i=1}^k [(1 + K_i^{MT}) \sum_{k=1}^{l_i} N_{ik} C_{ik} + C'_i] + N_{exp} C_{SR},$$

where $C'_i = C_i^{sal} t_i K_{OH}$ – development costs;

$C_{SR} = \sum_{i=1}^k \sum_{k=1}^{l_i} C_{ik}$ – SR cost in mass production;

K_{unc} – uncertainty factor;

K_i^{MT} – the ratio of the cost of manufacturing tooling and preparation of production to the cost of manufacturing the i-th subsystem;

l_i – number of elements in the i-th subsystem;

N_{ik} – volume of working out of the k-th element of the i-th subsystem;

C_{ik} – manufacturing cost of the k-th element of the i-th subsystem;

C_i^{sal} – i-th subsystem developer salary;

t_i – the complexity of developing the i-th subsystem;

K_{OH} – overhead ratio;

N_{exp} – number of experimental launches.

The amount of development (number of tests) of structural elements, SR systems and ground equipment units are determined based on the required reliability, the degree of novelty of design solutions and the existing scientific and technical reserve.

The cost of the main structural elements, SR systems and ground equipment units are determined on the basis of data on analogue samples that are at the stages of pilot and mass production in proportion to the mass of the structure, taking into account their design and technological features and expected production conditions.

For each of the technical systems, a manufacturing cost is determined by the following formula: [4]:

$$C_{ik} = a_{ik} M_{ik}^{x_{ik}},$$

where M_{ik} — mass of the k-th element of the i-th subsystem;

a_{ik} — system-specific constant value of the k-th element of the i-th subsystem;

x_{ik} — system-specific cost-to-mass sensitivity factor of the k-th element of the i-th subsystem.

The complexity of design work is determined in accordance with the regulatory documents in force at the developer enterprise.

The costs of supporting the spacecraft launch program are determined by the following formula:

$$C_{pr} = \sum_{j=1}^T [Q_j(C_{SR} + C_{serv} + C_{ins})] + C_{GE},$$

where $C_{serv} = C_{lf} + C_{transp} + C_{crew}$ — launch service cost;

$C_{ins} = C_{SR}(1 + (K_{SR}^{ins})/100) + C_{GE}(1 + (K_{GE}^{ins})/100) + C_{dam}(1 + (K_{dam}^{ins})/100)$ — the cost of insurance for each launch;

T — launch program period;

Q_j — number of launches in j-th year;

C_{GE} — cost of ground equipment units;

C_{lf} — the cost of landfill services, including payment for the work of landfill measuring complexes along the launch route;

C_{transp} — transportation cost;

C_{crew} — service crew costs;

C_{dam} — possible damage to a «third party» in the event of an emergency start;

$K_{SR}^{ins}, K_{GE}^{ins}, K_{dam}^{ins}$ — interest rate for insurance of SR, ground equipment units, for damages of a «third party».

Then the cost of launch services is defined as

$$C_{launch} = (1 + K_{prof}/100)C_{pr} / \sum_{j=1}^T Q_j,$$

where K_{prof} — profitability ratio.

Thus, within the framework of this paper, the results of studies on the choice of a comprehensive efficiency criterion in the design of a solid-propellant SR are given, the main provisions of a technical and economic analysis and dependencies for estimating the cost of R&D and the cost of launch services are presented.

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Позиционирование заготовки в системе ЧПУ с помощью технологий машинного зрения

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Рассмотрен способ автоматизированного позиционирования заготовки с помощью машинного зрения. Показана разработка программно-аппаратного комплекса для позиционирования заготовки. Приведены используемые алгоритмы для обработки изображения и извлечения информации из него. Выявлена зависимость между разрешением изображения и точностью позиционирования. По результатам эксперимента подобрано оптимальное разрешение изображения для проведения автоматизированного позиционирования.

Ключевые слова: машинное зрение, металлорежущие станки, позиционирование заготовки, фрезерование

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Positioning a Workpiece in the CNC Applying Machine Vision

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The article deals with a method of automated workpiece positioning applying machine vision. The author describes the development of a hardware-software system for workpiece positioning. The algorithms used for image processing and information extraction from the image are given. The dependence between the image resolution and the positioning accuracy is revealed. Based on the results of the experiment the optimum image resolution for carrying out automated positioning is selected.

Keywords: machine vision, metal cutting machine, workpiece positioning, milling

Today, to improve the efficiency of product lifecycle management, companies are looking to optimize their operations in all stages of production. The main elements making manufacturing processes more efficient are considered to increase productivity, improve quality, reduce the volume of cuttings and decrease the machine time. To position a workpiece automatically on the machine tool and in the CNC system is supposed as the way of reducing the machine time [1]. The article deals with a method of automated workpiece positioning applying machine vision technology.

Machine vision is a practical application of computer vision for a wide range of manufacturing tasks [2]. Computer vision is a set of algorithms for extracting and processing information from images captured by optical or non-contact sensors. Typical tasks solved by computer vision are quality control, counting, spatial positioning and others. Fig. 1 shows a classic scheme of a machine vision system for visual inspection of objects. This system works according to the following algorithm. When the object 7 located in the triggering area of the non-contact sensor 6, the field of vision of the camera 2 is uniformly illuminated by the lighting system 1 and the image is captured. The received image is converted into digital format and processed using special algorithms, on the basis of the received information an output signal is formed then transmitted to the control system.

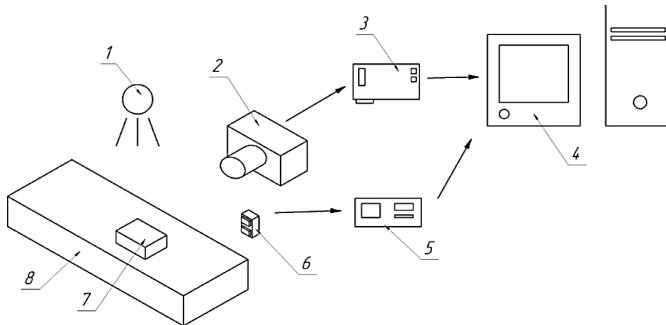


Fig. 1. Schematic drawing of a machine vision system:

- 1 — illumination;
- 2 — camera;
- 3 — image capture device;
- 4 — image processing device;
- 5 — operating device;
- 6 — non-contact sensor;
- 7 — workpiece;
- 8 — conveyor belt

One of the most common operations on the machine is the machining of marked or existing holes, e.g. machining castings, forging or stampings. Positioning the tool in the center of the selected hole is difficult and requires the operator to be experienced in such operations. A hardware-software package has been developed to solve these problems. The system consists of the software part and the module with a camera fixed to the working body of the machine. The software part is developed on python using OpenCV library for finding contours on image and their processing. The special algorithm for contour shape checks up the distance between diametrically located points.

The area of the working field is captured with the camera [3]. It is then converted into a single-channel image using the cv2.cvtColor function [4] and the cv2.canny border detector is used to highlight areas of different brightness in the image, then the resulting image is transferred to the cv2.findcontours function, where it is converted into a list of contours. A contour is a defined sequence of points represented as coordinates. The resulting contours are checked for the shape of the circle via a self-developed function. This function calculates the distance between opposite points and then checks this distance against the

arithmetic mean value of the distance for the given contour. If the distance deviates no more than the predefined value, the contour is considered to be a circle. Then via the cv2.minEnclosingCircle function, the coordinates of the center and the radius of the circle are determined.

Positioning the tool in the center of the hole on a pre-fixed workpiece uses the following algorithm: The image of the working area is captured by the camera and processed using the code described above, then an ISO 7-bit command is generated and transmitted to the NC of the machine and the tool is initially guided to the centre of the hole. To minimize the effects of the lens distortion, the tool is re-positioned using a similar algorithm to the primary positioning.

To improve the accuracy of detection circle centre coordinates it is proposed to change the algorithms of circle recognition in the image [5] or to increase the resolution of the captured image. This paper describes a study of the relation between the accuracy of circle detection and the resolution of the captured image. There are four resolutions available in the camera used. To determine the accuracy of circle coordinate detection the tool positioned in the centre of the newly drilled hole and the coordinates are zeroed after the system has been calibrated. By moving the tool to a random distance of about 30 mm the hole recognised again and the tool is positioned in the centre of the hole. By repeating this action at least 50 times, the coordinates of the hole are obtained for each available camera resolution.

After processing the results, plot the distribution of the resulting hole coordinates for each resolution. The diagrams are shown in Fig. 2. The resulting uncertainties for each resolution are presented in Table. Also, to determine the feasibility of using one or another resolution we will measure the image processing time. The time will be measured via the motherboard's internal clock.

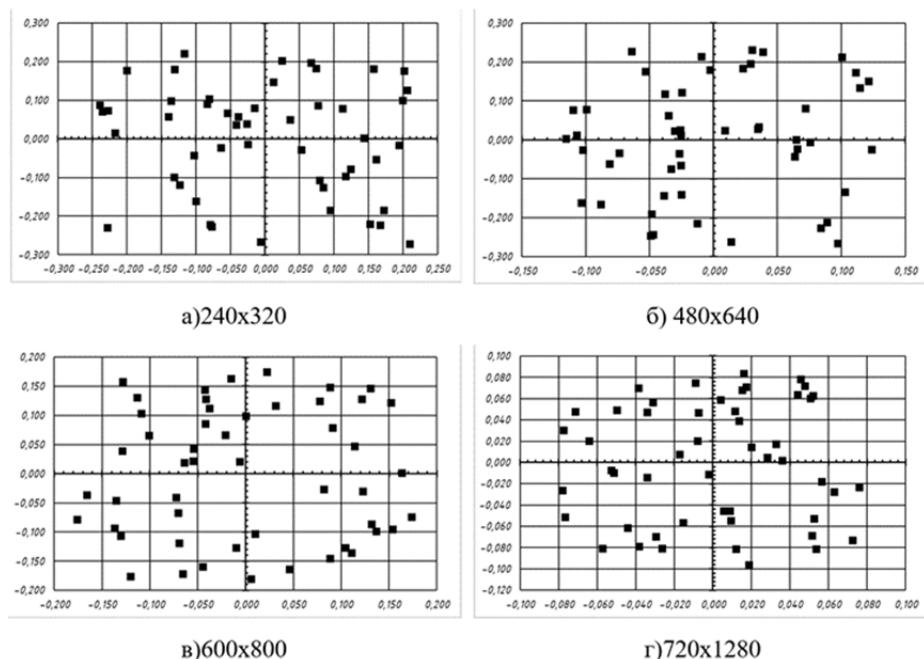


Fig. 2. Results of the experiment to determine the accuracy of the hole coordinates

Processed results of the experiment

Resolution, px	Range of values, mm	Accuracy at $N = 50$, $P = 95\%$, mm	Circle detection time, ms
240×320	0.47	0.044	126
480×640	0.39	0.038	154
600×800	0.35	0.033	179
720×1280	0.17	0.025	203

From the results it can be concluded that the error in recognizing the coordinates of the circles in the image is inversely related to the resolution of this image. Hence, the use of a higher resolution can increase the accuracy of the recognition of the circle centres. For this combination of equipment: machine and camera are reasonable for applying the maximum permissible resolution as the time spent on recognition of circles does not exceed 250 ms plus time on approach the working body that is much faster positioning the working body in manual mode.

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Энергетика

Power Engineering

УДК 66.074

Извлечение гелия из неоногелиевой смеси адсорбционным методом

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Рассмотрены основные методы выделения гелия из неоногелиевой смеси, изученные материалы собрали с разных стран мира. Сравнив методы ректификации, вымораживания, мембранныго разделения и сорбции, был получен вывод: метод адсорбции позволяет проводить разделение при относительно высоких температурных интервалах и более энергоэффективный, чем другие рассмотренные методы разделения. Приведены существующие примеры применения адсорбционного метода очистки гелия от неона, которые реализованы в КНР и на территории СНГ. Представлен обзор по адсорбционному разделению на новом сорбенте — одностенных углеродных нанотрубках. В дальнейшем будут проведены эксперименты, чтобы заполнить пробелы данных по адсорбции и десорбции неоногелиевой смеси на разных адсорбентах.

Ключевые слова: инертные газы, адсорбция, разделение газовых смесей, очистка газа

Гелий — ценный ресурс природы, имеющий большое значение для научных исследований. В настоящее время его извлекают в основном из природного газа или с помощью крупных воздухоразделительных установок. Гелий обычно вместе с неоном отводятся из ректификационной колонны. В целях получения чистого неона и гелия производится их дополнительная очистка.

Гелий содержится в воздухе около 5,24 ppm по объему. Он необходим для промышленного, химического, военного и высокотехнологичного развития. В настоящее время гелий извлекают в основном из крупных воздухоразделительных установок или из природного газа. Он обычно вместе с неоном отводится из ректификационной колонны. В целях получения чистых неона и гелия производится их дополнительная очистка с помощью низкотемпературной ректификации, вымораживания, мембранныго разделения или физической адсорбции.

Метод ректификационного разделения основан на отличии температур кипения компонентов газовых смесей. Он является традиционным и хорошо изученным методом, но характеризуется сложным управлением процесса.

Метод вымораживания заключается в выделении в твердом виде компонента смеси при охлаждении. При разделении неоногелиевой смеси обычно используется жидкий водород в качестве хладагента. Недостатки этого метода: кипящий жидкий водород требует специализированное аппаратное исполнение, кроме того метод предполагает высокие требования к чистоте разделяемой смеси (отсутствие в ней примесей азота, влаги, углекислоты).

Мембранные разделения — это механический метод разделения смеси, основанный на избирательной проницаемости одного или нескольких компонентов смеси через разделительную мембрану. По сравнению с традиционными методами разделения, мембранный метод характеризуется низким энергопотреблением, простотой использования и высокой эксплуатационной гибкостью, благодаря возможной

работе при комнатной температуре, но существует сложность в изготовлении разделительных мембран [1].

Адсорбией называют концентрирование веществ на поверхности раздела фаз или в объеме пор твердого тела. Она является обратимым процессом, поэтому адсорбент должен быть отрегенерирован после достижения состояния насыщения. Силикагель, цеолиты и активированный уголь часто используются в качестве адсорбента при очистке гелия. Достоинством адсорбционного метода является возможность работы в достаточно широких интервалах параметров, легкость управления. Однако адсорбционный метод отличается периодичностью процесса, поскольку адсорбент необходимо регенерировать, либо необходимо устанавливать несколько адсорбционных блоков.

Для получения гелия высокой чистоты для сверхпроводящих установок обычно требуется двухступенчатая адсорбция: при температуре 80 К для поглощения кислорода, азота, аргона и при температуре ниже 50 К для очистки от неона и водорода. В Китае была реализована адсорбционная установка очистки гелия от неона, на второй ступени очистки в качестве адсорбента использовали активные угли из кокосовых скорлуп, температура процесса была 35 К. Во входной смеси было 14,5 ppm неона, а на выходе среднее содержание менее 2 ppb. Данные показывают, при большем давлении смеси сорбционная емкость по неону больше. При этом получены изотермы адсорбции по неону при 77 и 35 К и разных давлениях смеси. Также был получен вывод — неон лучше адсорбируется на активном угле, чем на силикагели и цеолитах [2].

На территории СНГ реализована установка по адсорбционной очистке неоногелиевой смеси. Была разработана относительно «высокотемпературная» система и создана экспериментальная установка в интервале температур от 28 до 80 К. Статическая емкость по неону на силикагели при 28 К больше, чем на угле СКТ-4 при азотной температуре [3].

Данные из этих опытов дают сильное расхождение, возможная причина — процесс исследовали при разных давлениях смеси.

Угольные наноматериалы в последние годы много изучены. Одностенные нанотрубки обладают отличными адсорбционными свойствами и являются наиболее перспективными материалами для хранения водорода. Несколько зарубежных исследователей изучали адсорбцию редких газов на таком сорбенте. Были получены изотермы адсорбции и коэффициенты разделения неоногелиевой смеси. Структура пор нанотрубки — микропоры и мезопоры.

Изотермы адсорбции гелия и неона имеют сходную форму — форма Ленгмюра.

В диапазоне исследуемых параметров наблюдалась явления избирательности адсорбции неона от гелия. Такая избирательность сильно зависит от концентрации неона в смеси. При температуре 40 К она больше, чем при 4 К, это объясняет сильное взаимодействие неона-неона при 4 К, чем взаимодействие гелия-гелия [4].

Также получена изотерма адсорбции неоногелиевой смеси при 100 К и 0,1 МПа. Смесь почти линейно удерживается в нанотрубках. Избирательность по неону почти прямо пропорциональна его количеству в смеси [5].

Согласно плану научной работы в дальнейшем буду проводить эксперименты, исследовать процессы адсорбции неона, водорода, гелия и их смеси при разных температурах и давлениях. На слайде представлена принципиальная схема планируемой экспериментальной установки по статике объемным методом для определения изотермы адсорбции.

В адсорбере известного объема находится адсорбент. Для начала работы адсорбент должен быть отрегенерирован, система — отвакуумирована. После подготовки системы калибранный объем заполняется исследуемым газом, т. е. отдувка установки разделения неоногелиевой смеси (на базе лаборатории). Определение количества адсорбтива нужно проводить по показанию манометра. Затем пусть газом заполняется адсорбер. После того, как показание на манометре станет стабильным, можно определить количество поглощенного газа. С помощью данного эксперимента будут получены статические емкости на разных сорбентах по газам и смесям. По этим данным можно сделать вывод о выборе адсорбента, режима — давления и температуры процесса.

На следующем этапе будущий изучать динамику адсорбции, т. е. поглощение вещества в массе адсорбентов. Проводя эксперименты по динамике, можно сделать выбор эффективную конструкцию и размер адсорбера.

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Extraction of Helium from Neon-Helium Mixture by the Adsorption Method

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This article discusses the main methods of extracting helium from the neon-helium mixture. Having compared rectification, freezing, membrane separation and sorption methods, the authors concluded that the adsorption method allows separation at relatively high temperature intervals and is more energy-efficient than the other methods considered. The paper presents existing examples of the application of the adsorption method for the purification of helium from neon, which have been implemented in China and in the CIS. An overview of adsorption separation on new adsorbents, both on metal-organic bases and on single-walled carbon nanotubes, is also presented. In the future, the authors will conduct experiments to fill in the data gaps on adsorption and desorption of neon-helium mixture on different adsorbents.

Keywords: inert gases, adsorption, gas separation, gas purify

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**Робототехника
и комплексная
автоматизация**

**Robotics
and Complex
Automation**

УДК 007.52

Современные возможности беспилотных летательных аппаратов и актуальные проблемы их использования

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Рассмотрены современные возможности беспилотных летательных аппаратов, история разработки этой технологии и актуальные проблемы использования этих летательных аппаратов в разных областях. Обращено внимание на то, что беспилотные летательные аппараты стали многоцелевым оружием, за обладание которым соревнуются страны. Подчеркнута ключевая роль беспилотных летательных аппаратов в военной, гражданской и экологической инфраструктуре, что делает их незаменимой технологией в будущем. Рассмотрены тенденции развития беспилотных летательных аппаратов и их практическое применение в технике, народном хозяйстве, включая военные цели.

Ключевые слова: беспилотные летательные аппараты, технические возможности беспилотных летательных аппаратов, классификация, область применения

Введение

Стремительное развитие технологий привело к массовому появлению беспилотных летательных аппаратов (БПЛА) в нынешнюю эпоху. Ожидается, что рынок беспилотных летательных аппаратов будет продолжать расти вместе с соответствующими технологиями в будущем, БПЛА используются в научной, военной, промышленной, культурной и развлекательной сферах. В настоящее время БПЛА интенсивно разрабатываются и производятся в США, Италии, Китае, Японии, Южной Корее, Бразилии, Германии, России, Франции, Израиле, Австралии, Швеции, Великобритании, Новой Зеландии и др. Лидеры в производстве БПЛА в настоящее время находятся в США, Японии и Китае. Растущая потребность в применении БПЛА как в военных, так и в гражданских службах вызвала большой интерес к этим дистанционно управляемым системам. Развитие БПЛА переживает бум, и в него вкладывается все больше и больше инвестиций.

Краткая история беспилотных летательных аппаратов

Первый беспилотник появился в Англии в 1917 г., затем он был разработан в 1924 г. После Первой мировой войны США, Германия и Великобритания стали первыми странами, применившими его в своих армиях в 30-е гг. XX в. Роль БПЛА в разведывательных целях проявилась после войны во Вьетнаме в 1955–1975 гг. В результате постоянного развития этой отрасли и растущего спроса на приобретение БПЛА многие страны стремятся разработать новые типы беспилотников для замены пилотируемых боевых самолетов-истребителей и бомбардировщиков.

Типы беспилотных летательных аппаратов:

- БПЛА с дистанционным управлением;
- автономные летательные аппараты, в которых используются парадигмы искусственного интеллекта, такие как нейронные сети. Этот тип обладает большей автономией в принятии решений и обработке данных.

Классификация применения беспилотных летательных аппаратов

Военное использование. БПЛА стали третьей революцией в военном деле в текущем столетии. Они являются одними из самых важных видов оружия, используемых в современной войне. Эти самолеты обычно различаются по размеру в зависимости от их использования в военных целях (рис. 1):

- разведка, атака и наблюдение за полем боя в режиме реального времени, где выдаются отдельные изображения, позволяющие командиру принять соответствующее решение;
- постановка помех ракетам и станциям ПВО;
- обнаружение цели;
- управляемая ракета-самоубийца в случае неудачи или прекращения ее миссии, если есть жизненно важная цель, которую необходимо уничтожить.
- спасательные операции;
- предоставление информации оперативным центрам и сухопутным войскам;
- организация воздушного движения;
- морская разведка.

Характеристики БПЛА по размерам, массе, датчикам и боевому оснащению превратили их в важнейшие потребности при боевых действиях, что привело к снижению веса и стоимости самолета. Этот самолет изменил характер ведения боевых действий в воздухе, так что диспетчер самолета не подвергается реальной опасности.



Рис. 1. Беспилотные летательные аппараты

Экологические виды использования беспилотных летательных аппаратов:

- использование БПЛА для борьбы с пожарами, снижающее риски, которым может подвергаться пилот;
- изучение атмосферы, наблюдение за вулканической активностью и испытания новых аэродинамических систем; тушение пожаров и мониторинг трубопроводов [1];
- использование БПЛА в сельском хозяйстве:
 - 1) обработка урожая, мониторинг состояния сельскохозяйственных угодий, Мониторинг здоровья животных и дистанционное введение лекарств животным;

2) топографическая съемка местности, изучение экологического и социального состояния объектов градостроительной деятельности, контроль за выполнением работ, контроль за состоянием крыш, зданий и других сооружений [2].

Гражданское использование беспилотных летательных аппаратов. С помощью данных аэрофотосъемки БПЛА могут создаваться карты и изображения, которые можно использовать для следующих целей:

- инспекция зданий, предоставление клиентам и персоналу визуальных материалов (фотографии и видео), наблюдение за масштабом работ, выполненных на строительной площадке, контроль безопасности и картографирование;

- одной из самых больших проблем во многих городских районах и городах с большим количеством промышленности является загрязнение воздуха. БПЛА могут дать полное представление о том, что происходит в любой точке трехмерного пространства, что делает этот подход к контролю загрязнения воздуха более успешным, чем контроль с использованием мобильных эколабораторий в результате технологических достижений.

- Мониторинг таяния ледников.

Эффективное использование БПЛА особенно рекомендуется в следующих ситуациях:

- *расследование ДТП.* Камера БПЛА фиксирует все детали аварии, срочность вызова медицинских служб и направление к месту происшествия.

- *сдерживание толпы.* Большие толпы обычно присутствуют на крупных мероприятиях, таких как концерты, спортивные состязания и парады. БПЛА позволяют проводить оценку угроз, контролировать скопление людей на путях, не допускающих сдавливания, и обнаруживать посторонние предметы.

- *выслеживание преступников.* БПЛА оснащены тепловизионными камерами для ночных операций, а изображения, которые они снимают, передаются в систему распознавания лиц для идентификации преступников.

- *доступ в труднодоступные места и розыск пропавших людей* [3].

Проблемы, с которыми сталкивается технология беспилотных летательных аппаратов

Несмотря на разработки в области БПЛА, они по-прежнему сталкиваются с различными техническими проблемами, которые стали причиной многих аварий. Поскольку существует несколько различных способов взлома дронов, как только дрон будет обнаружен, хакер может взять его под контроль или отправить удаленную связь с видео или другими изображениями, которые дрон передает на свою базовую станцию. Взлом дронов технически не сложен [4].

Хакеры могут взломать сигнал управления и контроля БПЛА, хакер может получить полный контроль над БПЛА и его системами, а радиосигнал часто не зашифрован, что упрощает его расшифровку с помощью анализатора пакетов (или «наблюдателя за сетью»).

Потоки Telelink позволяют хакеру перехватывать данные, которые БПЛА отправляет обратно на базовую станцию.

Плохие погодные условия, такие как облака и дождь, могут влиять на перехват данных.

Существует также проблема обнаружения движущихся транспортных средств с помощью камер БПЛА [5].

Перспективные области использования беспилотных летательных аппаратов в будущем

По данным Организации Объединенных Наций (ООН), ожидается, что население мира достигнет 9,7 миллиарда человек в 2050 г., и это огромное население, вероятно, удвоит спрос на продукты питания в будущем. В связи с этим постоянный рост населения может вызвать нехватку продовольствия. В этом отношении пилотируемые летательные аппараты играют важную роль в сфере сельского хозяйства и сельскохозяйственного производства, в обеспечении населения продуктами питания.

Большую роль в борьбе с загрязнением окружающей среды сыграла проектно-исследовательская компания NAS-DRA, выдвинувшая новую идею небольшого беспилотного летательного аппарата, который может стать важной частью программ борьбы с загрязнением, особенно в крупных городах, полных ярких вывесок. Самолет-паразит несет растения на своих крыльях и в течение дня летает над городами на средней высоте, используя солнечный свет для питания этих растений и поглощая углерод из атмосферы через поглощающий углерод-полимер. Ночью установленный на рекламном щите паразит складывает крылья и выпускает углерод из полимерного материала. Используя тепло от освещения рекламных щитов для питания завода на крыле, углерод можно улавливать и превращать в топливо. Хотя эта идея кажется очень амбициозной, тем не менее в случае ее реализации мог бы быть очищен воздух и, таким образом, уменьшено загрязнение, особенно в людных общественных местах.

Одной из перспективных областей применения БПЛА является метеорологическое наблюдение за водными и воздушными бассейнами.

Перспективным направлением применения БПЛА является превращение летательного аппарата в службу такси и построение квадрокоптера, способного перевозить пассажиров.

Важно отметить, что размер европейского рынка коммерческих дронов постоянно растет: в 2020 г. он превысил 3 миллиарда долларов США, и, по прогнозам, в период с 2021 по 2027 гг. будет расти более чем на 10 % (рис. 2). Растущее внедрение решений для воздушной мобильности, включая БПЛА, дроны и т. д., повысит спрос на региональном рынке.

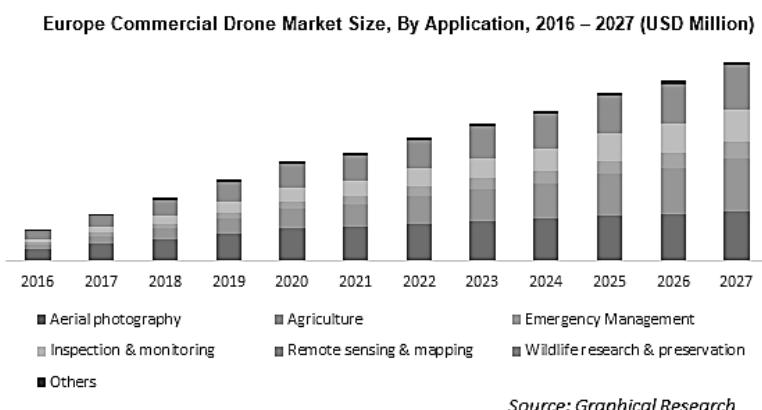


Рис. 2. Рост европейского рынка коммерческих беспилотных летательных аппаратов в период с 2021 по 2027 гг.

Заключение

Исходя из важности применения беспилотных летательных аппаратов во всех сферах жизни, нужно уделять большое исследовательское внимание работе по решению всех задач и проблем, которые стоят перед данной технологией с точки зрения безопасности, устранения помех использования БПЛА и их уязвимости при плохих погодных условиях. Решение этих задач поможет продвинуться вперед в развитии авиационной техники БПЛА, в разработке лучших беспилотников с уменьшением затрат на их производство.

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Modern Capabilities of Unmanned Aerial Vehicles and Actual Problems of Their Use

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The article is devoted to the description of the modern capabilities of unmanned aerial vehicles (UAVs), the history of the development of this technology and the actual problems of using UAVs in various fields. Attention is drawn to the fact that unmanned aerial vehicles have become a multi-purpose weapon, for the possession of which countries compete. The key role of UAVs in military, civil and environmental infrastructure is emphasized, which makes them an indispensable technology in the future. The trends in the development of UAVs and their practical application in technology, the national economy, including military purposes are considered.

Keywords: *unmanned aerial vehicles, UAVs, technical capabilities, classification, applications*

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DOI: <https://doi.org/10.1109/ACCESS.2019.2909530>

УДК 004.5

Обзор существующих мобильных робототехнических комплексов с целью выявления возможностей повышения эффективности работы оператора

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Приведен обзор существующих мобильных робототехнических комплексов для ликвидации последствий чрезвычайных ситуаций. Такие комплексы обычно управляются дистанционно человеком-оператором. Проблема заключается в наличии психофизиологических ограничениях человека-оператора, значительно снижающих эффективность управления робототехнической системой. Ограничения оператора зачастую не учитываются при проектировании робототехнической системы, поэтому требуется создание удобного и эргономичного человека-машинного интерфейса. Рассмотрены основные возможности повышения эффективности работы оператора при дистанционном управлении мобильным робототехническим комплексом. Предложено использовать расширенный человеко-машинный интерфейс с использованием технологий дополненной реальности для организации дистанционного управления мобильными робототехническими комплексами.

Ключевые слова: мобильный робототехнический комплекс, мобильный робот, мультиагентная робототехническая система, дистанционное управление, человеко-машинный интерфейс, расширенный человеко-машинный интерфейс, диалоговое управление, дополненная реальность

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The Review of Existing Mobile Robotic Complexes to Identify the Possibility of Increasing Operator's Efficiency

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The paper presents a review of existing mobile robotic complexes for emergency response. Such complexes usually are controlled by a remote human operator. The problem is the psychophysiological limitations of a human operator which significantly reduces the efficiency of the system. Such limitations often are not taken into account while designing a robotic system. Therefore, a development of a convenient and ergonomic based human-machine interface is required. The article describes the main possibilities of increasing the efficiency of a remotely controlled mobile robotic complex controlled by an operator. The authors propose the use of an extended human-machine interface with augmented reality technologies for mobile robotic complexes.

Keywords: mobile robotic complex, mobile robot, multi-agent robotic system, remote control, human-machine interface, extended human-machine interface, dialog control, augmented reality

Introduction

Currently, mobile robotic complexes are widely used to eliminate the consequences of emergency situations. First of all, the emergency rescue measures are carried out to save lives and preserve people's health in emergency situations. The use of mobile robotic systems also can reduce the risk to the health of human rescuers and speed up the search and rescue of victims. Recently, a large number of mobile robotic complexes useful for such situations have been designed. The leading developers of these complexes are researchers of Bauman Moscow State Technical University (BMSTU), the Russian state scientific center for robotics and technical cybernetics (RTC) (St. Petersburg), Research Institute of Fire Protection (Moscow). Patent no. 2364550 of the RF “Mobile robotics complex” and Patent no. 2574547 “Mobile robotics complex” are known, as well as a large number of scientific papers on the topic.

It is very important to reduce the time to solve the task, that's why such auxiliary equipment as unmanned aerial vehicles (UAVs) is actively used. The multi-agent robotic systems including UAV allow to divide responsibilities between mobile robots, as well as to provide the operator with more information on the situation at the accident site, thereby increasing the efficiency of the tasks solving. However, there is an unsolved problem associated with the psychophysiological limitations of the operator, which significantly reduce the efficiency of entire system. The main purpose of this study is to determine the possibilities to increase the efficiency of the operator's remote control of existing mobile robotic complexes, taking into consideration the human psychophysiological limitations.

Methodology

To make a literary review journal articles, conferences proceedings and collections of scientific works devoted to extreme robotics were analyzed. The materials were selected according to two main criteria:

1. A purpose of the robotic complex.
2. An architecture of a control system.

Materials describing mobile robotic complexes for emergency response equipped with a remote control system were selected: ten articles on the topic were selected from Scientific electronic library eLIBRARY.RU and reviewed according the mentioned criteria.

Results

Currently used complexes that meet the specified criteria are selected and presented below.

In the paper [1] the mobile robotic fire extinguishing systems named El-4, El-10 (BMSTU, Moscow) are described. The remote control systems of both machines have the ability to work independently. At the same time, they work with separated radio frequency ranges of control and telemetry, and their actions were mutually coordinated by operators of each machine. To improve the coordination efficiency, it was proposed to use a single control center for a group of robots. Also, the authors describe the mobile robotic complex «Kedr», which is an improved version of these complexes. The architecture of the robotic complex provides the ability to control two robotic means simultaneously. The control center «Ataman» is used for a remote control of a group of robots. Remote videos and infrared cameras mounted on a multicopter-type unmanned aerial vehicle are used to conduct reconnaissance and control actions, control and processing the information from the mobile point «Ataman». Human capabilities in managing a system of such an architecture are limited, moreover with the simultaneous management of a large number of robots, the operator's efficiency is significantly reduced. The human-machine interface may be improved by organizing an augmented reality interface and dialog mode of each robot control.

The mobile multifunctional robotic complexes of light class MRK-MW, MRK-RH, MRK-RP (BMSTU, Moscow) are described in paper [2]. Remote control of these complexes is carried out using a remote control, which includes a flat screen and joysticks to control the robot movement. In the article [3] the authors conclude that in order to effectively control such robotic complexes, it is necessary to inspect the work area from various positions. It is advisable to use unmanned aerial vehicles to solve the problems of eliminating the consequences of accidents. The management of several robotic agents by a single operator becomes difficult. The implementation of an extended interface with

augmented reality allows to reduce the load on the operator, and to provide him with only relevant and situational information.

The mobile robotic complex «Varan» (BMSTU, Moscow). The authors Poezhaeva E.V., Gimadeev I. R., Safronov A. S. in their work «Modernization of the mobile robotic complex «Varan»» describe the robotic complex, which is wide-produced. The control is carried out both from a stationary control panel and from a mobile one. The operator's interface contains several flat screens and motion control joysticks [4].

The robot RTK-05 (RTC, St-Pb). The authors Logvinov V.I. Galchenko G.A. in their work «Remote control of robots for extreme work» describe the robot RTK-05, which is produced by the RTC. It is designed for radiation reconnaissance and contains a control panel with a flat screen and motion control joysticks. The human-machine interface has the same features as those of the above-described robotic systems, and therefore can be modified taking into account the psychophysiological characteristics of the operator of a mobile robotic complex. Also the authors analyze the human-machine interface for the MRK-27 robotic complex (SKTB PR, Moscow), taking into consideration the psychological limitations of the human-operator that affect the control process. The authors propose the further research of augmented and virtual reality tools application for mobile robots control [5].

Dementey V.P. in his work "Experience of creation and application of mobile robotic complexes for elimination of consequences of emergency situations" describes Mobile multifunctional complex «Assistant-2» (BMSTU, Moscow). The complex is designed for remote visual and radiation reconnaissance of the accident site during the daytime, at night, as well as in smoke conditions. The composition of the complex: a vehicle based on KAMAZ-535- with a 6x6 wheel formula, an RTC with attachments, an unmanned aerial vehicle (UAV) with a target load, a complex of radiation monitoring equipment, RTC computer simulators and UAVs. The main task solved by the complex is the identification of radioactive radiation, as well as the determination of the surface temperature of objects and the distance to them. The control panel includes a screen and controls in the form of joysticks, switches, toggle switches [6].

Granada VA-1000 (YVS-Avia) and Orlan-10 (Special Technology Center) were described by K.N. Akkuzin, E.S. Makeev in the article "Analysis of the state of development and application of unmanned aerial vehicles designed to solve the tasks of RCB security". These are widely used UAVs for solving chemical safety problems. The operator controls proposed using a portable laptop [7].

In the all above-mentioned mobile robotic systems (including a multi-agent system, according to Patent no. 2658684 RF "Multi-agent robotic system"), the remote control is carried out from a portable remote control using a flat screen and motion control joysticks.

The capabilities of the operator of a remotely controlled mobile robot are not unlimited and depend on psychological and physiological characteristics of a person. Due to the fact that the operator does not have a natural perception of the environment in which the mobile robot is located, the control efficiency is significantly reduced. On the other hand, when controlling a multi-agent robotic system, the interface through which a person interacts with a robot plays an important role. The human operator because of his limitations, is not able to simultaneously process a large amount of information through different control channels, which significantly increases the time of solving the task. To increase the efficiency of the operator's work it is advisable to use augmented reality tools to implement an extended interface (according to Patent no. 0086370 of the USA "Negotiation-based Human-Robot Collaboration via Augmented Reality").

The augmented reality allows, firstly, to improve the effect of presence and bring the work of the remote operator to work conditions directly on board of the mobile robots as close as possible. Secondly, the advanced interface is able to combine information from both control channels: a mobile robot and an unmanned aerial vehicle. A dialog or supervisory control mode implementing an extended augmented reality interface increases the intelligence of the system management and significantly reduces the information load on the operator. Also, efficiency can be improved by optimizing the interaction between the agents of the robotic system without operator intervention (according to Patent no. 2773987 of the RF "Multi-agent robotic search and rescue complex"). The organization of a dialogue between robots significantly reduces the information load. At the same time, it is worth noting that the interaction language between robots is much simpler than between humans. In his works V.E. Pavlovsky (Lomonosov Moscow State University) described the ability of robots to communicate effectively in their own artificial language [8].

In this research, possible ways of increasing the efficiency of the operator of a remotely controlled mobile robotic complex are proposed.

1. The implementation of an extended interface with augmented reality allows to get operator's perception as close as possible to presence directly on board of the mobile robot, which significantly reduces the complexity of the operator's work.

2. Organization of a dialog between an operator of the mobile robotic complex and a leading robot-agent as an efficient mode of control of the multi-agent robotic system.

3. Development of an optimized algorithm for the interaction of master and assistant agents in a multi-agent robotic system, including the implementation of an artificial language.

Discussion

Currently, there are no wide-produced mobile robotic complexes using augmented reality to control the system. However, in the work of I. Shuai and A.S. Yuschenko (BMSTU, Moscow) [9] a method of designing a robot assistant surgeon controlled by voice commands has been developed. A. Schwandt in his work [10] also considers the use of virtual reality for offline programming of an industrial manipulative robot. In these works, high scientific and technical results have been achieved. This can be very useful in the development of a mobile robotic complex with an extended operator interface.

Conclusion

As a result of the study, the known mobile robotic complexes were analyzed, and the main ways of improving the efficiency of previously developed systems were proposed. We are going to conduct future research on the psychophysiological limitations of an operator to determine the necessary hardware and software retrofitting of complexes to identify the needs of information support of an operator in solving various specific tasks by multi-agent robotic system.

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**Информатика
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**Computer Science
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Технология преобразования текста в речь с использованием генеративной модели на основе WaveNet и Tacotron-2

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Представлен обзор технологии текст в речь (TTS) и различных моделей, методов и этапов, которые используются для генерации естественно звучащей речи. Рассмотрены основные компоненты конвейера TTS, включая анализатор признаков, акустическую модель и вокодер, и описано, как они взаимодействуют друг с другом в процессе генерации речи. Описаны различные модели TTS, в том числе статистические параметрические модели и генеративные модели, с фокусом на WaveNet и Tacotron-2. Описаны различные этапы предварительной обработки, включая нормализацию и процесс G2P, и объяснено, как они помогают улучшить качество генерируемой речи. Представлено описание платформы SV2TTS, которая является end-to-end TTS системой, способной генерировать естественно звучащую речь. Представлена полная картина технологии TTS, ее преимущества и ограничения, и определены векторы дальнейшего развития этой области с помощью глубокого обучения и end-to-end систем.

Ключевые слова: текст в речь, WaveNet, Tacotron-2, генеративная модель, нормализация, G2P, end-to-end система

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Text-to-speech Technology Using a Generative Model Based on WaveNet and Tacotron-2

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An overview of text-to-speech (TTS) technology and the various models, methods, and steps that are used to generate natural-sounding speech is presented. The main components of the TTS pipeline, including the feature analyzer, acoustic model, and vocoder, are considered and how they interact with each other during speech generation is described. Various TTS models are described, including statistical parametric models and generative models, with a focus on WaveNet and Tacotron-2. The various pre-processing steps, including normalization and the G2P process, are described and how they help improve the quality of the generated speech is explained. At the end of the article, a description of the SV2TTS platform is provided, which is an end-to-end TTS system capable of generating natural-sounding speech. A complete picture of TTS technology, its advantages and limitations is presented, and vectors for further development of this area using deep learning and end-to-end systems are identified.

Keywords: text-to-speech, WaveNet, Tacotron-2, generative model, normalization, G2P, end-to-end system

IntroductionIn

Real-time text-to-speech technology is a groundbreaking advancement in the field of artificial intelligence and speech synthesis. This technology has been made possible by the development of deep learning models such as WaveNet and Tacotron 2. These models have revolutionized the way text is converted into speech, allowing for more natural and human-like sounds.

The combination of these two models has made it possible to create real-time text-to-speech technology that can be used for a variety of applications. For example, this technology can be used to create more natural-sounding voice assistants, improve accessibility for individuals with speech impairments, and enhance the overall user experience for text-to-speech applications [1].

Real-time text-to-speech technology has the potential to revolutionize the way we interact with technology and each other. As these models continue to evolve and improve, we can expect to see even more applications and use cases for this technology in the future.

The general text-to-speech pipeline typically consists of three main components: the feature analyzer, the acoustic model, and the vocoder. These components work together to convert text into natural-sounding speech.

The feature analyzer takes in the input text and extracts various linguistic features such as phonemes, stress patterns, and prosody. These features are then used as inputs to the next component, the acoustic model.

The acoustic model takes the linguistic features extracted by the feature analyzer and generates acoustic parameters such as fundamental frequency, spectral envelope, and duration. This step is where the deep learning models like WaveNet and Tacotron 2 come into play, as they can generate these parameters in a more natural and human-like way [2].

Finally, the vocoder takes the acoustic parameters and converts them into an audio waveform that can be played back as speech. The vocoder essentially synthesizes the speech waveform from the acoustic parameters.

Each of these components plays a crucial role in the text-to-speech pipeline, and advancements in each area can lead to significant improvements in the quality and naturalness of synthesized speech.

Sequential TTS model

The Sequential Model of text-to-speech (TTS) (Fig. 1) is a type of deep learning model used for converting text into speech. It is called a «sequential» model because it takes the input text as a sequence of symbols and produces the output speech as a sequence of audio samples.

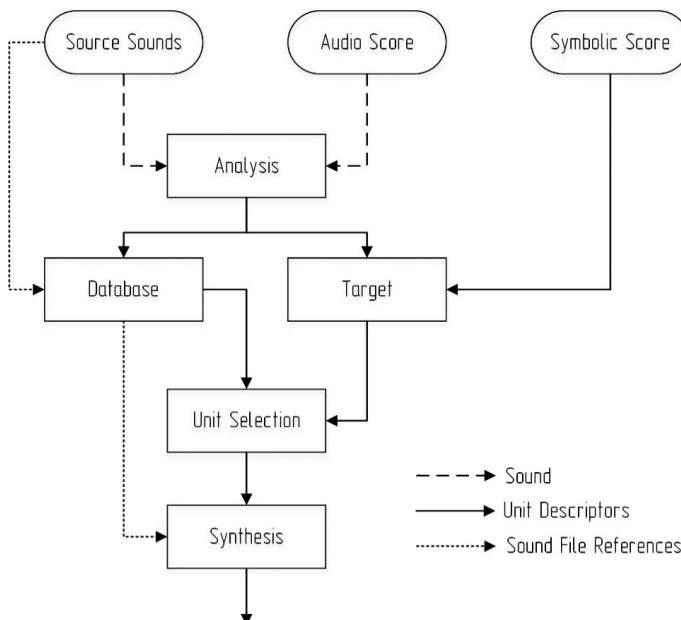


Fig. 1. Architecture of sequential TTS model

The Sequential Model typically consists of three main components: the text encoder, the audio decoder, and the attention mechanism. The text encoder takes in the input text and converts it into a sequence of hidden states, which represent the linguistic features of the text. The audio decoder takes these hidden states as input and generates a sequence of audio samples, which are combined to form the final synthesized speech. The attention mechanism is used to align the hidden states of the text encoder with the audio samples generated by the audio decoder, allowing the model to focus on the most relevant parts of the input text at each step of the audio generation process [3].

The Sequential Model of TTS has several advantages over other approaches, including its ability to generate high-quality, natural-sounding speech, its flexibility in handling different languages and speaking styles, and its ability to learn from large amounts of data. However, it can also be computationally expensive and require large amounts of training data to achieve optimal performance.

Statistical parametric model

The statistical parametric model (SPM) is a type of text-to-speech (TTS) model that uses statistical models to synthesize speech from input text. The SPM is also known as the Hidden Markov Model (HMM) based TTS.

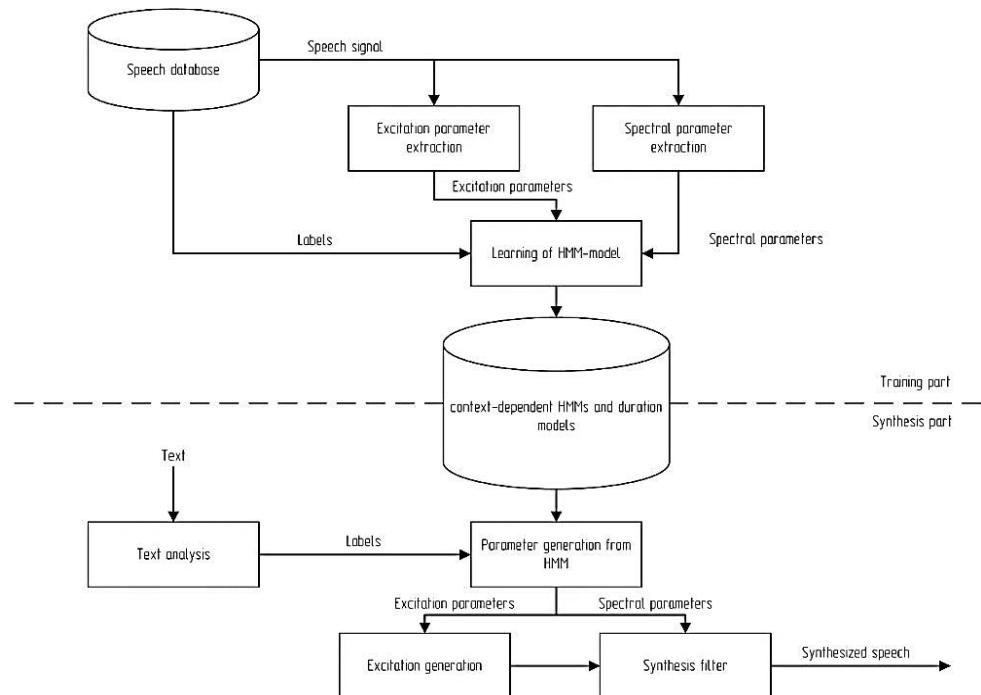


Fig. 2. Architecture of the SPM TTS model

SPM (Fig. 2) is a generative model that learns to represent the mapping from text to speech waveform through a set of statistical parameters that are learned from a large corpus of speech data. These statistical parameters are typically represented as a sequence of

feature vectors, such as mel frequency cepstral coefficients (MFCCs), which are used to describe the acoustic properties of speech [4].

In the SPM-based TTS, the text is first converted into a sequence of linguistic features, such as phonemes or graphemes. These linguistic features are then used to predict the sequence of acoustic feature vectors that correspond to the speech waveform. Finally, the predicted acoustic feature vectors are transformed into a speech waveform using a signal processing technique, such as a vocoder.

One of the key advantages of SPM-based TTS is its ability to generate high-quality, natural-sounding speech, even for languages with complex and diverse phonetic systems. Additionally, SPM-based TTS systems can be trained using a relatively small amount of data compared to other types of TTS models.

However, one of the main disadvantages of SPM-based TTS is its reliance on statistical models, which may not capture all of the complex variations in speech that occur naturally. Additionally, SPM-based TTS models can be computationally expensive to train and require large amounts of storage for the acoustic feature vectors.

Generative model

The text-to-speech (TTS) generative model you are referring to is a multi-stage pipeline that converts input text into synthesized speech. The pipeline consists of several stages, including:

1. Sentence processing: The input text is first preprocessed to identify the sentences or phrases that need to be synthesized.
2. Text analysis: The text is then analyzed to identify the phonetic and linguistic features, such as phonemes, stress patterns, and prosody.
3. Acoustic modeling: The phonetic and linguistic features are then used to generate a spectrogram, which represents the frequency content of the speech signal over time.
4. Waveform generation: The spectrogram is transformed into a time-domain waveform using a vocoder or other signal processing techniques.
5. Audio signal: The final output is the synthesized audio signal, which can be played back through a speaker or other audio device.

The generative model you describe is a statistical parametric model, which uses statistical models to represent the mapping between text and speech. The model is typically trained on a large dataset of speech recordings and corresponding text transcriptions, using techniques such as deep learning to learn the complex relationships between linguistic features and acoustic properties of speech [5].

One advantage of this generative model is that it can generate high-quality, natural-sounding speech with good prosody and intonation. However, it can be computationally expensive and requires a large amount of training data to achieve optimal performance. Additionally, the model may struggle with certain types of speech, such as emotions or accents, which are not well-represented in the training data.

Normalization process

Normalization is an important step in the generative model of text-to-speech (TTS) that aims to ensure consistency in the output speech across different speakers, recording conditions, and devices. In the context of TTS, normalization refers to the process of

adjusting the acoustic features of the synthesized speech to match a target distribution, such as a mean and variance calculated from a large dataset of speech recordings.

Normalization can be applied at different stages of the TTS pipeline, including during acoustic modeling, waveform generation, and post-processing. One common approach to normalization is to use mean and variance normalization, where the mean and standard deviation of the acoustic features are calculated from a large dataset of speech recordings, and then used to normalize the acoustic features of the synthesized speech [6].

Another type of normalization that is often used in TTS is volume normalization, which adjusts the overall loudness of the synthesized speech to match a desired level. Volume normalization is important to ensure that the synthesized speech is consistent in loudness across different recordings and devices.

Normalization can also be applied to specific aspects of the speech signal, such as the pitch or spectral shape. For example, spectral normalization can be used to adjust the spectral tilt or shape of the synthesized speech to match a target distribution.

Overall, normalization is an important step in the generative model of TTS that helps to ensure consistency and quality in the synthesized speech. By adjusting the acoustic features of the synthesized speech to match a target distribution, normalization can improve the intelligibility, naturalness, and overall quality of the synthesized speech, and make it more suitable for a wide range of applications.

G2P process

In the context of text-to-speech (TTS), G2P refers to the process of converting graphemes (written letters or symbols) in a given language to phonemes (sounds or units of speech). G2P is an important step in TTS systems that rely on statistical parametric models to generate synthesized speech.

The G2P process involves mapping the graphemes in a given input text to their corresponding phonemes, which can be used to generate a spectrogram of the desired speech. The mapping between graphemes and phonemes can be performed using rule-based approaches, machine learning algorithms, or a combination of both.

One common approach to G2P in TTS systems is to use machine learning models such as neural networks to learn the mapping between graphemes and phonemes from large datasets of annotated text. These models can be trained to identify the most likely pronunciation for a given sequence of graphemes, taking into account factors such as the context and neighboring phonemes [7].

Another approach to G2P is to use rule-based methods, which rely on a set of predefined rules to map graphemes to phonemes. These rules can be based on the orthography and phonology of the language being synthesized and can be manually crafted by linguists or automatically generated from linguistic knowledge sources.

Regardless of the approach used, accurate G2P is essential for producing high-quality synthesized speech that accurately reflects the intended language and speech style. The quality of the G2P process can impact the overall naturalness and intelligibility of the synthesized speech, making it an important consideration in TTS system design and development.

Role of Tacotron-2 in TTS generative model

Tacotron 2 (Fig. 3) is a deep learning model that is widely used in the generative model of text-to-speech (TTS) systems. It is a neural network-based model that converts a

sequence of input text into a corresponding sequence of acoustic features, such as mel-spectrograms, which can be used to synthesize high-quality speech.

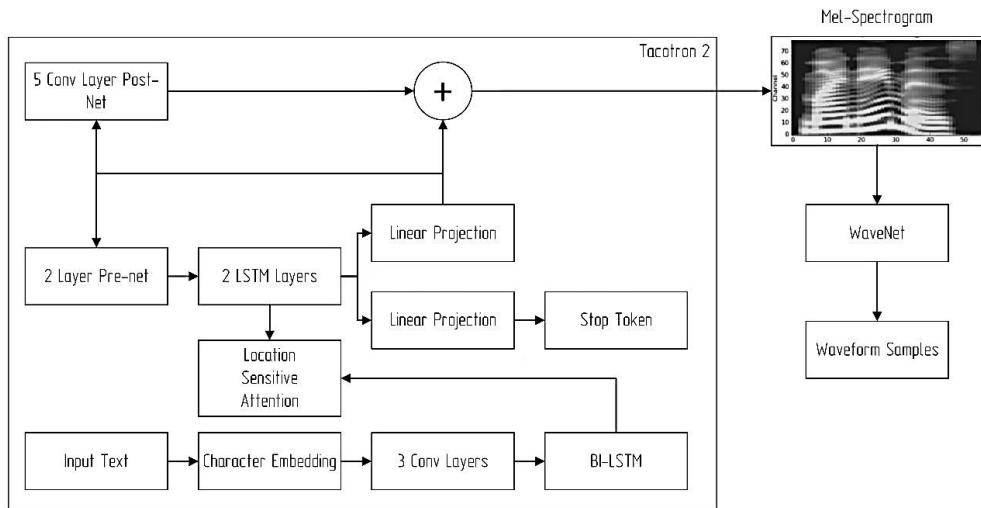


Fig. 3. Architecture of Tacotron-2 model

The role of Tacotron 2 in the TTS generative model is to take as input a sequence of characters or phonemes, and output a corresponding sequence of mel-spectrograms that represent the speech signal. The model consists of two main components: an encoder that processes the input text sequence and produces a sequence of high-level features, and a decoder that synthesizes the corresponding acoustic features from the encoded representation [8].

The encoder in Tacotron 2 is a deep convolutional neural network (CNN) that processes the input text sequence character by character or phoneme by phoneme, and produces a sequence of high-level features that capture the semantic content of the input text. The decoder is a recurrent neural network (RNN) that takes the output of the encoder and generates a sequence of mel-spectrograms that represent the speech signal.

One of the key strengths of Tacotron 2 is its ability to generate highly natural-sounding speech that is similar in quality to human speech. This is due in part to the use of a multi-speaker training dataset, which allows the model to capture variations in speech patterns across different speakers and dialects.

Tacotron 2 also includes a number of other features that improve the quality and accuracy of the synthesized speech, such as attention mechanisms that help the model to focus on important parts of the input text, and a post-processing module that applies additional signal processing techniques to further enhance the quality of the generated speech.

Role of WaveNet in TTS generative model

WaveNet (Fig. 4) is a deep learning model that is used in the generative model of text-to-speech (TTS) systems to synthesize high-quality speech. It is a type of autoregressive

model that is capable of modeling complex temporal dependencies in the raw waveform of speech, which makes it well-suited for TTS applications.

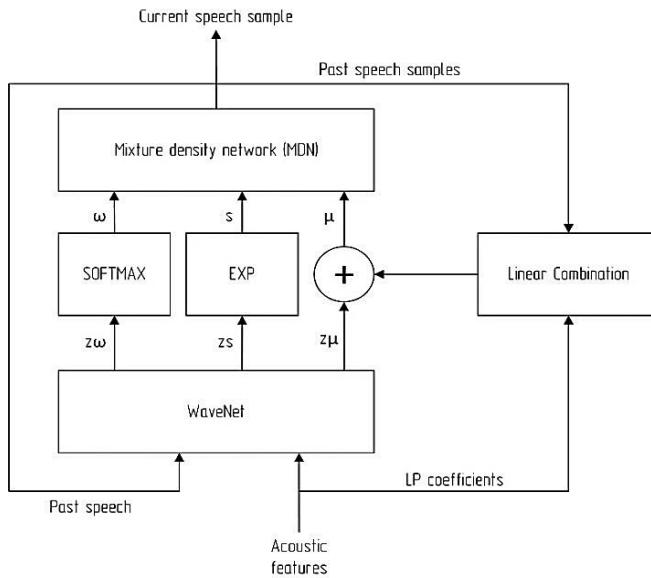


Fig. 4. Using WaveNet in TTS generative model (LP-modification)

The WaveNet model consists of a stack of dilated causal convolutional layers that model the conditional probability distribution of each audio sample given the preceding samples. The model takes as input a sequence of acoustic features, such as mel-spectrograms, and generates a corresponding sequence of raw audio waveform samples.

One of the key advantages of WaveNet is its ability to generate highly natural-sounding speech with a high level of detail and realism. This is due in part to its ability to model complex temporal dependencies in the raw waveform of speech, which allows it to capture subtle nuances and variations in speech patterns that are difficult to reproduce using other methods.

WaveNet also includes a number of other features that contribute to its ability to generate high-quality speech, such as conditioning on linguistic features such as phonemes or characters, and the use of skip connections to help propagate information across different layers of the network [9].

One of the main limitations of WaveNet is its high computational cost, which can make it difficult to use in real-time TTS applications. However, recent advances in hardware and software optimization have helped to mitigate this issue, making it more feasible to use in practical TTS systems.

SV2TTS platform

SV2TTS is a text-to-speech (TTS) platform developed by the Montreal Institute for Learning Algorithms (MILA) at the University of Montreal. It is an end-to-end system that uses deep learning techniques to convert input text into a natural-sounding speech

waveform. The SV2TTS platform is based on two main components: a speaker embedding model and a neural vocoder model.

The speaker embedding model is a deep neural network that is trained to extract a low-dimensional representation of a speaker's voice from a few seconds of their speech. This embedding is then used to condition the neural vocoder model to generate speech with the same characteristics as the target speaker.

The neural vocoder model is a generative model that takes as input the speaker embedding and a sequence of mel-spectrogram features that represent the acoustic features of the speech signal. The model then generates a high-quality speech waveform that matches the input features [10].

One of the key advantages of the SV2TTS platform is that it can generate high-quality speech with very little training data. This is achieved by using a technique called unsupervised pre-training, where the neural vocoder model is first trained on a large corpus of unlabeled speech data, before being fine-tuned on a smaller dataset of labeled speech data for a specific speaker.

Another advantage of the SV2TTS platform is its flexibility in terms of input text format. It can accept input text in a wide range of languages and dialects, and can even generate speech with different emotional tones.

Overall, the SV2TTS platform is a powerful and flexible text-to-speech system that has achieved state-of-the-art results in several benchmarks.

Conclusion

In conclusion, text-to-speech technology has made significant progress in recent years, with deep learning models such as Tacotron 2 and WaveNet producing high-quality and natural-sounding speech waveforms. There are various approaches and techniques used in the text-to-speech pipeline, including statistical parametric models and generative models. Preprocessing steps such as normalization and G2P conversion are important for improving the quality of the generated speech. Finally, the SV2TTS platform is a powerful and flexible text-to-speech system that has achieved impressive results in several benchmarks.

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Методы обнаружения пожара на изображениях

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Обнаружение пожаров является особенно важной задачей для предотвращения крупномасштабных пожаров в промышленных зонах и населенных пунктах. Традиционные детекторы дыма обнаруживают физическое присутствие частиц дыма. Однако их область применения имеет ряд ограничений на открытых пространствах, и решение с видеокамерой и детектором, использующим специальный алгоритм или нейронную сеть для обнаружения объектов, может дополнить традиционный детектор. Рассмотрены методы обнаружения пожаров на изображениях с использованием извлечения признаков изображения, нейронных сетей и специальных камер, их преимущества и недостатки. Показатели моделей обнаружения пожара представлены в виде обнаружения объекта.

Ключевые слова: обнаружение возгораний, дискретный оператор Лапласа, локальный двоичный шаблон, метод опорных векторов, нейронная сеть, классификация изображений, обнаружение объектов, семантическая сегментация

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Fire Detection Methods on Images

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Fire detection is a particularly important task for the prevention of large-scale fires in industrial areas and communities. Traditional smoke detectors detect the physical presence of smoke particles. However, their field of application has a number of limitations in open spaces, and a solution with a video camera and a detector that uses a special algorithm or neural network to detect objects can complement the traditional detector. The article discusses methods for detecting fires in images using image feature extraction, neural networks and special cameras, their advantages and disadvantages. The metrics of fire detection models are presented as object detection.

Keywords: fire detection, Laplacian operator, local binary patterns, support vector machine, neural network, image classification, object detection, semantic segmentation

Introduction

Fire detection is a particularly important task for the prevention of large-scale fires in industrial areas and communities.

Traditional smoke detectors detect the physical presence of smoke particles. However, their scope has a number of limitations, and a solution with a video camera can complement a traditional detector.

Incorporating smart video technologies into existing surveillance camera infrastructure provides faster response times than traditional smoke detectors. This paper discusses the advantages and disadvantages of various smoke detection methods on real-time video images.

Image analysis

One of the ways to detect fires are image analysis algorithms. Such algorithms are characterized by ease of implementation and fast response time.

Detection of fires and smoke with the image sharpness

The measure of sharpness can be calculated by applying the discrete Laplace operator to the original image and then calculating the standard deviation [1]. The measure of sharpness will decrease for images where the edges are not clearly visible. It also decreases if the image has smoke on it (Fig. 1, 2) [2].

One should note a decrease in sharpness that occurs during rain, as well as an occasional increase in the considered parameter when thick smoke appears near objects that lack clearly defined boundaries or in a cloudless sky, as shown in Fig. 3 and 4.



Fig. 1. Sharpness of an image with smoke



Fig. 2. Sharpness of an image without smoke



Fig. 3. Sharpness of an image showing clear sky



Fig. 4. Sharpness of an image with smoke in a clear sky

Local Binary Patterns

Local Binary Patterns [3], or LBP for short, is a texture descriptor. LBPs compute a local texture representation. This local representation is built by comparing each pixel with its surrounding neighborhood.

The first step in building an LBP texture descriptor is to convert the image to grayscale. Next, for each pixel in the image, a neighborhood of size r is selected surrounding the central pixel. An LBP value is then calculated for that center pixel and stored in the output 2D array with the same width and height as the input image.

Consider an original LBP descriptor that operates on a fixed 3×3 pixel neighborhood as follows:

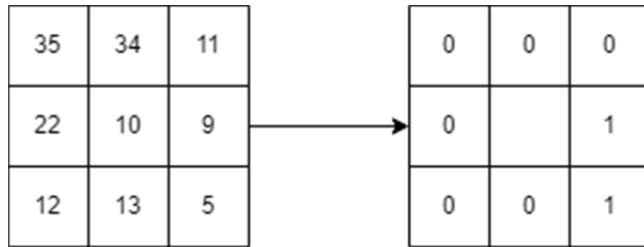


Fig. 5. Descriptor example

In Fig. 5 above, the center pixel is selected and compared to the 8 neighboring pixels. If the intensity of the central pixel is greater than or equal to the neighboring pixel, the value is set to 1, otherwise 0. With 8 surrounding pixels, there are a total of $2^8 = 256$ possible combinations of LBP codes.

Next, you need to calculate the LBP value for the central pixel. You can start at any neighboring pixel and move clockwise or counterclockwise, but the order must be the same for all image pixels and all images in the dataset in question. Thus, given a 3×3 neighborhood, there are 8 neighbors on which to perform a binary test. The results of this binary test are stored in an 8-bit array, which is then converted to decimal, like so:

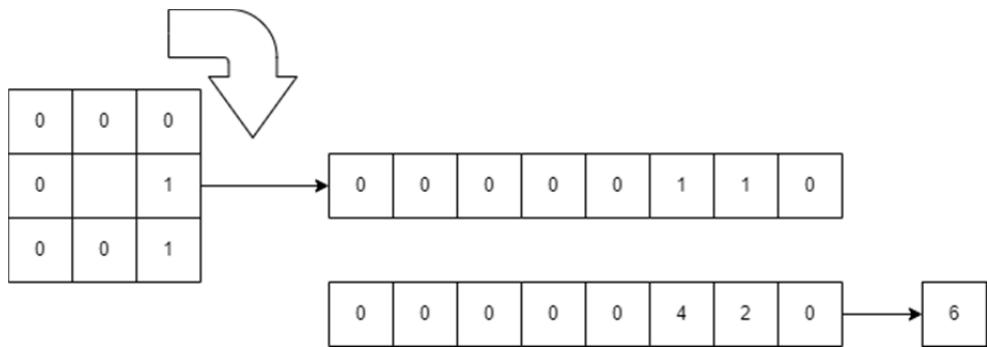


Fig. 6. Descriptor calculation

In the example shown in Fig. 6, the top right point is taken as the start of the traversal, from which the traversal is made clockwise, with the accumulation of a binary string as it goes. Then you need to convert the binary string to decimal.

The last step is to calculate the histogram from the LBP output array. Since a 3×3 neighborhood has $2^8 = 256$ possible patterns, our 2D LBP array has a minimum value of 0 and a maximum value of 255, allowing us to construct a 256-bit histogram of LBP codes as the final feature vector.

After obtaining the feature vectors of all the necessary images, the support vector machine should be trained to find feature differences [4].



Fig. 7. Correct result of the LBP algorithm



Fig. 8. Incorrect result of the LBP algorithm

It can be seen that in the case shown in Fig. 7 and 8, the obvious case of fire was not recognized [5]. When using the local binary patterns algorithm, smoke and flames must occupy most of the frame for their successful recognition. In this case, for successful early detection of fires, it is necessary to divide the image into a large number of separately processed fragments.

Neural networks applications

Image classification

Image classification [6] is the task of assigning a label or class to an entire image. Image classification models take images as input, producing a prediction about their belonging to a certain class as a result.

As a disadvantage of this approach, it should be noted that images can only be assigned to one class, while in reality, both smoke and fire can be captured in one image.

Object detection

Object detection [7] is the task of detecting instances of objects of a certain class in an image and selecting objects with a bounding box. Such classes in the problem under consideration include smoke and fire.

It should be noted that such a model takes more time to train than an image classification model. The shape of smoke and fire does not always allow you to draw a bounding box around them without other objects falling into it, which can be a problem in training.

Semantic segmentation

Semantic segmentation [8] is a deep learning algorithm that associates a label or category with each pixel in an image. It is used to recognize a set of pixels and highlight the contours of objects divided into classes. Semantic segmentation is well suited for fire detection because smoke and fire outlines have different shapes and cannot always be separated by a bounding box.

Processing the outline of an object is more computationally intensive than the bounding box approach.

Image augmentation

Image augmentation can be used to enhance the result of neural network and possibly reduce its size.

In this algorithm [9], all pixels that move and are colored gray are selected on the image. A median filter is then applied to this matrix to remove all scattered non-aggregated pixels since they are noise. Next, the resulting matrix is fed to the input of a small-sized convolutional neural network to localize smoke in the original image.

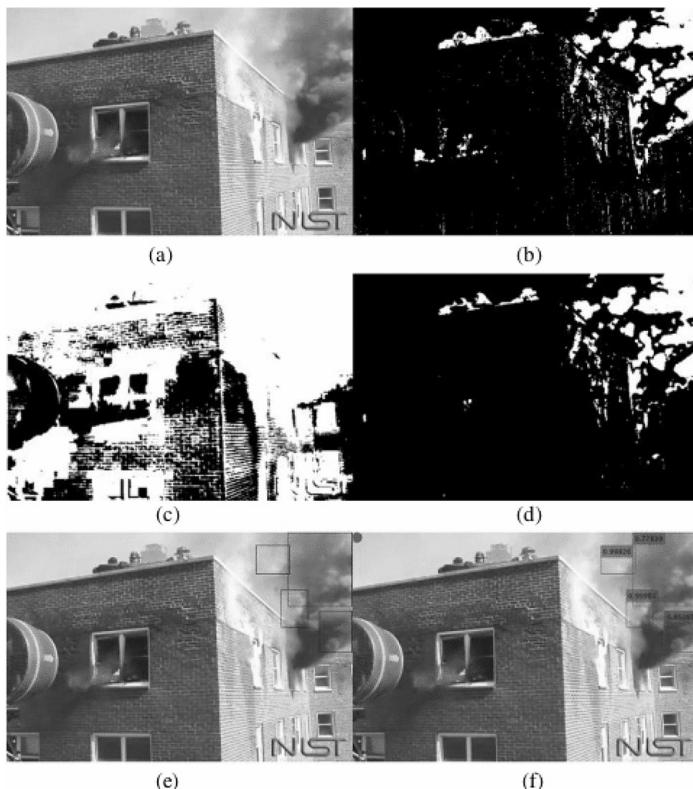


Fig. 9. Image augmentation example

However, it should be taken into account that when only gray pixels are selected, red pixels are skipped, so the flame is skipped, as seen in Fig. 9. To solve this problem, additional image processing and an additional neural network will be required.

Specialized cameras

The use of cameras sensitive to both UV and IR wavelengths for smoke and flame detection is based on a comparison of the threshold signals for both bands. Then the smoke borders are superimposed on the image of a conventional camera for segmentation.

However, UV sensors are also sensitive to other sources of UV radiation such as lightning, welding and sunlight. IR sensors practically do not work in humid conditions (rain, fog).

Conclusion

All methods and systems discussed can be used to detect smoke and / or fire, as well as in combination with other fire and smoke alarms in small rooms, however, it should be borne in mind that:

- In open spaces, such as forest belts, parking lots, stadiums, construction sites, highways, it is best to use object detection and semantic segmentation systems. Cameras sensitive to UV and IR wavelengths may not work correctly at these sites due to weather conditions.
- In buildings with a large internal volume, such as warehouses, hangars, shopping and exhibition centers, industrial premises, tunnels and any other structures with high ceilings and / or active ventilation, it is permissible to use special chambers, since there is no serious influence of weather factors.
- Real-time video analysis systems need to be improved by dividing the original images into equal parts. However, splitting into a large number of images can slow down the system as a whole.

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Применение метода коэффициентов для анализа комбинаторных свойств задачи о рюкзаке

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Рассмотрены комбинаторные свойства множества решений в задачах об ограниченном рюкзаке. Найдены производящие функции для множества допустимых решений задачи об ограниченном рюкзаке и значения функционала задачи на этом множестве. Получены формулы, позволяющие вычислять среднее значение функционала задачи на множестве ее допустимых решений и мощность этого множества через число решений подзадач меньшей размерности. Показано, что метод коэффициентов может быть применен для анализа комбинаторных задач.

Ключевые слова: задачи о рюкзаке, производящие функции, NP-полные задачи, метод коэффициентов

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Application of the Method of Coefficients for the Analysis of Combinatorial Properties of the Knapsack Problem

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The article deals with combinatorial properties of the bounded knapsack problem. Generating functions for feasible solutions of the knapsack problem are considered. The formula for expressing the average value of the problem functional is obtained. An expression for a number of solutions to the problem through a number of solutions to its subproblems is focused on. The method of coefficients is worked out. Successful application of this method to the analysis of combinatorial problems is presented.

Keywords: knapsack problems, generating functions, NP-complete problems, method of coefficients

Introduction

The bounded knapsack problem is a variant of the classic knapsack problem, in which each item is available in a certain limited quantity. There is a set of items containing m copies of each item, where the k -th item ($1 \leq k \leq n$) has two non-negative integer parameters — weight a_k and cost c_k . The limitation of the capacity of the knapsack b is also defined. The task is to select a subset of items with the maximum total cost, the total weight of which does not exceed the capacity of the knapsack.

In the form of optimization, the bounded knapsack problem is given by the expression [1]:

$$\sum_{j=1}^n c_j x_j \rightarrow \max \quad (1)$$

$$\sum_{i=1}^n a_i x_i \leq b \quad (2)$$

where $x = (x_1, \dots, x_n)$ — is an n -dimensional vector with integer components $x_i \in \{0, 1, \dots, m\}$, c_1, \dots, c_n ; a_1, \dots, a_n ; b — are non-negative integers.

The knapsack problem and its variants find application in the field of mathematical programming. In particular, this problem has become the basis for several cryptographic systems, the security of which depends on the complexity of obtaining its solution [2]. As a result, the literature on this question is extensive and covers both issues related to the development of algorithms [1] and theoretical aspects related to the properties of the problem [3]. Since the problem is NP-complete, decomposition and enumeration algorithms are used to obtain its exact solution, and the question of the relationship between the complexity of the problem and complexity of its subproblems is relevant.

To obtain main results, the method of coefficients is used in this research [4]. The method of coefficients is one of the variants of the method of generating functions. This method defines a linear functional on a set of formal power series with a finite number of terms of negative degree, which maps each power series to a coefficient of its term of the minus first degree. For power series converging in the neighborhood of zero, this coefficient coincides with the residue at point 0. To express restrictions on the set of feasible solutions to the problem, an integral expressing the Iverson bracket is used

$$[0 \leq l \leq k] = \frac{1}{2\pi i} \oint_{|u|=r} \frac{u^l}{u^{k+1}(1-u)} du.$$

Auxiliary expressions

Firstly, we express the generating functions in the form of polynomials for the set of feasible solutions and values of the functional of the problem on this set. The set of feasible solutions V_b to the problem is the set of n — dimensional vectors x with $x_i \in \{0, 1, \dots, m\}$, $i=1, \dots, n$ satisfying the inequality (2). By analogy with the continuous case, we will call the set V_b a polyhedron of feasible solutions to the problem. The volume of V_b is the number $|V_b|$ of feasible solutions to inequality (2).

To analyze the distribution of points in the polyhedron of feasible solutions to problem (2), a polynomial is used

$$P_b(z_1, \dots, z_n) = \sum_{x \in V_b} z_1^{a_1 x_1} z_2^{a_2 x_2} \dots z_n^{a_n x_n} \quad (3)$$

Lemma 1. For the problem of a bounded knapsack (1), (2) the following formula is valid [5]

$$\sum_{b=0}^{\infty} P_b(z_1, \dots, z_n) u^b = \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{(1+(z_1 u)^{a_1} + \dots + (z_1 u)^{ma_1}) \dots (1+(z_n u)^{a_n} + \dots + (z_n u)^{ma_n})}{1-u} du \quad (4)$$

Proof. We transform the sum (3) using the coefficients method. The internal summation is carried out over the entire set of vectors (x_1, x_2, \dots, x_n) with coordinates from $\{0, 1, \dots, m\}$. Using the method of coefficients allows us to select from this set only those vectors that satisfy the constraints (2).

$$\begin{aligned} P_b(z_1, \dots, z_n) &= \sum_{t=0}^b \sum_{\{x_1, \dots, x_n\}} z_1^{a_1 x_1} z_2^{a_2 x_2} \dots z_n^{a_n x_n} \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{u^{\sum_{i=1}^n a_i x_i}}{u^{t+1}} du = \\ &= \frac{1}{2\pi i} \oint_{|u|=\rho} \sum_{t=0}^b \frac{1}{u^{t+1}} \sum_{x_1=0}^m (z_1 u)^{a_1 x_1} \dots \sum_{x_n=0}^m (z_n u)^{a_n x_n} du = \\ &= \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{1}{u^{b+1}(1-u)} \prod_{k=1}^n (1 + (z_k u)^{a_k} + \dots + (z_k u)^{m a_k}) du \end{aligned} \quad (5)$$

Comparing expressions (4) and (5), it can be seen that (4) is contained in (5).

Corollary. For the volume of the domain of feasible solutions of the problem (1), (2) with $m \in \mathbb{N}$, the equality holds

$$|V_b| = \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{(1+u^{a_1} + \dots + u^{m a_1}) \dots (1+u^{a_n} + \dots + u^{m a_n})}{(1-u) u^{b+1}} du \quad (6)$$

(Here and further, the parameter ρ satisfies the conditions $0 < \rho < 1$.)

To study the properties of the values of the problem functional (1) at the feasible points of the polyhedron of solutions, a polynomial is considered

$$F_b(z_1, \dots, z_n) = \sum_{x \in V_b} z_1^{c_1 x_1} z_2^{c_2 x_2} \dots z_n^{c_n x_n} \quad (7)$$

Lemma 2. The equality holds:

$$\sum_{b=0}^{\infty} F_b(z_1, \dots, z_n) u^b = \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{(1+(z_1 u)^{c_1} + \dots + (z_1 u)^{m c_1}) \dots (1+(z_n u)^{c_n} + \dots + (z_n u)^{m c_n})}{1-u} du \quad (8)$$

Proof. We transform the sum (7) using the method of coefficients

$$\begin{aligned} F_b(z_1, \dots, z_n) &= \sum_{t=0}^b \sum_{\{x_1, \dots, x_n\}} z_1^{c_1 x_1} z_2^{c_2 x_2} \dots z_n^{c_n x_n} \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{u^{\sum_{i=1}^n c_i x_i}}{u^{t+1}} du = \\ &= \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{1}{u^{b+1}(1-u)} \prod_{k=1}^n (1 + (z_k u)^{c_k} + \dots + (z_k u)^{m c_k}) du \end{aligned}$$

Obtained formula

We introduce the following expression

$$\Phi_b(z) = F_b(z, \dots, z) = \sum_{x \in V_b} z^{c_1 x_1} z^{c_2 x_2} \dots z^{c_n x_n}$$

The following relation follows from the formula (6) and expression given above

$$|V_b| = \Phi(1)$$

In future, we will assume everywhere that all points of the polyhedron V_b have equal probability. Then the values of the functional $f(x_1, \dots, x_n) = \sum_{i=1}^n c_i x_i$ is a random variable $\xi = \xi(a_1, \dots, a_n, c_1, \dots, c_n, b)$ with a probability generating function $P(z) = \frac{\Phi(z)}{\Phi(1)}$.

We denote by $\mu(\xi)$ the mathematical expectation of this random variable. The mathematical expectation (the first moment) of a random variable is determined by the first derivative of its generating probability function at the point $z = 1$

$$\mu(\xi) = P'(1) = \frac{\Phi'(1)}{\Phi(1)} \quad (9)$$

We introduce the following expression to determine the first derivative of the function $P(z)$

$$\phi(z, u) = \prod_{k=1}^n (1 + z_k^{c_k} u^{a_k} + \dots + z_k^{m c_k} u^{m a_k})$$

The derivative of this expression has the form

$$\phi'(z, u) = \sum_{k=1}^n \frac{(c_k z_k^{c_k-1} u^{a_k} + 2 c_k z_k^{2 c_k-1} u^{2 a_k} + \dots + m c_k z_k^{m c_k-1} u^{m a_k})}{(1 + z_k^{c_k} u^{a_k} + \dots + z_k^{m c_k} u^{m a_k})} \phi(z, u)$$

From here and from formula (8) we express the value of the first derivative of the function $\Phi_b(z)$.

$$\begin{aligned} \Phi'_b(z) &= \\ &= \frac{1}{2\pi i} \oint_{|u|=r} \sum_{k=1}^n \frac{(c_k z_k^{c_k-1} u^{a_k} + 2 c_k z_k^{2 c_k-1} u^{2 a_k} + \dots + m c_k z_k^{m c_k-1} u^{m a_k})}{(1 + z_k^{c_k} u^{a_k} + \dots + z_k^{m c_k} u^{m a_k})} \frac{\phi(z, u)}{(1-u)^{b-1}} du \end{aligned}$$

Setting $z = 1$ in this expression, we get

$$\Phi'_b(1) = \frac{1}{2\pi i} \oint_{|u|=r} \sum_{k=1}^n \frac{(c_k u^{a_k} + 2 c_k u^{2 a_k} + \dots + m c_k u^{m a_k})}{(1+u^{a_k}+\dots+u^{m a_k})} \frac{\phi(z, u)}{(1-u)^{b-1}} du \quad (10)$$

For each of the variables x_k in the initial problem, we define an $m + 1$ «sections» of the set of feasible solutions to the problem V_b , each of which corresponds to a subset of solutions to the initial problem with the variable x_k set to a certain value. Each section V_b^{dk} with the number d ($0 \leq d \leq m$) contains all feasible solutions of the problem of smaller dimension satisfying the condition:

$$\sum_{i=1, i \neq k}^n a_i x_i \leq b - d a_k, x_i \in \{1, \dots, m\}$$

From corollary (1) we get

$$|V_b^{dk}| = \frac{1}{2\pi i} \oint_{|u|=r} \frac{\prod_{i=1, i \neq k}^n (1+u^{a_i}+\dots+u^{m a_i})}{(1-u)^{b+1}} du \quad (11)$$

Theorem 1. The relation is valid

$$\mu(\xi) = \frac{1}{|V_b|} \sum_{k=1}^n c_k (|V_b^{1k}| + 2|V_b^{2k}| + \dots + m|V_b^{mk}|) \quad (12)$$

Proof. Decompose expression (10) by the first factor into m terms and note that the terms of this expression contain the right parts of expressions (11)

$$\begin{aligned}\Phi'(1) = & \sum_{k=1}^n \left(c_k \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{\sum_{i=1, i \neq k}^n (1 + u^{a_i} + \dots + u^{m a_i})}{(1-u) u^{b+1-a_k}} du + \right. \\ & 2c_k \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{\sum_{i=1, i \neq k}^n (1 + u^{a_i} + \dots + u^{m a_i})}{(1-u) u^{b+1-2a_k}} du + \dots + \\ & \left. m c_k \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{\sum_{i=1, i \neq k}^n (1 + u^{a_i} + \dots + u^{m a_i})}{(1-u) u^{b+1-m a_k}} du \right).\end{aligned}$$

Taking into account the equalities (11), we replace the integrals with their notations and obtain the relation:

$$\Phi'(1) = \sum_{k=1}^n (|V_b^{1k}| + 2|V_b^{2k}| + \dots + m|V_b^{mk}|)$$

Inserting the found values into expression (9), we finally get the desired ratio:

$$\mu(\xi) = \frac{\Phi'(1)}{\Phi(1)} = \frac{1}{|V_b|} \sum_{k=1}^n c_k (|V_b^{1k}| + 2|V_b^{2k}| + \dots + m|V_b^{mk}|)$$

The theorem is proved.

This formula can be used in the analysis and evaluation of both the set of feasible solutions and the values of the functional on optimal solutions, in particular, for evaluating the effectiveness of algorithms for solving the problem (1), (2).

The expression $|V_b|$ can also be represented by the sum of V_b^{dk} , decomposing by the bracket corresponding to the variable x_k .

Multiplying and dividing expression (6) by $1 + u^{a_k} + \dots + u^{m a_k}$, we get

$$|V_b| = \frac{1}{2\pi i} \oint_{|u|=\rho} \frac{(1 + u^{a_k} + \dots + u^{m a_k}) \prod_{i=1}^n (1 + u^{a_i} + \dots + u^{m a_i})}{(1 + u^{a_k} + \dots + u^{m a_k}) (1 - u) u^{b+1}} du$$

Now we decompose this expression by the numerator $1 + u^{a_k} + \dots + u^{m a_k}$ on m terms and note that they contain expressions (11) for $d = 0, \dots, m$.

Replacing the integrals with their notation from (11), we obtain

$$|V_b| = |V_b^{0k}| + 2|V_b^{1k}| + \dots + m|V_b^{mk}| \quad (13)$$

This formula reduces the number of calculated values in the formula (12). To do this, it is enough to substitute in (12) the value $|V_b|$, determined by the formula (13) for some variable x_j , for example, the smallest value a_j . Then

$$\mu(\xi) = \frac{1}{|V_b^{0k}| + 2|V_b^{1k}| + \dots + m|V_b^{mk}|} \sum_{k=1}^n c_k (|V_b^{1k}| + 2|V_b^{2k}| + \dots + m|V_b^{mk}|)$$

These calculations allow us to decompose the solution of the original problem into subproblems of smaller dimension, in which the value of the constraint b is less than the original one. In addition, it is obvious that $V_b^{di} \subseteq V_b^{ci}$ for $i = 1, \dots, n$; $d \geq c$, therefore, when

calculating V_b^{ci} for $i = 1, \dots, n$ by dynamic programming, we can immediately get the values of V_b^{di} for $d=1, \dots, m$.

Conclusion

The method of coefficients can be successfully applied to the analysis of similar problems having a combinatorial nature. Using it, the formulas for estimating the average value of the functional on the set of feasible solutions to the problem depending on the number of solutions to subproblems of smaller dimension are obtained in the research. The obtained formulas can be refined when considering problems of a special kind that arise in specific applied fields, in particular in mathematical models of information security that take into account the real features of the initial statements. The results presented in this paper can serve as a basis for further studies of the properties of the structure of polyhedra of knapsack problems. The expressions found can also be used directly in computational algorithms as auxiliary procedures.

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Проблемы обеспечения оперативного мониторинга сети в условиях импортозамещения

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Рассмотрены проблемы импортозамещения иностранного программного обеспечения на отечественное. Показано, что при отсутствии автоматизации процессов, время выполнения диагностических команд составляет от 14 до 33 ч. Сделаны выводы, что автоматизация подключения к отечественному программному обеспечению значительно сокращает обработку данных до 335...790 с, не предъявляя при этом требований к высокой квалификации инженера. Разработан шаблон подключения к отечественному программному обеспечению Zelax с помощью библиотеки `text_fsm`.

Ключевые слова: информационная система, информационная безопасность, риск, угрозы безопасности, уязвимости, сетевая безопасность, мониторинг состояния, контроль состояния оборудования, локальные сети

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Problems of Ensuring Operational Network Monitoring in the Context of Import Substitution

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The article discusses the problems of import substitution of foreign software for national software. It is shown that in the absence of process automation, the execution time of diagnostic commands ranges from 14 to 33 hours. It is concluded that the automation of connection to the national software significantly reduces the data processing up to 335-790 seconds, without the requirement of high qualification of the engineer. A template of connection to the national Zelax software with the use of `text_fsm` library was developed.

Keywords: information systems, information security, risk, security threats, vulnerabilities searching process, network, monitoring, local area networks

Monitoring the network infrastructure of any company is a very topical issue today. Due to the evolution and diversity of business processes, the intensity of information exchange between automated and telecommunications systems forces IT professionals to create increasingly complex networks from an organizational point of view. Large telecom operators store and process sensitive information about their employees, customers, valuable assets, etc., the compromise of which can lead to all kinds of commercial and reputational damage.

With the increase in malware such as viruses and keyloggers, as well as various attacks on system resources (phishing, denial of service, etc.), the risk of compromising confidential information is also increasing, as it is now a strategically valuable asset. The loss of valuable information can cause irreparable damage to the company and even lead to bankruptcy. In addition, methods and means of penetration of malicious information into company information systems are constantly evolving and changing, so the task of ensuring information security in these systems today is quite difficult and urgent.

However, ensuring information security should be a continuous process, the essence of which lies in introducing the most effective methods of protection, constantly monitoring its condition in real time, and identifying the most vulnerable areas. According to international and national standards, information security can be ensured only through a set of protection measures in all structural elements of the system and at all stages of the technical cycle of information processing. One of the most effective elements of this set of measures to prevent information loss is the monitoring of vulnerable nodes throughout the company's network infrastructure.

There are many tasks for which IT security professionals and system administrators need to be able to obtain up-to-date information about the network structure in real time, to be able to manually check the configuration of a device, and to be able to connect to it remotely:

1. System administrators of information and communication systems:

- Monitor events occurring during the operation of the infocommunication system;
- Putting into operation hardware, software and software of the information and communication infrastructure;
- Maintaining peripheral equipment;
- Taking inventory of technical equipment;
- Setting up networking elements of the information and communications technology system;
- Monitor the use of network devices and software resources;
- Manage the security of network devices and software;
- Diagnose network hardware and software failures and errors;
- Monitor the performance of the network infrastructure of the information and communication system;
- Perform scheduled maintenance on network devices and software of the information communication system.

2. Computer systems and network security specialists: Maintain information security software and hardware in computer networks:

- Operate hardware and software security devices on computer networks;
- Carry out performance tests and audits of the efficiency of the applied firmware for protection of information;
- Develop security requirements, security policies for computer systems and networks;
- Conduct security analysis of computer systems;

- Perform instrumental security monitoring of computer systems and networks;
- Conduct expert investigations of computer crimes, offences and incidents;
- Design software and hardware security measures to protect information on computer systems and networks;
- Develop and test security measures to protect information on computer systems and networks;
- Support the development of information security measures for computer systems and networks.

There are several ways to retrieve information from a network device remotely. Selected Zelax devices and most other switches and routers can be accessed via telnet, SSH and HTTP. Let's discuss the advantages and disadvantages of these methods [1]:

3. Telnet (teletype network) is a network protocol that uses port 23 by default and is designed to establish a terminal connection to a device. Its main disadvantage is that it does not encrypt all commands and data sent from one linked device to another, including credentials for authorisation on the device.

4. SSH (Secure Shell) is a network protocol, by default using port 22 and also designed to establish a terminal connection to a device, but already in encrypted form with integrity checks of transmitted information.

5. HTTP-connection via Web interface and device configuration via graphical menu. Used to control home devices due to a clearer interface, but limited in functionality.

SSH connection is deservedly the most popular method of connecting to the device, as it allows a technician-friendly set of commands through a terminal and protects the connection with encryption, but the initial setup of devices is usually done using the Web interface, then the user mode login data is distributed to those employees who need access, with each employee needing information from the device:

- know your credentials for logging on to the network device's terminal;
- be able to connect via SSH to a network device;
- know the commands for a specific device on a specific version of the operating system;
- be able to read command output;
- have a way to store and process the output, e.g. in tables and graphs.

It should be clarified that for manual network structure control conditions: a technician needs to obtain command output containing routing table entries, vlan list and vrf list, on the basis of routing table manually make list of subnets and list of ip addresses specifying vrf and device which is closest to the host with that ip address. The following set of commands should be used to obtain this information:

- Show version — Displays information about the downloaded software and OS;
- Show ip route — Displays the router's IPv4 routing table;
- Show ip next-hop — Displays the next-hop list parameters for routing;
- Show running-config — Displays the configuration currently running in RAM;
- Show vlan — Displays VLAN information;
- Show vrf — Displays VRF information.

The time costs of each manual mode step were experimentally obtained, shown in Table.

Thus, it would take between 335 and 790 seconds to poll one device manually. As there are on average 150 such devices in the network infrastructure, it would take from 50250 to 118500 seconds (14 to 33 hours) for one iteration by one employee, with the resulting table losing relevance by the minute and having limited filtering and correlation search functionality with the risk of error due to human error and duplication of data.

Steps in the process of manually controlling the network structure

Step	Time, s	Assistance tools	Level of competence
Connecting to the device via SSH	5–10	SecureCRT — terminal emulator for Telnet and SSH connection	Low
Entering commands and saving the output as a table file	30–60	SecureCRT and the MyOffice spreadsheet editor	High
Structuring the output into the desired form of tables containing data like «source-destination-device-vrf-vlan», «ip-device-vrf»	240–600	MyOffice spreadsheet editor	Middle
Clarification and correction of data by additional commands	60–120	SecureCRT	High

The scope of work suggests that consideration should be given to partially automating this process in order to remedy the disadvantages of the manual method:

1. Requirement of a high level of competence of the employee.
2. High time costs.
3. The need for additional software.
4. Risk of error due to manual data processing.
5. Presentation as a tabular file, which has limited functionality for creating links and options for visual representation of the data.
6. Access to data as a file limits multi-user viewing and editing.
7. Risk of leakage and unauthorised changes to the file due to storage on a local device or network folder.

The `text_fsm` library is used to convert text output into json format. Thanks to this library it is possible to create templates for any OS network devices of any configuration and any commands, i.e. the prospects of using the software package are very extensive, and the capabilities of the web application allow you to create a base not only for subnets, IP addresses, vlan and vrf networks, but also for other objects that require control and documentation to perform tasks of network administrators and information security specialists.

This library is designed to connect to foreign network devices, and there are no templates for domestic operating systems in this library. In case of substitution of foreign network equipment, solutions of Zelax company are a worthy analogue. They have their own peculiarities of text output of commands [2], therefore for each command it is necessary to make its own template for `text_fsm` library, used in Python programming language [3, 4].

One of the most common commands used by network engineers, «show ip route», which outputs the entire routing table (Fig. 1), was taken as the basis.



Fig. 1. Record from the network device routing table on Zelax OS

To convert the routing table strings from text output to a Python-friendly dictionary format, a template was written, which is shown in Fig. 2. It allows capturing strings that contain the following information:

- packet transmission protocols;
- addresses and subnets;
- masks;
- next hop ip address;
- next hop interface (next hop interface);
- the active connection time (uptime) and so on.

```

Value Filtdown PROTOCOL (\w)
Value Filtdown TYPE (\w{0,2})
Value Required,Filtdown NETWORK (\d{1,3}.\d{1,3}.\d{1,3}.\d{1,3})
Value Filtdown MASK (\d{1,2})
Value DISTANCE (\d+)
Value METRIC (\d+)
Value NEXTHOP_IP (\d{1,3}.\d{1,3}.\d{1,3}.\d{1,3})
Value NEXTHOP_IF ([A-Z][\w\-\.:]+)
Value UPTIME (\d[\w\.:]+)

Start
^Gateway.* -> Routes
# Capture time-stamp if vty line has command time-stamping turned on
^Load\s+for\s+
^Time\s+source\s+is

Routes
# For "is (variably )subnetted" line, capture mask, clear all values.
^s+\d{1,3}.\d{1,3}.\d{1,3}\$/\${MASK}\$is -> Clear
#
# Match directly connected route with explicit mask
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK}\$is\$directly\$connected,\$${NEXTHOP_IF} -> Record
#
# Match directly connected route (mask is inherited from "is subnetted")
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK}\$is\$directly\$connected,\$${NEXTHOP_IF} -> Record
#
# Match regular routes, with mask, where all data in same line
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK}\$s\${DISTANCE}/\${METRIC}\$\$via\$${NEXTHOP_IP}(\,\s\${UPTIME})? -> Record
#
# Match regular route, all one line, where mask is learned from "is subnetted" line
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK}\$s\${DISTANCE}/\${METRIC}\$\$via\$${NEXTHOP_IP}(\,\s\${UPTIME})?\$${NEXTHOP_IF}? -> Record
#
# Match route with no via statement (Null via protocol)
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK}\$s\${DISTANCE}/\${METRIC}\$,\$${UPTIME},\$${NEXTHOP_IF} -> Record
#
# Match "is a summary" routes (often Null)
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK}\$is\sa\$summary,\$${UPTIME},\$${NEXTHOP_IF} -> Record
#
# Match regular routes where the network/mask is on the line above the rest of the route
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK\$/\${MASK} -> Next
#
# Match regular routes where the network only (mask from subnetted line) is on the line above the rest of the route
^${PROTOCOL}(\s|\*)\${TYPE}\s+$NETWORK -> Next
#
# Match the rest of the route information on line below network (and possibly mask)
^s+\${DISTANCE}\$/\${METRIC}\$\$via\$${NEXTHOP_IP}(\,\s\${UPTIME})?\$${NEXTHOP_IF}? -> Record
#
# Match load-balanced routes
^s+\${DISTANCE}\$/\${METRIC}\$\$via\$${NEXTHOP_IP} -> Record
#
# Clear all variables on empty lines
^\s* -> Clearall

EOF

```

Fig. 2. Text_fsm template written to retrieve the output of the "show ip route" command as a json file from Zelax type network device operating systems

Each parameter will be represented as a key-value, which are then convenient for quick automated conversion. An example output in dictionary format, created using the developed template, for a routing table entry (see Fig. 1) is shown in Fig. 3.

```
{  
    "protocol": "0",  
    "type": "IA",  
    "network": "10.74.0.0",  
    "mask": "24",  
    "distance": "110",  
    "metric": "51",  
    "nexthop_ip": "10.5.0.252",  
    "nexthop_if": "Vlan990",  
    "uptime": "7w0d"  
},
```

Fig. 3. Record converted to JSON from routing table

Thus, with the netmiko library and the developed text_fsm template, it is possible to retrieve a huge amount of data on all entries of all routing tables of all network devices built on the same Zelax OS, significantly reducing the time required to obtain the necessary information on network status, regardless of specialists' skills.

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Обзор подходов к построению моделей для генерации изображений по текстовому описанию

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Генерация изображений по текстовому описанию — одна из самых новых возможностей искусственного интеллекта. Данная тема в последние годы продемонстрировала отличное развитие, вызывая растущий интерес в различных исследованиях. Приведен обзор существующих типов моделей, предназначенных для решения задачи генерации изображений по текстовому описанию. Рассмотрены генеративно-состязательные нейронные сети, вариационные автоэнкодеры, авторегрессионные и диффузионные модели.

Ключевые слова: генеративно-состязательные сети, вариационный автоэнкодер, авторегрессионные модели, диффузионные модели, генерация изображений

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Overview of Approaches to Building Models for Generating Images Based on a Text Description

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Generating images based on a text description is one of the latest features of artificial intelligence. This topic has shown excellent development recently, causing a growing interest in various studies. This article provides an overview of the existing types of models designed to solve the problem of generating images based on a text description. Generative adversarial neural networks, models based on a variational autoencoder, autoregressive and diffusion models are considered.

Keywords: generative adversarial networks, variational autoencoder, autoregressive models, diffusion models, text-to-image

Introduction

This article provides an overview of existing approaches to building models for solving the problem of generating images based on a text description. In total, there are 4 main types of models used: generative adversarial neural networks (GAN), models based on a variational autoencoder (VAE), autoregressive models (AR) and diffusion models (Diffusion models).

Generative Adversarial Neural Networks

A Generative Adversarial Network (GAN) is a class of machine learning models that work by having two neural networks that compete with each other [1].

The first network (generator) synthesizes new images, and the second one (discriminator) classifies the generated images and tries to distinguish them from the original ones (Fig. 1). During the learning process, the generative network strives to ensure that the discriminator cannot distinguish the generated images from the original ones.

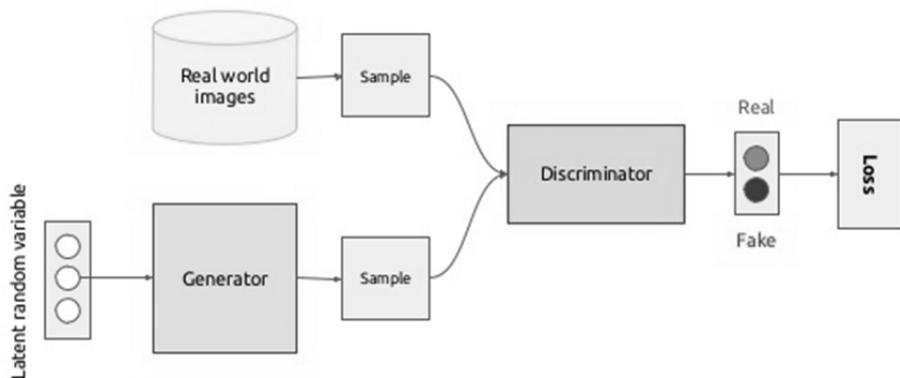


Fig. 1. Classical generative adversarial network

The significance of the training dataset cannot be underestimated. It has the ability to produce realistic features in newly created photographs that can pass off as genuine to the human eye, all thanks to the model that was trained on it.

Models Based on the Variational Autoencoder

The variational autoencoder (VAE) is a type of artificial neural network architecture that falls under the categories of probabilistic graphical models and variational Bayesian methods. This is commonly used in machine learning [2].

Probabilistic generative models like variational autoencoders do not solely depend on neural networks, but they do form a significant part of their architecture, such as in VQ-VAE. Generally, these neural networks have two components, namely, the encoder and decoder, which are responsible for the first and second components, respectively (Fig. 2).

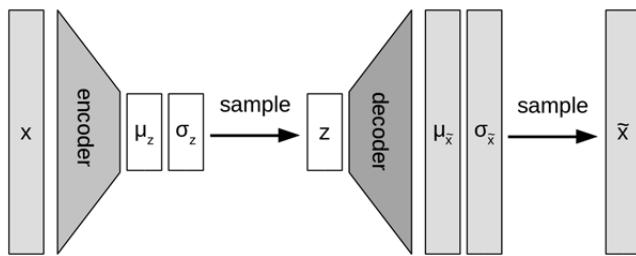


Fig. 2. Variational autoencoder architecture

In variational autoencoder architecture, there are two neural networks, namely, encoder and decoder. The encoder converts the input variable into the latent space connected to variational distribution parameters, generating several samples coming from the same distribution. On the other hand, the decoder performs the opposite function by mapping from latent space to input space to create new data. These networks are usually trained together using the reparametrization technique.

Autoregressive Models

Autoregressive (AR) models are applied to various time-varying processes in nature or economy. Such models are stochastic processes that depend on the previous values of the output variable linearly and on the stochastic term. This formulates the model in the form of a stochastic difference equation [3]. Fig. 3 shows an example of generating pixels for images based on the values of previous pixels.

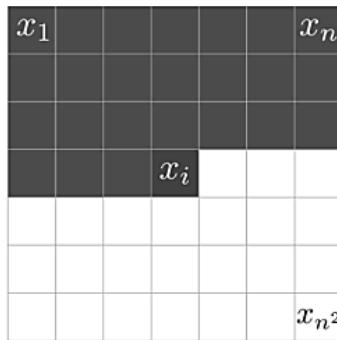


Fig. 3. Generation of pixels in the model

Diffusion Models

Diffusion models, also known as diffusion probabilistic models, are a kind of latent variable model in machine learning. These models are trained by using variational inference to create Markov chains. The primary objective of diffusion models is to reveal the underlying structure of a data set by modeling how data points spread through a latent space [4].

The fundamental idea behind this model is to use a noise reduction algorithm that can take a highly distorted image and restore it to its original quality. This technique is commonly known as backward diffusion (Fig. 4).

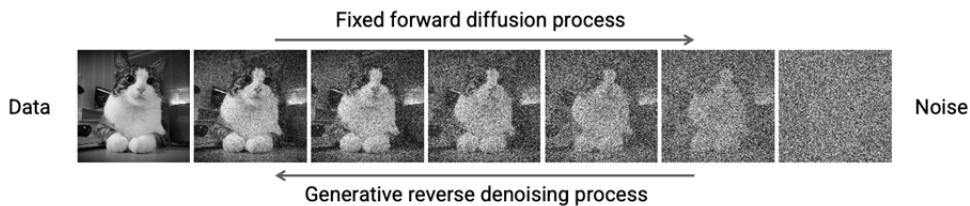


Fig. 4. Forward and backward diffusion

Conclusion

In this article, the main types of models used to generate images based on a text description are considered.

Thus, diffusion models are the most promising and actively developing. Since 2023, images generated by models such as OpenAI's DALL-E 2, Google Brain's Imagen, and StabilityAI's Stable Diffusion have been approaching the quality of real photographs and artwork.

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УДК 004.2

Моделирование темпоральных графов в гетерогенной системе обработки ультра-графов Тераграф

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Рассмотрены основные принципы и схемы моделирования темпоральных графов в гетерогенной системе обработки ультра-графов Тераграф. Темпоральные графы рассматриваются как распределенные во времени последовательности локальных графов, объединяемые в единую структуру посредством темпоральных связей. Введены модели темпоральных графов для оптимизации запросов получения темпоральной доступности, темпорального наименьшего расстояния между вершинами и др. Предложена схема темпоральных графов, предназначенная для размещения их в хранилище гетерогенной системы обработки ультра-графов Тераграф.

Ключевые слова: графы, темпоральные графы, моделирование темпоральных графов, гетерогенные вычисления

Научно-исследовательская работа «Высокопроизводительный аппаратно-программный комплекс для реализации систем предиктивной аналитики больших данных» (Шифр ПРИОР/СН/НУ/22/СП2/2)

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Modeling Temporal Graphs in the Teragraph Heterogeneous Ultra-Graph Processing System

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The paper discusses the basic principles and schemes for modeling temporal graphs in the Teragraph heterogeneous system for processing ultra-graphs. Temporal graphs are considered to be sequences of local graphs distributed in time, combined into a single structure through temporal connections. Models of temporal graphs are introduced to optimize requests for obtaining temporal accessibility, the temporal smallest distance between vertices, etc. A scheme for generating temporal graphs is proposed for placing them in the Teragraph heterogeneous system for processing ultra-graphs.

Keywords: graphs, temporal graphs, temporal graph modeling, heterogeneous computing, Teragraph

Introduction

The interest in complex data analysis has grown significantly in the last decade. Graphs are known to be the most adequate form of real data representation in social networks, computer program structure, the topology of integrated circuits, bio-informatics, knowledge databases, and other areas. As the size of datasets increases, the need to find more efficient computer architecture and software tools for analysis and visualization of large graphs, including improved hardware, becomes obvious.

Data sets and graphs as fundamental concepts of discrete mathematics are usually implemented in the form of data structures in the computer's memory. There exist many types of data structures such as arrays and trees developed to accelerate computations [1, 2], it should be noted that generic CPU pipelines and slow memory subsystems cause latency problems for most types of data structures. These problems are crucial for graph processing since complex models need to be represented in distributed memory cells.

As a result of research to improve graph processing, initially the 32-bit-wide microprocessor in [3] to operate datasets was introduced. This system consists of two different microprocessors: the Central processing unit for working with the generic workload (CPU) and the Structure processing unit for discrete operations (so-called Leonhard SPU). For this reason, the SPU instruction set corresponds to the discrete mathematics operations and quantifiers and is known as a Discrete mathematics Instructions Set, or DISC. The performance level shown in [3, 4] allows one to apply the DISC system within many crucial areas. Execution of some principles of Discrete Instructions Set Computer was generalized for the new version of the 64-bit DISC protocol. In work [4] system improvement by adding a Local Arithmetic Processor (LAP) into one chip with SPU and extending the word to the 64 bits-wide to reach high performance and functionality of a new Leonhard $\times 64$ version was shown to be a general trend of SPU further development.

In the latest work [5] Teragraph supercomputer architecture based on multiple heterogeneous Graph Processing Cores (GPC for short) was introduced. One GPC consists of a multicore Leonhard $\times 64$ microprocessor and RISC-V-based LAP. Teragraph architecture is shown to be the next key stage of the development of Leonhard-based computing systems.

SPU data representation at the program level corresponds to the set of ordered records. Discrete mathematics commands set allows algorithm to efficiently search, add and delete these records. However, the representation of more complex data structure types, such as graphs, requires the development of special methods and their software interpretation.

By the moment, an SPU Application Program Interface (API) has been developed. API retranslates the management of the SPU to the system level. API includes a method of marking a record to fields, i.e. it allows designing data structures with a linear relationship between the location of the field in the record and its value when sorting.

The development of representing graphs for SPU as even more complex structures involve the records construction that has to have non-linear relations between each other, i.e. records should have pointers to other records. Such records are characterized not only by the mutual arrangement of fields but also by the location of records when searching in the set.

Teragraph architecture

The high-performance computer system named “Teragraph” is being developed at the Department of Computer Systems and Networks of the Bauman Moscow State Technical University and is funded under the Priority 2030 government program. The main application of the Teragraph system is to store and process ultra-large graphs. In its development, the main emphasis is on hardware and architecture optimization in order to speed up the work with graphs. The system includes three heterogeneous computing nodes of the same type that interact with each other to extend graph size and parallelism.

Each node consists of a Host subsystem, a Graph Main Memory, an interconnection unit, and a Graph Processing subsystem. The Host subsystem initializes the system and performs network connection to equivalent nodes and external agents (user browsers, sensors, storage, data sources, JavaScript programs, etc.). The Host is connected to the graph processing subsystem via a high-speed PCIe x16 bus, through which the initial graph is loaded into the GPC, as well as data exchange with the SPE and CPE. For that purpose, Host2GPC and GPC2Host FIFO buffers for 512 words for each GPC were established, and addressable Global Memory shared between GPC and Host was used. Every GPC has a significant amount of local structure memory (up to 16 GB for one GPC), which is organized as an associative memory (Local Structure Memory). In addition, every GPC can use DMA access to the Main Graph Memory to load and store the huge graph parts.

The Host subsystem includes two CPU blocks with 26 cores each, 8 TB of non-volatile storage, and the main memory of 1 TB, where graph vertices, edges, and attributes are temporarily stored. The Host subsystem uses now an x86 processor but can be rebuilt with ARM or MIPS microprocessors as well. The Host system's role is to initiate interconnection over the internal and external 100 Gb Ethernet networks, distribute jobs between Leonhard $\times 64$ v4 accelerator cards and collect information from external data sources, i.e. it controls the interaction of all graphs processing resources with the world.

Two parts of software interact with each other to share tasks between Host and graph processing resources. Host kernel is a central piece of software that interacts with the accelerator software core via the PCIe bus, queues, and Global Memory. Accelerator kernel is a RISC-V-based software that is assembled on the host, but transferred to the GPC during the initialization process (like a shader program in modern graphic accelerator cards).

The Graph Storage subsystem for one node includes a 30 TB Main Graph Memory, consisting of four NVMe SSD drives of 7.7 TB each. NVMe (Non-Volatile Memory

Express) technology provides a communication interface and a driver that takes advantage of the increased bandwidth provided by PCIe. It improves the productivity and efficiency of large-scale graph processing.

The Teragraph interconnection block consists of two 100Gb Ethernet modules and provides interaction between heterogeneous nodes and external resources. The Graph Processing Subsystem consists of some Leonard $\times 64$ v4 cards (from three to four card versions are used), each card including up to 4 Core Groups, each of which consists of up to 6 Graph Processing Cores (up to 24 GPC per card).

All GPCs of the Core Group use the same Global Memory and DDR memory, connected via the AXI buses. Thus, each Core Group is connected to 16 GB of DDR4 memory, which stores the graphs as a sequence of 64-bit key-value records. Thus, each GPC uses dedicated 2.5 GB of Local Structure Memory.

The SPE in GPC stores information in LSM as key-value pairs in the form of non-overlapping B+ trees. To provide the tree leaves execution, the SPE has a pipeline parallel microarchitecture, and not only performs the search in subtrees and provides insertion and deletion operations via the tree structure but also allocates and frees memory for nodes and leaves.

Tree processing is divided into “tree tracing” and “leaf operation” stages. This allows GPC to speed up the computing process over the keys and to store the search path in the internal B+ tree cache. The sequence of tree nodes on the path from the root to the target leaf is called “trace”, and is always ready for immediate access by the so-called Trace Block.

After the tree tracing has finished, the second stage starts by the Operational Buffer (OB) to operate keys and values on the bottom leaf level. To perform this for large data structures, the lnh64 SPE memory subsystem includes multilevel storage devices, described below. The first level is the register memory that stores nodes and leaves inside the Trace Block and OB. It is organized as an associative memory to perform key searching, shifting, union, and other low-level operations. The second level is the boundary addressable memory (Internal Structure Memory, ISM), accessed by the Trace Block to define the physical addresses for the next tree level. The third memory level is the Local Structure Memory, described above.

After the full path becomes known for the Trace Block, the target leaf is loaded to the Operational Buffer from the ISM. After the leaf is processed in the OB, it uploads the results back to the ISM. If any further processing is needed, then the Trace Buffer loads the new trace and OB processes the new leaf again. At the end of execution, the OB puts the result into the output queue, and since CPE can read it.

Temporal graphs

Temporal graphs is a graph representation that encodes temporal data into the local simultaneous structure while fully retaining the temporal information of the original data in the temporal structure. This representation allows us to explore the dynamic temporal properties of data via existing graph algorithms (such as shortest path) with no need for data-driven simulations. Metrics that could be applied to study and explore temporal graphs are presented in the work [6].

Let's define the temporal graph as shown in formula. In this definition, a temporal graph consists of a set of vertex sets belonging to particular graph at particular measurement time, a set of simultaneous edges, and a set of temporal edges. It is possible to

weigh both simultaneous and temporal edges, however, in this paper, only temporal edges are weighted. The weight of the temporal edge will denote the time difference between the vertices in time.

$$G = (\{V_t\}, E_{simultanius}, E_{temporal})$$

Additional rules for constructing a temporal graph are:

- Each point in time contains its own set of simultaneous vertices. The same vertex of the graph as a whole will thus be designated over time by a set of vertices, for example, $G_t = (V_t, E_{simultaneous}), G_t \subset G$.

- Temporal edges are necessarily directed and exist only between the same vertex at different times. So, temporal edges, taking into account the weight, will be set as a triple $(v_i, v_j, w) \in E_{temporal}, v_i \in V_i, v_j \in V_j, i < j$.

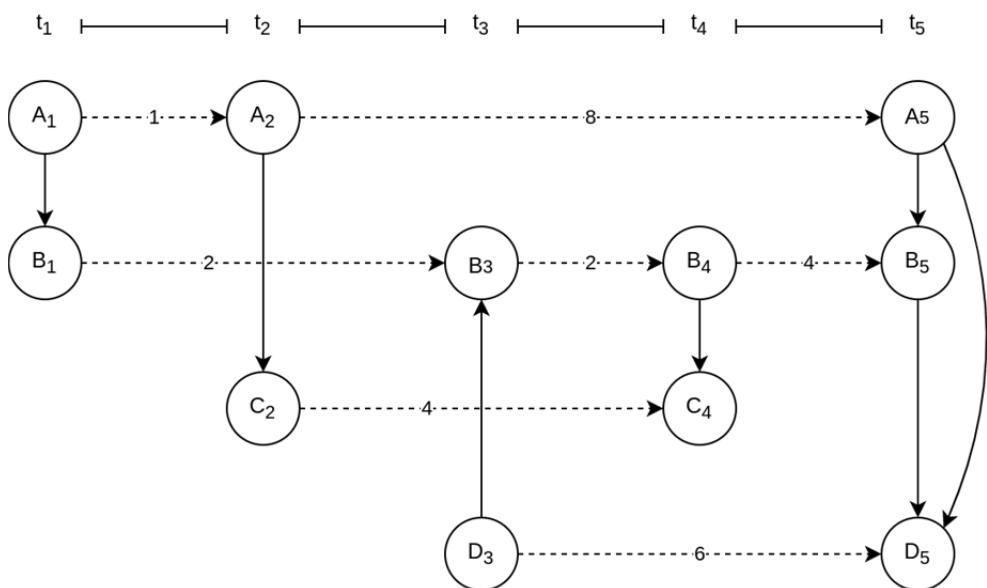
- Simultaneous edges are assumed to be directed with zero weight. Simultaneous edges can only exist between simultaneous vertices, i.e. the set of simultaneous edges will be given by the expression $(x_t, y_t) \in E_{simultaneous}, x_t, y_t \in V_t$.

Figure shows an example of a temporal graph built according to the rules indicated above. To provide an example, the difference between points in time is not constant, e.g., $t_5 - t_2 = 8$.

Work [6] defines several important parameters for operating a temporal graph:

- Temporal proximity, defined as the value of the shortest path between two vertices at different points in time. Designated as $p(a, b, i, j), a \in V_i, b \in V_j$.

- Temporal availability, defined as normalized number of paths between two vertices from a zero time point to the end of the data collection time. Mathematically, this would be as $V(a, b) = \text{size}\{p(a, b, i, null) | p! = null\}/n$.



An example of temporal graph

Temporal graphs modeling

The main idea of placing generic graphs in the Teragraph system is given in [7]. The basic principle is to use the DISC capabilities to search for keys in the Leonhard x64 working memory using NGR and NLS commands. These commands provide the ability to search for the nearest neighbor above or below existing keys without requiring full specification. Thus, it is possible to split the Leonhard \times 64 key into so-called fields and search for those fields at most significant digits of keys.

Using NGR and NLS commands it is possible to create a structure in Leonhard $\times 64$ memory with the pre-solved temporal proximity problem for all vertices.

In the case of using temporal graphs, in addition to vertex identifiers and edge weights, time parameters for temporal determination should also be taken into account. Further, the key should be split into meaningful fields from the most significant to the least ones:

- index of the current vertex;
 - time of registration of the current vertex;
 - weight of the total path from the current vertex to the first vertex in the path;
 - registration time of the previous vertex in the path;
 - index of the previous vertex in the path.

So to find the full path from some node to start (first vertex) NGR for this vertex and 0's should be called. The total path can be determined by applying NGR over the previous vertex. The algorithm of filling structure is implemented via NGR call over vertexes for another new weight in the convergence matrix. It is possible to optimize this algorithm for a specific task if needed.

The algorithm steps are:

- exclude the column of the vertex to which the path is searched from the adjacency matrix;
 - for each adjacency vector in a matrix (taken by row) and for every node in this vector:
 - NGR previous node (index of adjacency vector) to find the shortest path to this node;
 - increment path with the weight between current and previous nodes;
 - insert a new record in SPU with counted parameters.

Table 1 shows the adjacency matrix for the graph shown in Figure, and Table 2 shows the completed Leonhard \times 64 key structure for finding the shortest path starting from the top. It is easy to see that this matrix is sparse and effectively replaceable by SPU structures.

Adjacency matrix of temporal graph example

Table 2
Teragraph SPU structure key for shortest-path problem solution from vertex A₁

Teragraph SPU structure key				
Vertex	Vertex Time	Weight	Prev. Vertex Time	Prev. Vertex
A	2	1	1	A
A	5	9	2	A
B	1	0	1	A
B	3	2	1	B
B	4	4	3	B
B	5	8	4	B
B	5	9	5	A
C	2	1	2	A
C	4	4	4	B
C	4	5	2	C
D	5	9	5	A
D	5	9	5	B

This Leonhard $\times 64$ structure is only a stage in solving a complete problem, but it fully demonstrates the storage format of the described structure for a particular subtask. To prepare the complete structure only sort order change is required.

Vertex D₃ is not present in the structure because there are no paths from it to the vertex A₁. In fact, D₃ vertex should appear after the whole problem solution.

Edges of the temporal graph could be completely restored using the reverse procedure of passing from all end vertices to the first one.

According to the presented description of the temporal graph storing in the Teragraph system method, the temporal parameters of the graph could be obtained as follows:

- Temporal proximity is computable via requesting NGR from this vertex, which will match the request, where is the vertex on which the structure, e.g., $p(A, B, 1, 5) = NGR(B, 5, 0, 0, 0) = 8$;
- Temporal availability can be obtained as the quotient of dividing by the sum of record values between NGR and NLS query results by their number. In the case of an NLS query use, hFF as padding for blanks must be specified. Respectively,

$$V(A, B) = 1/N \sum (NGRleft(B, 0, 0, 0, 0), NLS(B, hFF, hFF, hFF, hFF)) = 4.8.$$

Conclusions

Temporal graph's basic principles and schemes for modeling in a heterogeneous Teragraph ultra-graph processing system are considered. Temporal graphs are presented as sequences of local graphs distributed in time, combined into a single structure through temporal connections. Models of temporal graphs are introduced in order to optimize requests for obtaining temporal accessibility, the temporal smallest distance between vertices, etc. A scheme of temporal graphs is proposed for placing them in the Teragraph heterogeneous system for processing ultra-graphs. As further work, the study of dynamic

features of temporal graphs behavior as part of the Teragraph system and experimental testing of the proposed models are planned.

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for implementing predictive analytics systems for big data”
(Cipher ПРИОР/CH/HV/22/СП2/2)*

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Разработка кросс-платформенного мобильного приложения для фитнес-упражнений

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НИУ ВШЭ

За последние несколько лет фитнес-индустрия пережила значительное падение доходов из-за пандемии. В то время как многие сотрудники фитнес-центров были уволены, виртуальные тренировки, домашние спортзалы и занятия на открытом воздухе стали чрезвычайно популярны. Исходя из этого, можно предположить, что спрос на занятия фитнесом со стороны опытных инструкторов сейчас превышает предложение. Основная цель данного проекта — обеспечить рабочие места для фитнес-тренеров и создать условия для общения посетителей тренажерного зала с профессиональными фитнес-инструкторами. Для достижения этой цели было создано кроссплатформенное мобильное приложение для фитнес-инструкторов и их потенциальных клиентов. Главной особенностью приложения является функция создания уроков, которая дает пользователям возможность указать тип занятий, которые они хотят предоставить или получать. Чтобы установить беспрепятственный контакт между пользователями, эта информация вместе со ссылкой на ее создателя размещается на карте на основе указанного местоположения заинтересованных участников в виде пин-поинта.

Ключевые слова: виртуальные тренировки, кроссплатформенное приложение, мобильное приложение для фитнеса, фитнес-индустрия

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Developing a Cross-Platform Mobile Application for Fitness Exercises

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Over the past few years, the fitness industry has experienced a significant drop in revenue due to the pandemic. While many fitness center employees have been laid off, virtual workouts, home gyms and outdoor classes have become extremely popular. Based on this data, it can be assumed that the demand for fitness classes from experienced instructors now exceeds the supply. The main goal of this project is to provide jobs for fitness trainers and to create an environment for former gym members to interact with professional fitness instructors. To achieve this goal, a cross-platform mobile app was created for fitness instructors and their potential clients. The main feature of the app is a lesson creation feature that gives users the ability to specify the type of fitness lessons they want to give or receive. To establish a seamless connection between users, this information, along with a link to its creator, is placed on a map based on the specified location as a pinpoint.

Keywords: virtual workouts, cross-platform application, fitness mobile application, fitness industry

Introduction

A number of studies [1–4] show that mobile applications motivate people to exercise on a regular basis. According to Pilloni et al. [4] the main focus in developing fitness and wellness apps should be to create a relationship between users, as well as to provide support from real personal trainers to make training safer and more motivating. Because of the pandemic-induced gym shortage and with the help of technological improvements in Internet connectivity and streaming, virtual fitness services such as Peloton are becoming increasingly popular. The online fitness market was valued at \$6 billion before restrictions were imposed, and is projected to grow significantly to nearly \$60 billion in 2027.

However, online fitness apps lack the helpful feedback, experience, and personal interaction that professional fitness trainers can provide. A reasonable solution to this problem is seen in the combination of the user experience of a mobile app and a personal fitness lesson given by an experienced instructor. The goal of this project is to create a service that realizes the potential of this combination. Initially, the service is to be implemented as an MVP. After obtaining the necessary funding, the product will serve as a prototype for further development. Thus, the main goal is to create an MVP and present it to investors.

A thorough analysis of the fitness app market has shown that many mobile apps, such as Strava™ or FitOn™, perform the task of motivating their users by providing them with daily goals and the ability to connect with their friends through an integrated and conveniently simplified social network. These two features allow users to experience the thrill of competition and achievement, which are essential emotions for fitness enthusiasts. However, the mobile app is designed for a different audience. The target audience is mostly made up of people for whom coaching and professionalism are important in self-improvement. The currently popular fitness apps mostly offer simple guides that users interpret on their own. Thus, no analogues currently exist in this market.

This research is organized around the following aspects: requirements list gathering; application architecture design; user interface design; laying the foundation for future platform development; database and API integration; functionality implementation; mobile application testing.

The mobile app being developed as a product faces competition in the following two markets: the fitness app market and the freelance market. All popular freelance platforms can be divided into two groups: apps for freelancers with specific skills and all types of freelancers. After conducting the study, no attractive fitness-oriented freelance sites were found among the platforms of the first group. Fitness instructors who are not able to work at the gym mostly accept orders on platforms from the second group. Since these platforms do not belong to a certain category, there is no need to check freelancers' professional skills before granting them access to the platforms' services. This app, which is specifically designed as a platform for freelance fitness trainers, guarantees high quality services by verifying instructors' identity and fitness experience.

Framework for cross-platform mobile app development and project implementation

Flutter was chosen as an open source framework because it has clear state management libraries and draws widgets very quickly. React Native was also one of the reasonable candidates, but it proved too complex for MVP.5. Currently, Yandex Maps and MapBox are integrated into the application. MapBox allows unlimited queries for free, and Yandex Maps is very accurate in Russia, which is the starting country where the app is originally supposed to be released.

The application backend is completely controlled by Firebase. This includes authentication methods, databases and hosting.

Authentication requires an email address and password. Any user can create an account, log in, and reset their password. Authentication data, including the user ID and email, is saved automatically. Fig. 1 presents a screenshot of authenticated accounts.

The application uses only one type of database: the Firestore database. It contains two collections: Users and Lessons. Each row in the users collection contains a user ID, a check digit, and user profile information. The rows in the lessons collection contain all the information provided by any user, including creator IDs and an array of user IDs that represents the people interested in any particular lesson.

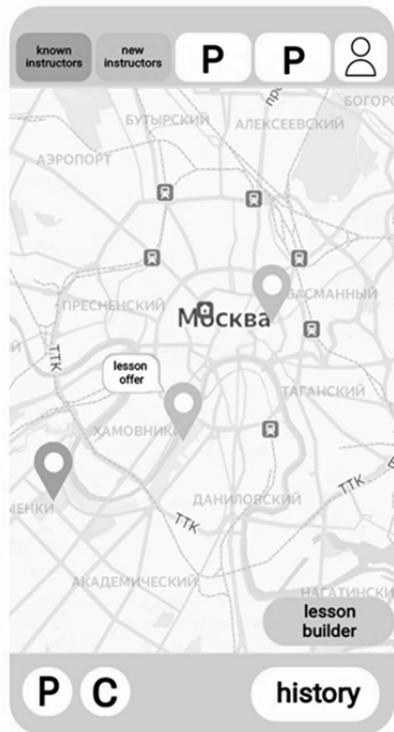
Hosting is automatically provided by Firestore. The application deployment process, which has been tested before is also very simple.

Since only authentication data is automatically loaded into Firebase, users and lessons must be loaded manually. This is achieved by creating two classes, one for users and one for lessons.

The user class contains the following variables: UID (user ID); Username; Email; Bio (short description); Profile picture; Phone number; Document information (for instructors); Contacts (list of social networks); Followers (list of user IDs); Following (list of user IDs); Verification check (for instructors).

The lesson class contains the following variables: UID (creator's ID); Location; Description; Type; Time (length of the lesson); Price; List of interested users.

It also has an account verification method for instructors and a method for changing profile information or deleting an account. The class also has a method for changing lesson information, deploying the lesson to the database, and deleting the lesson.



Map View

Fig. 1. Authentication

The application is built on several «screens», which are either stateless or statefull widgets. The Stateless widget does not react to user actions, while the Statefull widget has the ability to change its properties.

The user experience

When the user opens the application, he is greeted by a login screen. The screen prompts the user to enter their email and password. Since the user does not yet have an account, he cannot log in and is forced to press the login button below. The button has a tap function that, when triggered, creates a registration screen. To register, the user must provide a username, email address and password. Once the registration button is clicked, the user is taken to the map screen and can begin using the app. If the user forgets their password, there is a password reset screen.

Continuing with the theme of user experience, when the map screen is built, many options are offered to the user. First of all, the dots on the map are fitness lesson offerings. They are presented in purple and pink. The purple dot means that it was created by one of the people you are following, while the pink dots are created by random people living nearby. When a user clicks on a dot, a lesson viewer widget appears. If the user is interested in the lesson, they should click the «Like» button located in the lower right corner of the widget. If the other party decides to take/give lessons from/to another participant, they pair

up and get each other's nicknames. The nickname is enough information to keep track of the instructor/student and to write messages to them.

Authentication				
Users	Sign-in method	Templates	Usage	
<input type="button" value="Add user"/> <input type="button" value="C"/> <input type="button" value="::"/>				
Identifier	Providers	Created ↓	Signed In	User UID
[REDACTED]	[REDACTED]	Apr 18, 2022	Apr 18, 2022	i4yqRM@uGJMZxVKiuTxaly4bVwy2
[REDACTED]	[REDACTED]	Apr 18, 2022	Apr 18, 2022	pCAoYrGYANhZg3DQJGikP6X1NL...
[REDACTED]	[REDACTED]	Apr 16, 2022	Apr 16, 2022	4Xoqtisrr6gPwSkGokaSmdNmRq2
[REDACTED]	[REDACTED]	Apr 15, 2022	Apr 15, 2022	iUgf16sHUXQABG5tJKISV5CYYC2
[REDACTED]	[REDACTED]	Apr 15, 2022	Apr 15, 2022	GqX7jJo2QSOPVn8q0PCDqemY3...
[REDACTED]	[REDACTED]	Apr 15, 2022	Apr 15, 2022	3vHBxJpFQSOitNX3fhBj0Z7z07f1
[REDACTED]	[REDACTED]	Apr 15, 2022	Apr 15, 2022	oyWtExwdAR7umWuFFzEQ7bwV...
dzondberg@gmail.com	[REDACTED]	Apr 15, 2022	Apr 18, 2022	HjI4882pitQ2bMtXuufA1ENQwt2
[REDACTED]	[REDACTED]	Apr 15, 2022	Apr 15, 2022	EmPSgUZxD0a4mGNo11JxOh6lu...
Rows per page: 50 < 1 - 9 of 9 >				

Authenticated accounts

Fig. 2. The design of the app

The create lessons button is for creating lesson requests/proposals. The profile button in the upper right corner opens the profile screen. The «C» button opens the chat screen. The «History» button allows the user to view the number of lessons completed. Finally, the buttons labeled with a «P» are currently the conventions for future functionality. Fig. 2 presents the design of the application.

Conclusion

As it was discovered through a literature review, there are a number of factors that motivate people to use mobile fitness and physical activity apps. To address this, a mobile fitness app was developed and a high fidelity prototype was created.

To summarize, we can state that in the course of the project assignment, a cross-platform mobile application was created; a cloud solution was integrated; a state management system was developed; and several APIs were implemented.

The main focus in developing this app was that supporting a personal trainer, as well as encouraging sociability and creating communities of users is very motivating to exercise in the long run.

Prospects for further research in this area include an analysis of which mobile app design strategies are more suitable for increasing physical activity and motivating users.

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УДК 004.89

Использование диффузионных моделей для синтеза изображений по текстовому описанию: принципы, обучение и преимущества

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Рассмотрена проблема генерации изображений на основе текстовых описаний. Представлены диффузионные модели, как эффективный подход к решению этой проблемы. Диффузионные модели используют процесс диффузии для генерации выборок из распределения, и они могут быть легко скондиционированы на различные текстовые описания для генерации разнообразных и качественных изображений. Исследованы основные характеристики диффузионных моделей, включая использование скрытого пространства и встроенных текстовых эмбеддингов для улавливания сложных зависимостей между текстовыми описаниями и сгенерированными изображениями. Приведено обсуждение процесса обучения диффузионных моделей, который включает в себя изучение функции отображения, функций трансформации, расширения уровней шума, скрытого пространства и встроенных текстовых эмбеддингов с использованием максимального правдоподобия. Подчеркнуты преимущества диффузионных моделей перед другими подходами, включая их способность генерировать разнообразные и семантически значимые изображения.

Ключевые слова: диффузионные модели, генерация изображений, генерация изображений по тексту, пространство меньшей размерности, текстовые эмбеддинги

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Application of Diffusion Models for Text-to-Image Synthesis: Principles, Training, and Advantages

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This article discusses the problem of text-to-image synthesis, which involves generating realistic images from textual descriptions. The article presents diffusion models as an effective approach to this problem. Diffusion models use a diffusion process to generate samples from a distribution, and they can be easily conditioned on different textual descriptions to generate diverse and high-quality images. The article describes the key features of diffusion models, including the use of a latent space and clip text embeddings to capture the complex dependencies between the textual descriptions and the generated images. The article also discusses the training process for diffusion models, which involves learning the mapping function, transformation functions, noise level schedule, latent space, and clip text embeddings using a maximum likelihood estimation objective. Finally, the article highlights the advantages of diffusion models over other approaches, including their ability to generate diverse and semantically meaningful images.

Keywords: *diffusional models, image generation, text-to-image, latent space, text embeddings*

Introduction

Text-to-image synthesis is an emerging field that has been attracting considerable attention from the research community in recent years. This field involves the generation of realistic images from textual descriptions, which has numerous practical applications in areas such as entertainment, education, and advertising. The generation of images from text involves numerous technical challenges, such as the need to understand and interpret natural language descriptions and the need to generate images that are both semantically meaningful and visually realistic.

One of the most promising approaches to text-to-image synthesis is the use of diffusion models, which have been shown to be highly effective at generating high-quality images from text. Diffusion models are a class of generative models that use a diffusion process to generate samples from a distribution. These models have been shown to be highly effective at generating images that are both semantically meaningful and visually realistic, and they have several advantages over other approaches to text-to-image synthesis.

Existing Models and Approaches

There are numerous models and approaches to text-to-image synthesis, including generative adversarial networks (GANs), variational autoencoders (VAEs), and transformer-based models. These models differ in their architecture and training procedures, but they all share the goal of generating high-quality images from textual descriptions.

GANs are a popular approach to text-to-image synthesis that use a generator network and a discriminator network to generate realistic images from textual descriptions. The generator network takes as input a random noise vector and a textual description and generates an image, while the discriminator network evaluates the realism of the generated image [1]. GANs have been shown to be highly effective at generating realistic images, but they can be challenging to train and can suffer from mode collapse (Fig. 1).

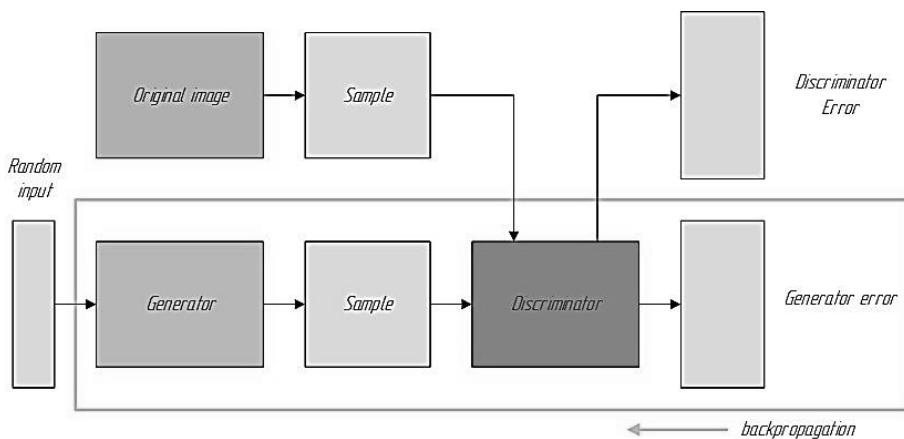


Fig. 1. General architecture of generative adversarial network(GAN)

VAEs are another popular approach to text-to-image synthesis that use an encoder network and a decoder network to generate images from textual descriptions. The encoder network takes as input a textual description and encodes it into a latent space, while the decoder network takes a sample from the latent space and generates an image [2]. VAEs have been shown to be effective at generating high-quality images, but they can be challenging to train and can suffer from blurry outputs (Fig. 2).

Transformer-based models are a recent development in text-to-image synthesis that use self-attention mechanisms to generate images from textual descriptions. These models have been shown to be highly effective at generating realistic images, but they can be computationally expensive to train and can require large amounts of training data.

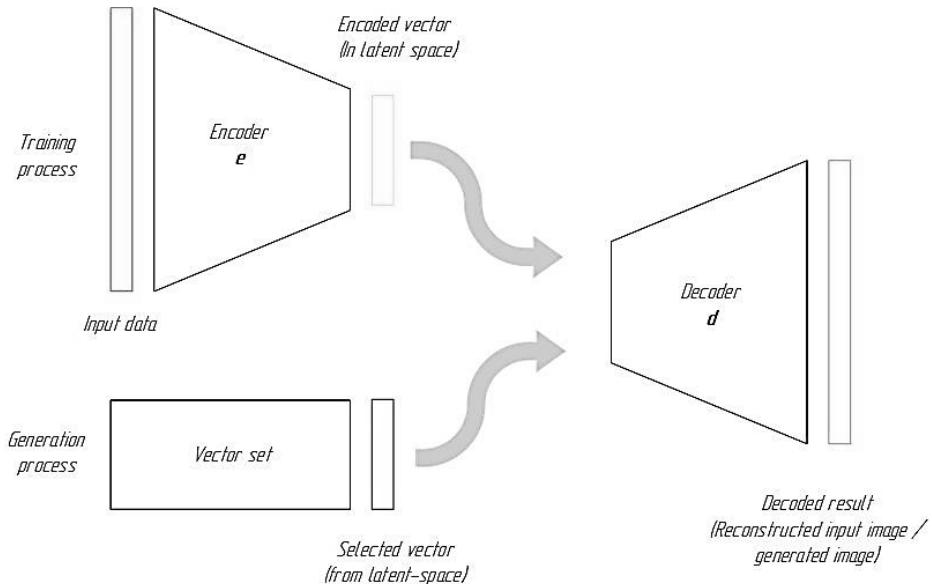


Fig. 2. General architecture of variational autoencoder

Diffusion Models

Diffusion models are a class of probabilistic models that aim to learn the underlying distribution $p(x)$ of a given dataset by progressively removing noise from a normally distributed variable. This process corresponds to the inverse of learning a fixed Markov chain of length T . In the context of image synthesis, these models utilize an overweighted variational lower bound $p(x)$ to reflect the denoising results. Specifically, these models can be represented as a sequence of denoising autoencoders, each of which is equally weighted [3]. The denoising autoencoders are trained to predict the original version of the input data, denoted as x_0 , given a noisy version of the input data, denoted as x_t , at each step t . Based on this, the corresponding problem can be simplified to

$$L_{DM} = E_{x, \epsilon \sim N(0,1), t} [\|\epsilon - \epsilon_\theta(x_t, t)\|_2^2],$$

with t uniformly chosen from $\{1, \dots, T\}$.

As with other generative models, diffusion models have the capability to model conditional distributions in the form of $p(z|y)$. To achieve this, a conditional denoising autoencoder $\theta(z_t, t, y)$ can be employed to drive the synthesis process with input Y , which may take the form of text, semantic maps, or other data types, for subsequent image-to-image conversion. However, in the realm of image synthesis, there is still much to be explored in terms of combining the generative power of diffusion models with conditions beyond class labels or blurred versions of the input image.

Efforts are currently underway to develop diffusion models into more adaptable image generators. In order to preprocess Y from various modalities, such as language prompts, a domain-specific encoder $\tau\theta$ is utilized to project Y into an intermediate representation $\tau\theta(y) \in RM \times dt$. This representation is subsequently mapped to the intermediate layers of the neural network via cross-attention mechanisms.

Principles of Diffusion Models

Diffusion models are a class of generative models that use a diffusion process to generate samples from a distribution. These models are based on the idea of simulating the diffusion of a signal through a system of interacting particles. The diffusion process is modeled using a sequence of diffusion steps, each of which transforms the current state of the system into a new state. The final state of the system is then used as a sample from the target distribution.

They are based on the principle of simulating the diffusion of a signal through a system of interacting particles. The diffusion process is modeled using a sequence of diffusion steps, each of which transforms the current state of the system into a new state. The final state of the system is then used as a sample from the target distribution (Fig. 3).

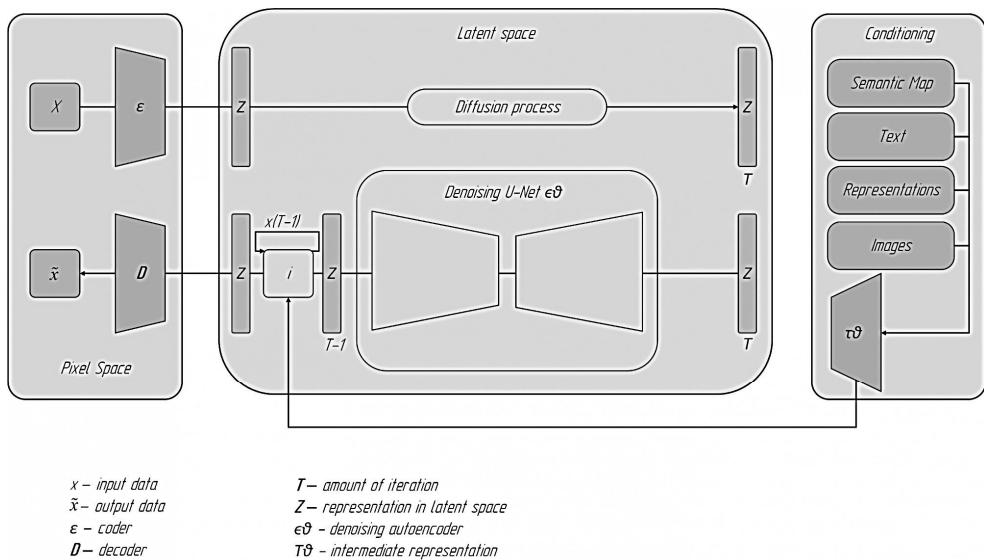


Fig. 3. Diffusion models architecture for image generation

In the case of text-to-image synthesis, the diffusion process is used to generate images from textual descriptions. The process starts with a noise vector z , which is transformed into an initial image x_0 using a learned mapping function f . The initial image is then transformed through a sequence of T diffusion steps, each of which corresponds to a transformation function that maps the current image x_t to a new image x_{t+1} [4]. The sequence of diffusion steps is controlled by a noise level schedule, which determines the amount of noise to add at each step (Fig. 4).

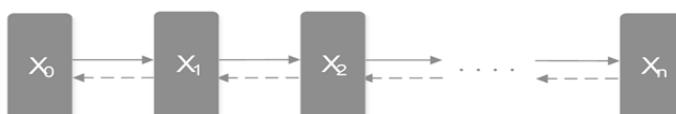


Fig. 4. General concept of diffusion models training

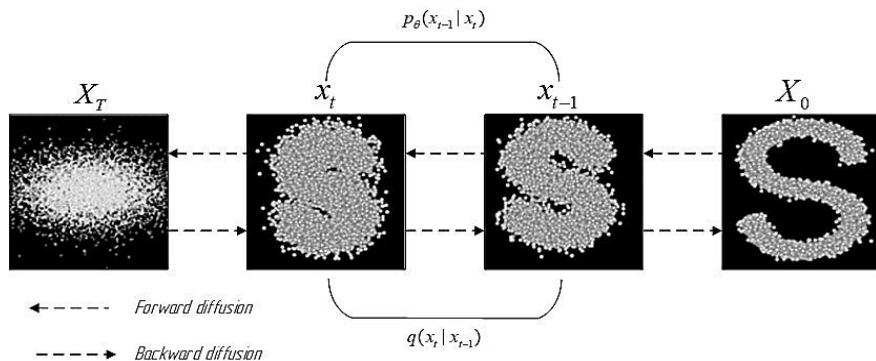


Fig. 5. Concept example of diffusion models training

At each diffusion step, the transformation function is applied to the current image x_t in the form of an additive Gaussian noise process, which is scaled by a factor that depends on the noise level schedule. The resulting image x_{t+1} is then used as the input to the next diffusion step, until the final image xT is obtained. The final image xT is then used as a sample from the target distribution (Fig. 5).

Latent Space usage in Diffusional models

One of the key features of diffusion models is the use of a latent space to represent the distribution of the images. The latent space is a low-dimensional representation of the images that captures the underlying structure of the data. In diffusion models, the latent space is learned through the training process, and it is used to generate new samples from the target distribution [5].

In the context of diffusion models, the latent space is learned through the training process. Specifically, the model learns to map the initial noise vector to the latent space and then maps the latent space to the final image. During the generation process, a noise vector is sampled from a standard Gaussian distribution and mapped to the latent space using the inverse mapping function. The resulting point in the latent space is then mapped to an image using the forward mapping function, resulting in a new image that is a sample from the target distribution.

The use of a latent space in diffusion models has several advantages. One of the main advantages is that it allows for efficient sampling from the target distribution. Instead of sampling directly from the high-dimensional space of images, which is computationally expensive, the model samples from the much lower-dimensional latent space. This results in faster generation times and more efficient use of computational resources.

Another advantage of the latent space is that it allows for fine-grained control over the generation process. By manipulating the points in the latent space, it is possible to control the visual features of the generated images, such as the shape, color, and texture. This can be particularly useful in applications where precise control over the visual content of the generated images is required.

Overall, the use of a latent space in diffusion models is a powerful technique for text-to-image synthesis. By learning a compressed representation of the image distribution, it allows for efficient sampling and fine-grained control over the generation process, resulting in high-quality and diverse images that are semantically meaningful and visually realistic.

Clip Text Embeddings

Clip text embeddings are another important feature of diffusion models for text-to-image synthesis. These are learned representations of textual descriptions that are used to condition the generation of images. Clip text embeddings are learned jointly with the latent space during the training process and they are used to control the semantic content of the generated images [6].

Clip text embeddings are extracted using the Contrastive Language-Image Pretraining (CLIP) model, which is a large-scale transformer-based model that learns joint representations of images and texts. The CLIP model is trained on a large dataset of images and their associated textual descriptions, which allows it to learn meaningful embeddings that capture the semantic content of the texts and the visual information of the images.

In the context of diffusional models for T2I, clip text embeddings are used to condition the generation of images. During the inference phase, a textual description is first encoded into a clip text embedding using the pre-trained CLIP model. This clip text embedding is then used to condition the generation of the corresponding image, by concatenating it with the latent vector that is sampled from the learned latent space. The concatenated vector is then passed through the generator network, which produces the corresponding image [7].

By using clip text embeddings, diffusional models for T2I are able to generate images that are semantically related to the input text. The learned joint representation of text and images allows the model to understand the correspondence between textual descriptions and visual content, which leads to the production of high-quality and diverse images [8].

Training Process

The training process for diffusion models involves learning the mapping function f , the transformation functions, the noise level schedule, the latent space, and the clip text embeddings. The training process is typically done using a maximum likelihood estimation (MLE) objective, which involves maximizing the likelihood of the training data under the model (Fig. 6).

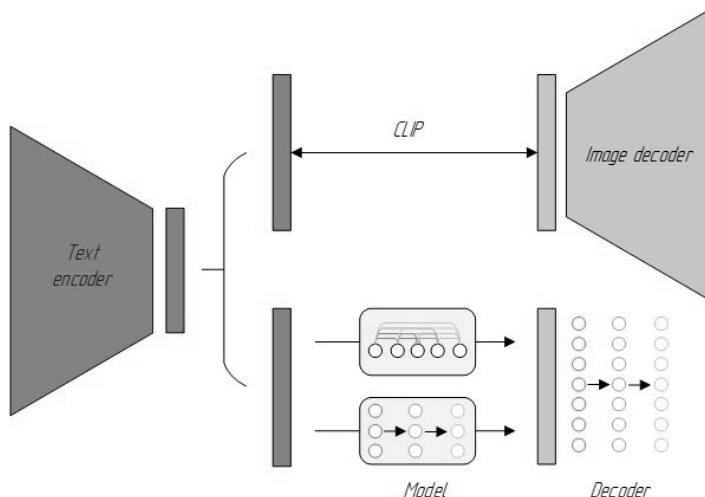


Fig. 6. The principle of Text To Image technology in diffusion models

The MLE objective is typically optimized using stochastic gradient descent (SGD) or a related optimization algorithm. The optimization process involves iteratively updating the parameters of the model to minimize the difference between the generated images and the training data [9].

Training Process for Diffusion Models:

1. Data preparation: The first step is to prepare the training data, which consists of pairs of textual descriptions and corresponding images. The images may be resized and normalized to a fixed size to facilitate training.

2. Learning the mapping function f : The next step is to learn the mapping function f , which maps a noise vector z to an initial image x_0 . The mapping function f is typically implemented using a neural network, such as a convolutional neural network (CNN). The mapping function is learned by minimizing the reconstruction error between the generated images and the training data using a loss function such as mean squared error (MSE).

3. Learning the transformation functions: Once the mapping function f is learned, the next step is to learn the transformation functions that are used to transform the initial image into the final image. The transformation functions are typically implemented using invertible neural networks, which enable the generation of high-quality and diverse images.

4. Learning the noise level schedule: The noise level schedule is a key component of the diffusion process, as it determines the amount of noise to add at each diffusion step. The noise level schedule is typically learned using a annealed Langevin dynamics (ALD) algorithm, which involves iteratively refining the noise level schedule until the generated images match the training data.

5. Learning the latent space and clip text embeddings: The latent space and clip text embeddings are learned jointly with the other components of the model during the training process. The latent space is learned using a maximum likelihood estimation (MLE) objective, which involves maximizing the likelihood of the training data under the model. The clip text embeddings are learned using a contrastive loss function, which encourages the embeddings of semantically related text descriptions to be close together in the embedding space [10].

6. Optimization: The model parameters are optimized using stochastic gradient descent (SGD) or a related optimization algorithm. The optimization process involves iteratively updating the parameters of the model to minimize the difference between the generated images and the training data. The training process may take several hours or even days to complete, depending on the complexity of the model and the size of the training data.

Advantages of Diffusion Models

Diffusion models have several advantages over other approaches to text-to-image synthesis. One of the main advantages is their ability to generate high-quality images that are both semantically meaningful and visually realistic. This is due to the fact that diffusion models can capture the complex dependencies between the textual descriptions and the generated images, which can be challenging for other approaches.

Additionally, diffusion models can easily be conditioned on different textual descriptions, allowing for the generation of a wide range of images that are semantically related to the input text.

Moreover, diffusion models use a latent space to represent the distribution of the images, which is learned through the training process and is used to generate new samples

from the target distribution. The clip text embeddings, learned representations of textual descriptions, are used to control the semantic content of the generated images.

Lastly, the training process for diffusion models involves learning the mapping function, the transformation functions, the noise level schedule, the latent space, and the clip text embeddings, and is typically done using a maximum likelihood estimation objective optimized through stochastic gradient descent or related algorithms.

Conclusion

In conclusion, the generation of images from textual descriptions is a rapidly evolving field with numerous practical applications. Diffusion models have emerged as a highly effective approach for this task, using a diffusion process to generate high-quality and visually realistic images that are semantically meaningful. This is achieved through the use of latent space and clip text embeddings, which allow for the capture of complex dependencies between the textual descriptions and the generated images.

Diffusion models also have the advantage of being able to generate diverse samples from the target distribution, making them a promising approach for future research in this field. The training process for diffusion models involves learning several key components, including the mapping function, transformation functions, noise level schedule, latent space, and clip text embeddings, through maximum likelihood estimation.

Overall, diffusion models represent a significant step forward in the field of text-to-image synthesis, offering a powerful solution for generating high-quality images from textual descriptions. As this field continues to evolve, diffusion models are likely to play an increasingly important role in a wide range of practical applications.

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Распознавание активности человека на основе данных видеонаблюдения

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Мониторинг активности является актуальной проблемой профилактики угрожающих жизни состояний. Этот вопрос особенно важен для людей старше 65 лет, которые падают как минимум раз в год. Шаткая походка является одним из предикторов падений и дальнейшего прогрессирования когнитивных заболеваний. Следовательно, обнаружение аномальной походки потенциально может быть полезным инструментом для предотвращения падений и диагностики когнитивных нарушений. Представлен бесконтактный подход к распознаванию активности человека. Данные видеонаблюдения восьми добровольцев (19–37 лет) использовались для обучения модели глубокого обучения для решения задачи классификации. Информация о ключевых точках скелета извлекалась из видеокадров с помощью нейронной сети BlasePose и использовалась для обучения рекуррентной нейронной сети с блоками долгой-краткосрочной памяти. Качество работы модели была оценена по метрикам точности и каппы Коэна. Результаты нашей работы потенциально могут быть использованы при разработке системы распознавания активности человека в парадигме технологии «умный дом».

Ключевые слова: видеонаблюдение, мониторинг активности, глубокое обучение, компьютерное зрение, технология "умный дом"

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Activity Recognition of Humans Based on Video Surveillance

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Activity monitoring is an actual problem in the prevention of life-threatening conditions. This question is especially important for people over 65 who fall at least once a year. Unstable gait is one of the predictors of falls and the future progression of cognitive diseases. Hence, abnormal gait detection can potentially be a useful tool for the prevention of falls and the diagnosis of cognitive impairment. In this paper, a contactless approach for human activity recognition is presented. Video surveillance data of eight volunteers (19–37 years old) were used for training the deep learning model for the classification problem. Information about skeletal key points was extracted from video frames by means of a BlazePose neural network and used for training the recurrent neural network with long-short-term memory units. The performance of the model was quantified using accuracy and Cohen's kappa metrics. The results of our work can be potentially used for the design of the system for human activity recognition in the smart home technology paradigm.

Keywords: video surveillance, activity monitoring, deep learning, computer vision, smart home technology

Introduction

It is known that the trend of population aging is common nowadays in developed countries. According to the World Health Organization, the number of people older than 60 is expected to grow to 1.4 billion by 2030 [1]. Changing demographics lead to many concerns that have become so pressing that the years 2021–2030 have been announced as the United Nations Decade of Healthy Aging [2]. Therefore, much attention ought to be paid to developing convenient and adaptive housing for the elderly.

The elderly suffer from many chronic diseases, including neurological diseases causing cognitive impairment, which have a wide range of social and economic consequences for these people and society at large [3]. Meanwhile, there is a lack of tools

for accurate and timely diagnosis of diseases with predominantly motor symptoms (dementia, ataxia, or Parkinson's disease) in clinical practice [4]. These tools should include quantitative information on gait, postural control, and other types of movement activity, allowing for proper interpretation of symptoms and, additionally, a reduction in fall risk for patients [4].

Nowadays, the most common tools that are used for clinical evaluation of gait and postural control are self-reporting, observation, and rating scales, such as [5] and [6]. However, these methods are not sensitive enough for early diagnosis and are prone to subjectivity and inconsistency.

Purpose

Substantive methods for activity monitoring in humans may be divided into three groups.

1. Ambient device-based methods using information from various sensors installed in the room, e.g., pressure, ultrasound, vibration sensors, video cameras, etc. The detection accuracy of these methods is affected by the number and placement of sensors [7, 8]. In the case of the video camera, privacy issues appear.

2. Wearable sensor-based methods based on accelerometers, gyroscopes, or magnetometers integrated into the devices that users turn on. These methods are highly accurate, but false alarms may be generated [9]. Moreover, the method becomes useless if the user forgets to <https://www.multitran.com/m.exe?s=bring+along&l1=1&l2=2> bring along the device.

3. Fusion methods based on sensors of different modalities, such as combinations of accelerometer, magnetometer, and force-sensitive resistors [10], pyroelectric passive infrared, thermopile infrared array sensor [11], etc. These methods are the most common for now, as the simultaneous use of various sensors allows for overcoming the disadvantages of using them separately.

In this paper, a method for real-time analysis of human activity based on video surveillance and computer vision is presented. The approach for the classification of five types of movement activity is discussed in the following sections more in detail.

Method

The task of movement activity recognition may be solved using machine learning (ML) techniques for a classification task. In the present work, the classes were normal gait (NG), turning up hands (UH) and large hand movements mimicking aggressive behavior (AB). In the problem of classification, the ML model predicts the class label given information about human movement as an input. Thus, the solution to the task includes the following steps:

- processing data from video surveillance;
- preparation of training and test data sets;
- training an ML model for the classification;
- validation and quality assessment of the model.

The implementation of these steps was realized in Matlab R2022b and Python 3.7.

The data set [12] was used in this paper. Experiments were carried out in the Remote Sensing Laboratory of Bauman Moscow State Technical University (RSLab). The data were collected with the Intel RealSense D435 system, which contained two stereo cameras,

an RGB sensor, and an active infrared projector. Only grayscale video surveillance data were used further.

8 young healthy females (ages 19-37) took part in the experiments. Informed consent was obtained from each volunteer prior to the experiment.

Experiments were carried out in two locations in order to collect a data set that can be used to develop robust methods for remote activity recognition. The distance between a volunteer and the RealSense system was 1.0-3.0 meters.

Each subject performed a normal gait, turning up and down with one or two hands or making large hand movements (mimicking aggressive behavior) during one experiment. In total, the experimental sample contained 117 video records (6–12 seconds in duration). The sampling rate and the resolution of the frames were 15 frames per second and 640 by 480 pixels, respectively.

Video recording processing consisted of the following steps: First of all, the coordinates of the skeleton's key points were detected with the pre-trained deep neural network. Nowadays, there are many ready-to-go solutions for key point detection. In the present work, low model weight and rapid calculation were two main criteria in the task of real-time classification. Therefore, light-weight BlazePose DNN [13], from Google, was chosen for key point extraction from the video sequence.

Secondly, the feature vector was extracted using key point information, i.e., the length of the radius vector for each detected key point was calculated using its x and y coordinates. In the present work only 17 key points were analyzed, therefore the feature vector corresponding to a single frame had a length of 17.

Finally, a bidirectional recurrent neural network with long-short-term memory units was trained using a hold-out validation technique for the classification problem. 70 % of the data (82 video recordings) were included in the training subsample, while the remaining 30% of the data (35 video recordings) were used for validation of the model. The results of the video model training were evaluated by accuracy and Cohen's kappa, which comprised 0.8 and 0.7, respectively.

Novelty and relevance

Novelty and relevance are as follows. In this paper, a novel method for movement activity classification using video surveillance data is presented. It is recommended that the video sensor be installed in common areas.

Conclusions

The limitations of the study are determined by the relatively small sample size (8 volunteers) and the laboratory conditions of the experiments with uniform illumination and background. In the future, it is planned to conduct experiments in real-life conditions (at home) with lightning variations and textured backgrounds. Next, possible data augmentation techniques such as random crops and shifts of the image data should be applied in order to enrich the sample and train robust models. Additionally, classification algorithms may be improved by using other feature extraction techniques. At last, the question of gait parameters' quantitative assessment should be addressed.

The results of the work may be potentially used for the development of smart home systems for human activity recognition, emergency states prevention and neurological diseases diagnosis

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Основы генерации музыки с использованием волнового и нотного формата

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В эпоху больших данных спрос на короткие саундтреки вырос благодаря стремительному развитию стриминговых платформ. Такие саундтреки не требуют высокого художественного уровня, но мало кто из музыкантов захочет тратить свое время на написание большого количества малосодержательной музыки. Цель работы — изучить основы генерации музыки, рассмотреть генерацию музыки в форматах wave (mp3, wav и др.) и нотной записи (MIDI) с поиском отличий и преимуществ в подходах к генерации музыки, в двух разных форматах. Рассмотренный фрагмент позволяет более детально рассмотреть идею генерации музыки в форматах wave и music, теоретически рассчитать количество элементов, которые необходимо сгенерировать для создания законченного музыкального произведения в обоих форматах, а также основные подходы к предварительному кодированию данных для создания музыки в музыкальном формате.

Ключевые слова: генерация музыки, волновой формат, MIDI формат, сэмплирование

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Fundamentals of Music Generation in Wave and Note Formats

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In the era of big data, the demand for short soundtracks has grown thanks to the rapid development of streaming platforms. Such soundtracks do not require a high artistic level, but few musicians will want to spend their time writing a lot of low content music. The aim of the work is to study the basics of music generation, to consider the generation of music in wave (mp3, wav, etc.) and musical notation (MIDI) formats with the search for differences and advantages in the approaches to generating music in two different formats. The considered fragment allows us to consider in more detail the idea of generating music in wave and music formats, theoretically calculate the number of elements that need to be generated to create a complete musical work in both formats, as well as the main approaches to preliminary data encoding for generating music in music format.

Keywords: music generation, wave format, MIDI format, sampling

The main formats for representing music on a computer

Music has been a fundamental part of human culture for centuries, and with the advancement of technology, it has become easier than ever to create and share music with people all over the world. One of the key aspects of music creation is understanding the fundamentals of music generation in wave and note formats.

Music in modern computers can be represented in two ways: as a digitized sound signal (formats mp3, wav, etc., allowing you to store sound in their amplitude and frequency representations) or as a set of notes, by analogy with classical music sheets (MIDI format), which do not take into account the nuances of sound production, music in this format is presented as a stream of musical events.

Fundamentals of music data synthesis

Wave format, also known as audio waveform, is a digital representation of sound that can be stored on a computer (Fig. 1). This format is often used to record and store music in a variety of digital audio workstations (DAWs). Waveform music can be generated by capturing analog audio with a microphone or by creating digital audio using virtual instruments or MIDI controllers.

Wave format is commonly used in AI-powered music generation tools because it allows for a high level of precision and detail in representing the sound of music. In wave format, sound is represented as a series of electrical signals that can be captured and recorded in high fidelity. This makes it possible for AI algorithms to analyze and manipulate sound in a very precise way.

AI algorithms can use wave format in music generation by analyzing the patterns and structures in existing music to create new compositions. This can be done through a process called feature extraction, where the AI algorithm analyzes the characteristics of the sound in wave format, such as frequency, amplitude, and duration. By extracting these features,

the AI can identify patterns and structures in the music, and use that information to create new music that is similar in style and structure.

One advantage of using wave format in AI-powered music generation is that it allows for a high level of creativity and experimentation. AI algorithms can generate music that is completely original and unique, while still maintaining the style and structure of the music it was trained on. This opens up new possibilities for musicians and producers to explore different musical styles and structures, and create music that is truly innovative and creative.

However, there are also some challenges associated with using wave format in AI-powered music generation. Wave format synthesis is a synthesis of 44100 data units in one second of a classic studio track. One-second tracks are of no practical interest, so it is advisable to consider at least a half-minute studio recording. To generate a half-minute studio recording with a sample rate of 44100, 1.3 million values would need to be generated. For comparison: generating an RGB image at a resolution of 512×512 will require the generation of about 700 thousand values, which is half as much. It becomes obvious that such a number of values is redundant; training such a model requires a huge amount of resources.

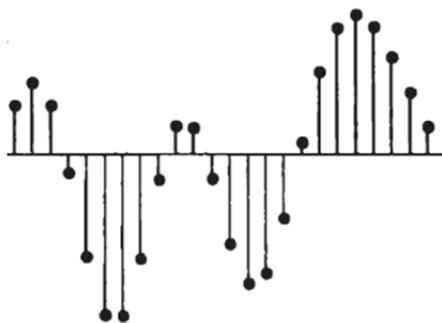


Fig. 1. Visualization of the wave format of music storage

Note format, on the other hand, is a way of representing music as a series of individual notes. In this format, each note is assigned a specific pitch and duration, and the music is created by combining these notes in various patterns and sequences. Note format is commonly used in music notation software such as Finale or Sibelius.

One of the advantages of working with note format is that it allows for greater flexibility when it comes to transposing and arranging music. This format also provides a standardized way of communicating musical ideas between musicians, as it is used in sheet music and other types of written music. Since MIDI data represents musical notes as individual events with specific parameters, such as pitch and velocity, it is easier for AI algorithms to manipulate and adjust those elements to create new compositions. This allows for a greater degree of precision and experimentation in music production.

However, one challenge with using MIDI format in AI-powered music generation is that it may not capture the full range of musical expression and nuance that can be captured in wave format. While MIDI data can represent pitch and duration, it may not capture the subtle variations in sound that can be captured in wave format. As a result, some AI-powered music generation tools may use both MIDI and wave formats in their analysis and composition processes to capture the full range of musical expression.

Both wave and note formats have their own strengths and weaknesses, and understanding how to work with both is essential for creating high-quality music. One way to combine the two formats is by using MIDI (Musical Instrument Digital Interface), which allows for the creation of note-based music that can be played through digital instruments.

Due to the compact form of storing music information, generating music in the form of a MIDI file requires much fewer computing resources compared to generating high-quality music in wave formats. Also, MIDI files can be easily loaded into sequencers that convert a track from musical notation to any audio format.

The effectiveness of this method lies in the fact that with the most basic MIDI format, the recording is reduced by several times compared to wave formats. Using only 2048 notes, you can get a track up to 2 minutes long, while to generate such a track in wave format, you will need to generate about 5 million values. In addition to this, a huge creative scope opens up in order to come up with the best way to encode data.

Music data encoding

The basic principle of data encoding in this approach is to reduce the number of values by creating a new alphabet from notes. At the same time, it is undesirable to make everything too compressed — you can lose important information. The easiest classical way is event-based MIDI coding.

There are several MIDI file formats. Format 0 contains one track, formats 1 and 2 contain multiple tracks. Most often, in practice, MIDI with format 1 is used, where each instrument has its own track: guitars play on one track, violin on another, etc. This introduces some difficulties in building grammar — you need to keep track of what is happening on the other track. Therefore, it is advisable to convert format 1 and 2 to format 0 so that all instruments are on the same track.

In MIDI representation, each note has 3 main characteristics. The vertical axis specifies the pitch of a note from a note to (C0) sub-contra-octave to a note to (C8) the fifth octave. The horizontal axis specifies the duration of the note. Separately, below are the volumes for each note (the higher the column, the louder the note, and the color of each note also indicates its volume). Each instrument has its own track with sequences of notes. MIDI file consists of an arbitrary number of such tracks for each instrument (Fig. 2).

The essence of event-based MIDI encoding is to track the pressing and releasing of keys, taking into account the force of pressing (Fig. 3). MIDI is converted into a sequence of key press, key release (128 tokens each), volume setting (32 tokens) and time step (100 tokens).

After encoding, the resulting file can be converted into XML format and get an even more convenient representation (Fig. 4).

This file stores all information about the melody. The `<TicksPerBeat>` tag is responsible for the tempo of the melody; in this example the theme is 384. First, the channel settings for each instrument are set. The most important part is the `<NoteOn>` and `<NoteOff>` tags — they are responsible for playing and stopping the sound of a note. These tags contain the channel the note is playing on, the number of the note, and its playback speed. This example uses absolute times for each event, but XML can be generated with relative times as well. Absolute time is the time elapsed since the beginning of the track, while relative time is the time elapsed since the last event. In the case of generating a multi-instrumental composition, it is more convenient to take an absolute time, by which you can easily group various musical events that occurred at the same time.

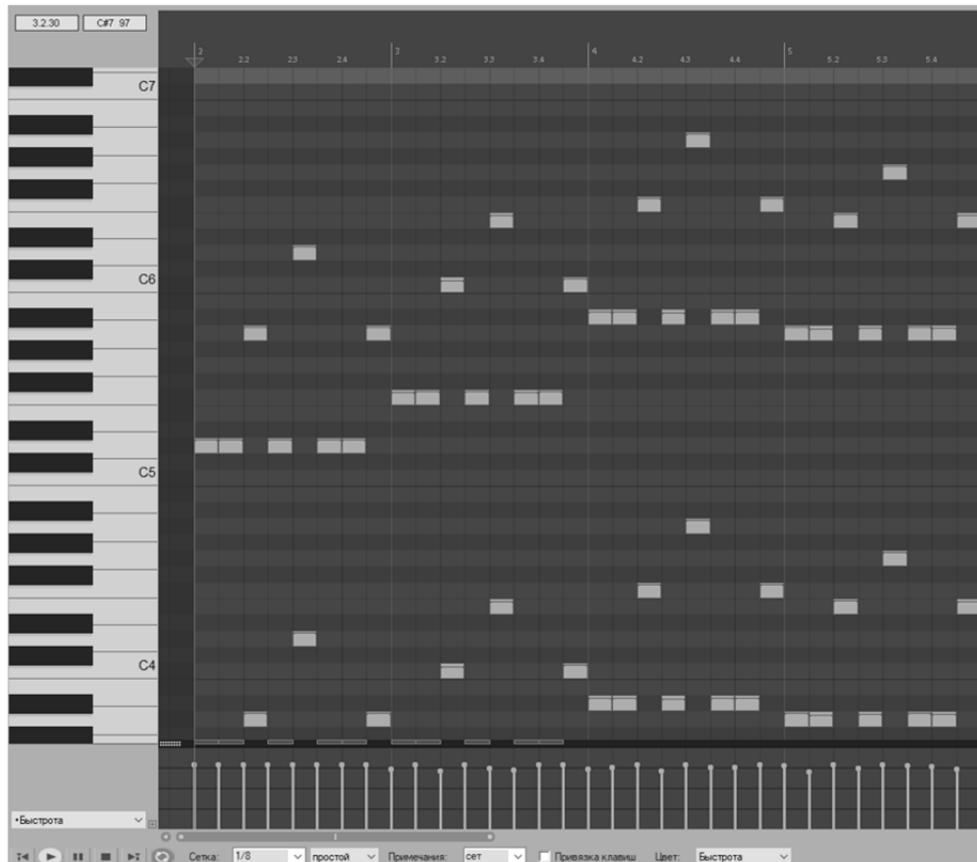


Fig. 2. MIDI file example

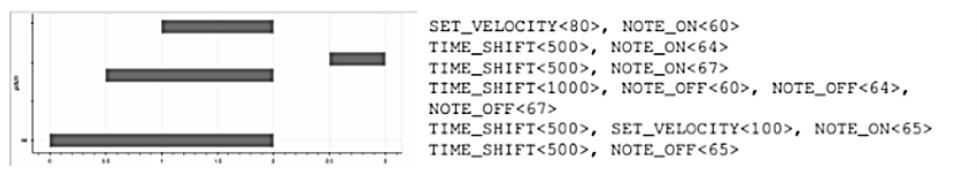


Fig. 3. Event-based encoding

```

<?xml version="1.0" encoding="ISO-8859-1"?><br><!DOCTYPE MIDIFile
PUBLIC<br> "-//Recordare//DTD MusicXML 0.9 MIDI//EN"
<br> "http://www.musicxml.org/dtds/midixml.dtd"><br><MIDIFile><br>
<Format>0</Format><br><TrackCount>1</TrackCount><br>
<TicksPerBeat>384</TicksPerBeat><br><TimestampType>Absolute</TimestampType><br>
<Track Number="0"><br> <Event><br> <Absolute>0</Absolute><br> <ControlChange
Channel="2" Control="91" Value="46"/><br> </Event><br> <Event>
<br> <Absolute>0</Absolute><br> <ProgramChange Channel="2" Number="49"/>
<br> </Event><br> <Event><br> <Absolute>0</Absolute><br> <ControlChange
Channel="2" Control="0" Value="0"/><br> </Event><br>...<br> <Event>
<br> <Absolute>24908</Absolute><br> <NoteOff Channel="11" Note="41"
Velocity="127"/><br> </Event><br> <Event><br> <Absolute>24912</Absolute>
<br> <NoteOn Channel="11" Note="41" Velocity="127"/><br> </Event><br> <Event>
<br> <Absolute>24956</Absolute><br> <NoteOff Channel="11" Note="41"
Velocity="127"/><br> </Event><br> <Event><br> <Absolute>24960</Absolute>
<br> <NoteOn Channel="11" Note="41" Velocity="127"/><br> </Event><br>...<br>
</Track><br></MIDIFile><br><br>* This source code was highlighted with Source
Code Highlighter.

```

Fig. 4. An example of an XML file obtained from MIDI after encoding

Conclusion

In conclusion, the fundamentals of music generation in wave and note formats are essential for anyone who wants to create high-quality music. Understanding the strengths and weaknesses of each format, as well as the different elements of music, is key to creating music that is both technically precise and creatively compelling. Whether you are a seasoned musician or a beginner, mastering these fundamentals is the first step towards creating music that resonates with your audience [1, 2].

Generative music is good not only for personal use, for example, for use in the background in some video or video game. Today, various hotels, beauty salons, restaurants, amusement parks, bars and other businesses pay big money for the use of the music they play for guests. Modern models are able to create a variety of compositions in various genres for every taste, so the ability to generate music using neural networks will allow businesses to save money without spending a lot of money and without violating copyrights [3–5].

According to the experience of various music generation services and projects, a stable proportion has developed — when generating symbolic music, about 60% of the time and resources are spent on encoding, about 30% is spent on data collection, and only 10% is spent on model training.

Thus, the uniqueness of each new project and service comes down to creating its own effective method for encoding MIDI files.

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Выявление чрезмерного риска в политиках контроля доступа с помощью нечеткой логики

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Представлено общее решение, которое было реализовано для выполнения экспериментального анализа файловой системы Microsoft New Technology, чтобы показать, как это работает на практике. Выполнено моделирование с использованием экспертных знаний для сравнения, чтобы продемонстрировать, насколько эффективно оно помогает пользователю идентифицировать потенциальные неправильные разрешения. Определены основные политики контроля доступа, рассмотрены их преимущества и недостатки. Проведен анализ возможных источников угроз несанкционированного доступа к информационной системе сервиса. Определены риски утечки данных. Разработана автором политика контроля доступа для применения в операционных системах для защиты данных.

Ключевые слова: нечеткое управление, нечеткие системы, безопасность, политики контроля доступа, анализ безопасности, риск, нечеткая логика, риск адаптивного контроля доступа

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Identifying Excessive Risk in Policies Access Control with Fuzzy Logic

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The paper presents a generic solution that was implemented to perform an experimental analysis of the Microsoft New Technology file system to show how this works in practice.

A simulation using expert knowledge for comparison is then performed to demonstrate how effective it is in helping the user identify potential improper permissions. The paper identifies the main access control policies, examines their advantages and disadvantages. The analysis of possible sources of threats to unauthorized access to the information system of the service. The risks of data leakage are identified. Developed a functional model of access control policy for use in operating systems to protect data. The author offers methods for analyzing different ways of fuzzy logic.

Keywords: fuzzy control, fuzzy systems, security, access control policies, security analysis, risk, fuzzy logic, risk-adaptive access control

Introduction

Analysis of access control policies is an experimental and important process to ensure that over-prescribed permissions are identified and removed. This is a time-consuming and science-intensive process, mainly because there is a tremendous amount of policy information that needs to be manually verified. In addition, an organization's access control policy lacks a standard definition of what constitutes an over-eligible authorization, making it impossible to develop automated rule-based approaches.

It is often the case that over-authorization depends on the role structure of the organization, where access is allocated and managed according to the needs of different employees. In this context, an irregular permission might be one in which an employee changed roles frequently, thereby accumulating a broad set of permissions.

There is no one-size-fits-all approach to defining permissions when an employee receives more permissions than necessary, and one must examine them in the context of the organization and determine how important their individual risk is.

Risk is not a binary metric, and this paper constructs an approach using fuzzy logic to determine an overall risk score, which can then be used to make a more informed decision about whether a user has excessive permissions and poses risk to the organization. This requires the prior use of resource sensitivity and user trust determinations as measures for determining the risk rating.

Access control systems are an integral mechanism of computing systems. Control systems often provide many levels of access beyond simply granting or denying access. They provide many different access gradations (e.g., read, write, etc.) to account for the many different potential security situations that may arise in an organization. There are many different types of access control models that are widely used.

For example, role-based access control focuses on granting permission levels based on the business function of the user in the organization, while discretionary access control systems provide a fine-grained level of control based on each resource that can be administered by the user. The emphasis of the research presented in this paper is on the access control systems that have been implemented. The common aspect is that they all provide mechanisms for the user to obtain permission from multiple policies, resulting in an accumulation of effective permission for the user. An effective permission describes the level of access to a resource for a particular user, taking into account the multiple permissions distributed, as well as the resolution of conflicts.

Access control implementations are often audited to verify security policies, with particular attention paid to identifying instances of over-authorization, where a user has more authority than they need to perform their role. Over-authorization can be particularly

dangerous. For example, if a user becomes involved in a security incident or becomes an adversary themselves, they may gain access to more resources and therefore cause more damage. This also applies to ransomware when it is run under a user account and gains the user's level of access.

The requirement to audit is common to all access control implementations, but the significant problem is that it is not a binary task, because even if irregular and potentially abnormal permissions can be identified, they do not necessarily indicate a high-risk situation requiring immediate intervention. Irregular and anomalous permissions can be thought of as permissions that differ markedly from a full access control policy. This may be a case where the permission is relatively different (in frequency of occurrence and strength) from all others and requires further investigation. For example, a trusted user with improper access to a non-sensitive resource is also of low importance. Determining whether an access level represents a potential security threat is by no means a trivial or binary task. It depends on the sensitivity of the restricted object and the trustworthiness of the user, which together can give the level of risk.

Resource sensitivity is far from new to access control systems, and scientific studies and patents discuss how to use it. However, determining user trust and resource sensitivity is challenging and requires an understanding of business activity, user behavior, and the importance of the protected resource.

Moreover, the expertise to determine these factors may be in short supply, or in some cases not available at all. For example, consider a large organization with many employees and electronic resources. It is unlikely that one person has enough knowledge to understand user trust and resource sensitivity across the entire organization. However, if someone has that knowledge, it is reasonable to assume that they would still benefit from technological assistance to help improve reliability (reduce human error) and reduce the time and effort required. Since various aspects such as user trust, resource sensitivity, and permission risk need to be considered when analyzing access control policies, it is necessary to consider their interaction. It was noted earlier that the relationship between these inputs is best modeled and represented in fuzzy logic, where values such as user trust, which are not binary, can be represented by probability of truth.

However, these approaches relate to the topic of introducing fuzzy sets into an access control model, rather than as part of the analysis process. In addition, there is the problem of constructing levels of resource sensitivity and user trust and considering their relationship to access control policy to establish a measure of risk.

We aim to solve this problem and use fuzzy logic in the analysis process by developing a new technique in which the effective user permission for all access-controlled objects is modeled in a risk-based fuzzy model, which is then used to analyze and identify the implemented permissions that have the highest level of risk. This information, being represented by to the user, can be used to identify any security risk and assist the user in determining the permissions that require further consideration. The assumption is that the organization lacks knowledge about how sensitive resources are and how a user's trust can change depending on his or her position.

For this reason, an approach to estimating resource sensitivity based on available information about system activity has been developed. This paper examines the research hypothesis that fuzzy logic analysis of access control elements, based on automatically extracted measures of user trust and resource sensitivity, makes it easier to detect high-risk and potentially anomalous permission entries.

The following new material is presented in this paper:

- Provides a fuzzy logic-based model for analyzing implemented access control policies using confidence and sensitivity measures to determine the risk measure for each user-access-object relationship.
- Technique for estimating trust and sensitivity values based only on available system information, which in the case of this study is extracted from sources of information about security events.

An empirical analysis using a systematic methodology to determine the capabilities of the method on simulated catalog structures.

The paper is structured as follows: the next section presents a discussion of previous and related works, and motivates the main research presented in this paper. The next section details the development of an access control analysis system based on fuzzy logic. An implementation of a fuzzy logic system for analyzing the Microsoft New Technology File System (NTFS) is then given. An empirical analysis is then conducted in which testing is performed on simulated file systems. It concludes with a conclusion that provides direction for future research.

Related work

Fuzzy logic was previously used in access control systems, where its purpose was to address the problem that implementing access control is often a problematic and error-prone activity. For example, assigning a user to inherit access rights through group membership can lead to giving the user too much or too little rights elsewhere. Previous work has presented a fuzzy logic-based access control system in which users are given access to objects based on appropriate risk and sensitivity assessments. [1, p. 154]

Basically, the system works by assigning security scores to both the user and the object, which are then used together with a fuzzy system to determine an overall risk rating to determine access. Similar work has also been presented to work in Internet of Things (IoT) architectures. The use of fuzzy logic in access control systems is diverse. Recent implementations include crowdsourcing environments, wireless body networks, cloud computing, and medical IoT systems. A key and common aspect of these approaches is that they require prior information used to determine the risk rating. This information is required for the operation of access control systems; however, they are superior to more traditional access control systems in terms of configuration and maintenance. In addition, requiring the administrator to set trust and sensitivity levels can be seen as a burden, but more significantly, the permissions may not be set correctly in the first place. [2, p. 10]

In terms of access control system analysis, a binary classification system is used in which access control rules are identified as normal or abnormal. This often includes the identification of individual user-access-object relationships:

$$\text{UPO} \in \text{USER} \times \text{PERMS} \times \text{OBJECT}$$

In terms of identifying irregular permissions, permissions are divided into regular and irregular sets, R and I, respectively. For a clear representation, an individual relation $(u, p, o) \in \text{UPO}$ is either a member of the set I or not.

This binary representation is modeled by the following indicator function. The inclusion of user-permission-object relations (u, p, o) in set I is determined by a measure of irregularity, that is, a single-valued lower, l, and upper, u, threshold is used to define relations in the set. As a result, the set I will contain all those elements where $l \leq I \leq u$. There is a significant problem with the binary and single-valued classification function. It lies in the fact that when performing classification on explicit sets, methods are developed

to determine whether the resolutions are normal or supernormal. Because of this binary classification, any ambiguity in the definition will lead to the misidentification of normal permissions or, more significantly, to the misidentification of permissions with supernormal access rights as normal. Earlier work on determining file permission violations using a statistical technique (χ^2) shows a good level of accuracy (70...90 %). This technique uses the χ^2 statistic and Jencks natural discontinuity to determine set boundaries. Other studies have included the use of Association Rule Mining to detect sparse and potentially redundant item sets, which also yielded comparable levels of accuracy to the statistical approach.

Although these methods show a good level of performance, problems arise when attempting further refinements. The methods are too sensitive, which means that they detect many false positives (normal permissions are incorrectly identified). There are also cases where permissions with overrides are incorrectly identified, such as when permissions with overrides are statistically indistinguishable from normal permissions. Further research presented the use of these methods to identify a particular type of violation (permission creep) with an average accuracy of over 90 %. [3, p. 215]

This level of accuracy is still significant, given that methods have no prior knowledge of what constitutes a breach; however, there is a strong motivation to identify all cases, given the need to maintain resource security.

Consideration of access control and risk has long been well-established. For example, early studies used fuzzy logic to determine user risk in systems. However, there are few works on the use of fuzzy logic for analysis. An expert system for system security analysis using fuzzy logic has been developed and tested, with an example of user risk determination based on password reliability. Other studies have demonstrated the potential of using a fuzzy approach to analyze buffer overflow vulnerabilities. Based on the large amount of research on the use of fuzzy logic in access control systems and the lack of research on analyzing traditional access control mechanisms using a fuzzy approach, this paper explores the potential for analyzing access control systems using fuzzy logic.

Modeling

There are many different types of access control models used in computing systems that have different properties with respect to administration and policy enforcement. Mandatory Access Control (MAC) is suitable for mission-critical systems where a central authority manages and enforces policy. MAC's properties make it suitable for use in military systems.

Role-based access control (RBAC) systems allow you to restrict access based on a user's role in an organization, such as financial management. Discretionary access control (DAC) requires administering and enforcing access control on a per-user basis. The main feature of DAC is that resource owners can assign permissions to other users as they see fit. Researchers have studied the security and complexity of DAC systems and developed algorithms to determine security. [4, pp. 256-267]

Common to all systems is that the user obtains an effective permission, which is essentially a resolved permission for a given resource given role inheritance, conflicts, etc. This paper is motivated by end-user concerns when analyzing access control systems; thus, we are interested in obtaining effective permission, regardless of which access control model is used. The reader should note that this research was motivated by the problems of analyzing the permissions of Microsoft's NTFS file system, which is a DAC system

combined with MAC, and their combination allows for flexible policies that can be used to represent the RBAC system. [5, p. 300]

This section presents an efficient permissions model. Objects (also known as resources), $\text{OBJECTS} = \{o_1, o_2, \dots, o_n\}$ represent system components that require controlled access. An object can be, for example, a file system resource, a printer, a software service, etc. Users, $\text{USERS} = \{u_1, u_2, \dots, u_n\}$ represent those who interact with the system and have prospective permissions. For example, the user can be a user, a process, etc. The permission level, P , is often described by a series of permission attributes, $\text{PERMS} = \{p_1, p_2, \dots, p_n\}$. The individual permissions will differ depending on the underlying access control system.

In this article, we do not consider how rights are assigned to users, and assume that the access control system has a mechanism for determining the effective right of a user to an object.

Effective resolution is a set of relationships:

$$\text{UPO} \subset \text{USERS} \times \text{PERMS} \times \text{OBJECTS},$$

which is a set of user-role assignments. When auditing, all effective permissions are computed, taking into account all permutations of users and objects; however, no records are created where there are no implemented object permissions for a given user.

Each user in the system is assigned a trust value, which is a numeric rating from 0 to 1. Similarly, each object is assigned a sensitivity value. Each permission is also assigned an authority rating, which also represents a score from 0 to 1 with respect to the capabilities of the permission. The combination of these values is then used to calculate the final risk rating.

Conclusion

Analysis of access control systems is a common activity for those who want to analyze and improve access control implementations. However, binary classification mechanisms have been found to have difficulty classifying permissions as normal or irregular. I hypothesized that analyzing access control systems using fuzzy logic based on automatically extracted measures of user trust and resource sensitivity makes it easier to detect high-risk and potentially abnormal permission records. This leads to a simulation of file system permissions with consideration. A practical implementation was then developed to obtain empirical observations. In developing this mechanism, it was necessary to develop a way to establish user confidence and resource sensitivity without the user having to provide additional information. This method was developed by monitoring adverse security activities and interactions with underlying resources in event logs. The methodology presented in this paper has been tested and yielded an overall average accuracy of 99 %. This demonstrates the potential of the method, especially considering that binary methods struggle to achieve accuracy above 90 %. This demonstrates the potential of the technique and supports the hypothesis; however, it should be noted that it adds a dependence on event data to establish user confidence and resource sensitivity, which in some systems may not be complete or available.

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Обзор методов поиска ближайшего соседа с использованием графов

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Отсутствует

Обоснована актуальность применения метода поиска ближайшего соседа в современных вычислительных системах, приведены примеры предметных областей. Показаны преимущества использования метода поиска ближайшего соседа с использованием графов перед методами без использования графов. Проведен сравнительный анализ трех методов: NSG (*Navigating Spreading-out Graph*), HVS (*Hierarchical Graph Structure*) и HNSW (*Hierarchical Navigable Small World*).

Ключевые слова: *граф, поиск ближайшего соседа, K-NNS, поиск ближайшего соседа с использованием графов, NSG, HNSW, HVS*

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Review on the Graph-Based Nearest Neighbor Search Methods

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Not working

The relevance of the nearest neighbor search application in modern computing systems is substantiated, examples of subject areas are given. The advantages of using the graph-based nearest neighbor search method over methods that don't use graphs are shown. A comparative analysis of three methods has been carried out: NSG (*Navigating Spreading-out Graph*), HVS (*Hierarchical Graph Structure*) and HNSW (*Hierarchical Navigable Small World*).

Keywords: graph, nearest neighbor search, K-NNS, graph-based nearest neighbor search, NSW, HVS, HNSW

Introduction

Nowadays, the amount of information in need of processing is constantly growing. This naturally led to the need of using effective search algorithms that reduce the cost of viewing the entire data volume.

One of the well-known methods for solving this problem is the nearest neighbor search (K-NNS). The essence of it is to search in some metric set of K elements that are closest to the given one. The measure of proximity is a function defined by the subject area: the smaller the proximity values, the more similar the compared elements can be considered and vice versa. The problem of finding the nearest neighbor is found in many areas, for example, in tasks of pattern recognition, object classification, recommendation systems, data compression, advertising on the Internet, semantic search, etc..

However, the complexity of the classical approach to the K-NNS algorithm increases linearly depending on the number of stored elements, which for large-scale data often leads to very long processing or lack of memory, or to significant losses in accuracy. Therefore, the problem of developing the most efficient and fastest search algorithms has become urgent.

The Graph-based nearest neighbor search methods significantly reduce the complexity of calculations and speed up the process of obtaining a result. Such methods include, for example, R-trees [1], NSG, NSW, HNSW. In this paper, an analysis and comparison of various methods will be carried out in order to identify the features, advantages, disadvantages and possible applications.

Navigating Spreading-out Graph (NSG)

The NSG (Navigating Spreading-out Graph) method is discussed in the article «Fast Approximate Nearest Neighbor Search With The Navigating Spreading-out Graph» [2]. NSG is a graph-based approximate Nearest Neighbor Search (ANNS) algorithm. It is based on an approximation of the Monotonic Relative Neighborhood Graph (MRNG) graph structure. NSG sets the center position as the navigation node, and then uses a specific edge selection strategy to control the degree of deviation of each point. Thus, it can reduce memory usage and quickly determine the location of the target nearby while searching for vectors.

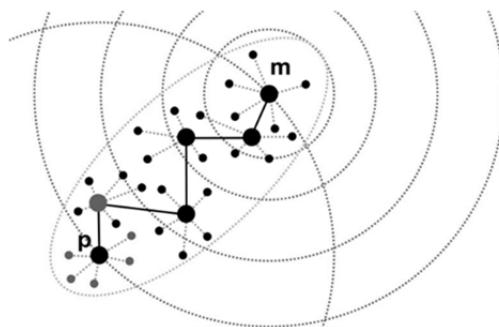


Fig. 1. Candidates for edge selection in NSG

An illustration of candidates for edge selection in NSG is shown in Fig. 1. Node « p » is the node to be processed, and « m » is the navigation node. The red nodes are the k nearest neighbors of node « p ». Large black nodes and solid lines form a possible monotonic path from « m » to « p » generated by the search and collect procedure. Small black nodes are nodes visited by the search and data collection procedure. All nodes in the figure will be added to the candidate set from « p ».

NSG provides an efficient approximate nearest neighbor search. This method simultaneously solves the problems of an unrelated cluster, traversal and large attachments of previous graph-based methods without using additional index structures.

Hierarchical Graph Structure (HVS)

The HVS method is described in the article «Hierarchical Graph Structure Based on Voronoi Diagrams for Solving Approximate Nearest Neighbor Search» [3]. HVS has a hierarchical structure of several layers, which corresponds to a series of subspace divisions from large to small.

In addition, each layer uses a virtual Voronoi diagram to speed up the search. By bypassing Voronoi cells, HVS can effectively reach the nearest neighbors for a given query, which leads to a reduction in the total cost of the search.

The Voronoi diagram of a finite set of points S on a plane represents a partition of the plane in which each region of this partition forms a set of points closer to one of the elements of the set S than to any other element of the set (Fig. 2).

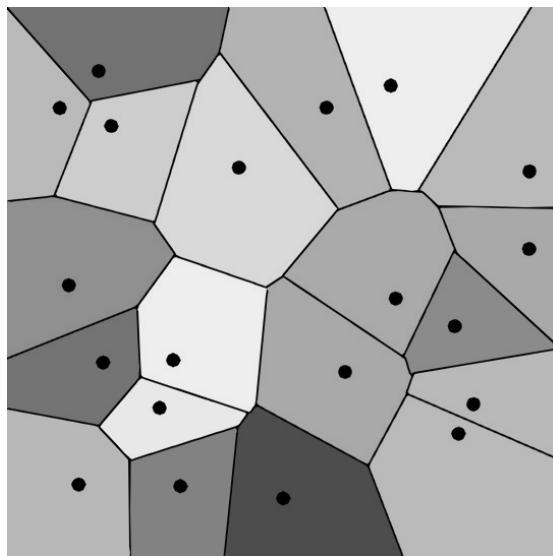


Fig. 2. Voronoi diagram of a random set of points on a plane

Let us consider in more detail the arrangement of the layers of the HVS method (Fig. 3). The space in each layer, with the exception of the base layer, is divided into virtual Voronoi cells. For the upper layer, these cells form a set of graph nodes without edges. In the second layer or lower layers, where the data size is reduced by layer, only high-density

cells are connected to the next deeper Voronoi cell. Each matching cell containing data points is connected to other neighboring cells in the same layer, and is also connected to a cell in the next lower layer. Some of these cells are connected directly to data points in the base layer. At the request stage, lowering the levels when searching locally for the closest cells to the request, a group of entry points for the base layer is determined. At the basic level, a standard search strategy is used and the final results are obtained.

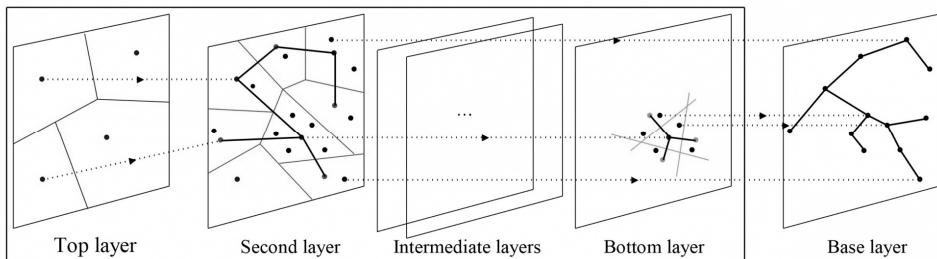


Fig. 3. Geometric illustration of HVS

The advantages of HVS over existing graph-based methods are:

1. Calculating the distance between two Voronoi cells is much more efficient than calculating the distance between two raw vectors.
2. HVS can search in the base layer by multiple Voronoi cells returned from the upper layers to ensure high query accuracy.

Hierarchical Navigable Small World (HNSW)

The HNSW (Hierarchical Navigable Small World) method is discussed in detail in the articles «Efficient and robust approximate nearest neighbor search using Hierarchical Navigable Small World graphs» [4] and «A Web-Scale Approximate Nearest Neighbor Lookup System» [5].

This algorithm is based on the NSW method using the «small world» graph. A pair of vertices in such a graph are most likely not adjacent, but they are achievable on average in $\log(N)$ number of steps. The search starts from a random vertex (Fig. 4), then the distances of unvisited neighboring vertices to the specified one are calculated (neighboring vertices are connected to the current vertex by an edge), and the vertex with the smallest distance is selected. In the process of the algorithm the list of nearest neighbors is gradually filled until it stops updating.

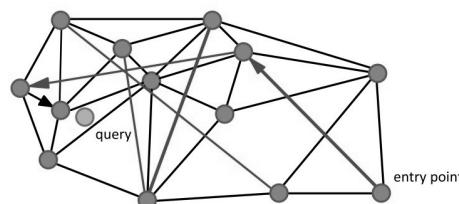


Fig. 4. Greedy search for the nearest neighbor

The idea of this algorithm was developed in the HNSW method. Its main difference is the presence of a hierarchy of graphs represented by layers. All objects are represented on the zero layer, and on the layers above, the selection of elements gradually decreases (Fig. 5). All objects on layer $n+1$ are present on layer n , but not vice versa.

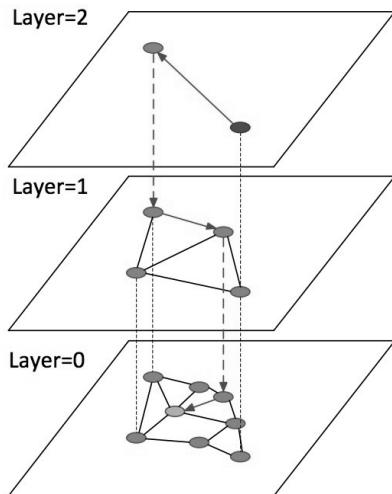


Fig. 5. The idea of HNSW

The search also begins with a random vertex of the upper layer, where the vertices closest to the given one are calculated, from which the search subsequently begins on the layer below and up to the zero layer.

HLSW supports continuous incremental indexing, and can also be used as an efficient method to obtain k-NN approximations and relative neighborhood graphs, which are by-products of index construction.

Conclusion

The nearest neighbor search currently has many applications and needs effective approaches to its implementation for processing large amounts of data. One of the options for upgrading the method is the use of graph structures, which significantly reduce the complexity of calculations. Therefore, further development of such graph-based methods as NSG, NSW, HNSW is relevant.

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УДК 004.93'11

Сравнительный анализ моделей для извлечения признаков из изображений

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Рассмотрены архитектуры моделей для извлечения признаков из изображений и их классификация. Приведены особенности обработки изображений сверточными нейронными сетями и трансформерами зрения. Выделены доступные современные модели для экспериментальной проверки точности распознавания. Проведен эксперимент для сравнения точности рассматриваемых моделей в прикладной задаче классификации художников по их картинам. Проанализированы предсказания моделей в эксперименте по поиску похожих изображений. В результате выявлены наиболее перспективные модели для использования в прикладных задачах.

Ключевые слова: сверточная нейронная сеть, трансформер, машинное обучение, компьютерное зрение, вектор признаков, извлечение признаков

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Comparative Analysis of Feature Extraction Models for Images

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Model architectures for feature extraction from images and their classification are considered. The difference between image processing by convolutional neural networks and by vision transformers is presented. Open-access modern models for experimental verification of recognition accuracy are chosen. An experiment is carried out to compare the accuracy of the aforementioned models in the task of classifying artists by their

paintings. The predictions of the models in a similar image retrieval experiment are analyzed. The most promising models for the use in real-world tasks are recommended.

Keywords: convolutional neural network, transformer, machine learning, computer vision, feature vector, feature extraction

Introduction

Digital progress in all spheres of social life has led to the accumulation of large data arrays. This made it possible to expand the scope of machine learning tasks, especially the ones, based on computer vision. Training on large datasets allows developers to improve recognition accuracy, but it comes with significant computational costs, which proved to be especially heavy for small businesses with limited resources. To address this problem the transfer learning method was invented. The idea of transfer learning is to train a foundation machine learning model on a large dataset and then use the model on a specific task after fine-tuning if necessary. In computer vision, the most reusable type of model is a feature extractor. It is used to transform an image into a compact feature vector, which is convenient for downstream processing tasks. Big research centers train such foundation models and often provide free access for everyone to support scientists and developers all over the world with cutting-edge technology.

In this paper, a comparison of feature extractors is provided both in theory and practice. Only open-source models are chosen for the comparison. All mentioned models are published with Apache 2.0 license, which allows their use for both commercial and non-commercial purposes.

Feature extraction architectures

Nowadays neural network technology is the state-of-the-art technology for feature extraction. Feature extractor neural networks can be divided into two classes based on their key architecture: CNN (convolutional neural networks) and ViT (vision transformers).

CNN is a class of architectures that led to the first acknowledged commercial success of neural networks in computer vision. CNN process input image with convolutional layers consisting of special filters named kernels. Layers can be represented as processing stages. The filters are used to recognize specific features. For example, one filter can be trained to recognize vertical lines, and another one can be trained to recognize gradients. In every convolutional layer, an image is consequently processed by every filter via a sliding window. This sliding window is usually small-sized: from 3x3 to 7x7px. It allows recognition of even small features of the input image. In the first layer, CNN recognizes basic features: lines, and gradients. In the next layer the filters process not just the input layer, but its features (a feature map), detected in the previous layer. This technology helps to reach a higher level of abstraction. That's why CNN with many layers can recognize even complex abstract features such as faces or buildings in its last stages. Special pooling layers are inserted between convolutional layers to decrease the size of the current feature map. In such a way, an image consequently transforms into a compact feature map, and a feature map flattens to a vector – the feature vector.

Such processing technology grants CNN invariance to the object's position on the image. The whole image is thoroughly analyzed at every step of the processing. However, at first, the image is analyzed only as its smallest pieces, and only in the last layers the filters eventually process almost the entire image, compacted to the tiny feature map. This

type of analysis can be called inductive (from part to whole) and is hardly comparable with human perception. Nonetheless, it allows CNN to detect even the tiniest details that human perception can easily miss.

Modern open-access CNN architectures for the use in image recognition systems are ResNet [1], EfficientNet [2], and ConvNext [3]. ResNet-based architectures are the foundation on which the majority of modern architectures are designed. A key feature of ResNet is special connections named skip connections, that allow passing the feature maps directly to the later layers while skipping some of the intermediary layers. It helps to solve the vanishing gradient problem – the gradual degradation of input information as it is passed deeper into the neural network. EfficientNet is the architecture designed via an automatic search of the most efficient architecture. It is intended to provide the highest reachable accuracy for a reasonable computational cost. EfficientNet can even be used on mobile devices because of its relatively small size and high computational speed. ConvNext is a heavily modified version of ResNet, created in response to the vision transformers since these transformers won the majority of computer vision competitions after their debut in 2020. ConvNext contains a lot of minor and major modifications such as alteration of the number of convolution layers, increase in filter size, and others. Some of the ideas were adopted from vision transformers, an example being non-overlapping convolution, that is similar to vision transformer patching.

Vision transformers are a class of architectures that became popular in 2020. After the transformer revolution in natural language processing, many researchers attempted to apply transformer ideas from text to image processing. Their attempts have led to success in designing the ViT architecture [4]. In vision transformers, the input image is divided into patches, each patch is 16x16px. These patches are linearly converted to compact vectors, which are passed to a sequence of transformer encoders along with their position vectors. The position vector is used to track the original position of the patch on the input image. In short, the image is treated like a sentence, and its patches are treated as a sequence of words because transformers are initially designed to process words. Every transformer encoder consists of an attention mechanism and an MLP (multilayered perceptron). The attention mechanism is a special processing unit, which compares the current patch with the whole image and seeks other patches which can be semantically connected to the current one. Parts of suitable patch vectors will be added to a vector of the current patch. It helps to recognize objects, which are bigger than 16x16 pixels or are present in several parts of the image simultaneously. At the end of transformer processing, the feature vector of the input image is generated.

Vision transformers consider the whole image at every stage of encoding because of the attention mechanism. So, at any given moment, the model analyzes the whole image, with a focus on one particular patch. It is worth mentioning that the patch size of ViT is significantly bigger than the sliding windows in CNN. ViT type of analysis can be called deductive (from whole to part) and it's more intuitive because it works on a similar principle as human vision logic. The attention mechanism can be compared with the focusing of an eye or a camera. ViT processing is more interpretable because of the mentioned characteristic.

Modern ViT architectures are modified versions of ViT. The most interesting ones are Swin [5] and XCiT [6]. Both architectures are created as attempts to decrease the minimum size of the patch in order to analyze the tiniest details of images. Unfortunately, patch size reduction leads to exponentially increasing computational costs — because of the attention mechanism. Swin combats this by using a processing hierarchy: at first tiny patches are analyzed and then an attention mechanism is used not on the whole image, but on a small window that contains only a few patches. Then the size of the patches is gradually increased and the size of the window grows accordingly until the latter reaches the size of

the entire image. XCiT attention mechanism has also been altered but in a sense of computational efficiency. It has been proposed to transpose matrix multiplication inside the attention mechanism. It is worth mentioning that, unlike CNN, vision transformers are very demanding in terms of training image dataset size. The ViT training process requires either vast image datasets or special training algorithms.

As one can see, some modifications of Swin were adopted from CNN. There is a productive rivalry between CNN and ViT, which leads to a useful experience exchange.

Experiment 1: Determining the applicability of each model type

For every aforementioned model, the creators provide ImageNet top-1 accuracy score. ImageNet is a dataset of millions of photos, that provides a classification task for 1000 classes and also serves as a popular scientific benchmark. The accuracies and exact versions of each considered architecture are provided in Table 1. Versions are chosen by the criteria of highest accuracy among provided open-access models.

Table 1
Comparison of ImageNet top-1 accuracy

Architecture	CNN			ViT	
	BiT-M (ResNet101)	EfficientNet-B7	ConvNext-xL	Swin-L	XCiT-L
top-1 accuracy on ImageNet, %	85.4	84.3	87.7	87.3	86.0

The experiment was conducted to check the real-task applicability of the models without additional fine-tuning. The task was the classification of painters by their artwork. There were 8 different painters in the dataset, which were retrieved as a fraction of the online gallery WikiArt. WikiArt was chosen for the experiment because none of the considered models were trained on it and because it contains a lot of various images. The dataset with a nearly uniform distribution of artists was chosen for simplicity, the exact dataset composition is provided in Table 2.

Table 2
Dataset for the experiment

Painter	Van Gogh	Matisse	Monet	Piranesi	Renoir	Roerich	Steinlen	Chagall	Total
Number of paintings	880	696	636	1286	726	859	932	986	7001

The dataset was divided into two groups: the training dataset and the test dataset (80% and 20% correspondingly). The training dataset was used for class reference vector calculation. The class reference vector for every class was calculated as the arithmetic means for each coordinate of all vectors of this class. The test classification was made guided by the following algorithm:

1. Calculate the Euclidean distance between every vector in the dataset and every class reference vector.
2. Label each dataset vector with its nearest reference vector class.

Calculated accuracy metrics for every model as classification results are listed in Table 3. Note that the accuracy for best and worst classified classes is the same for every model. The best classified was Piranesi, and the worst classified was Van Gogh. This is due to the visual difference between Piranesi's paintings and other artists in the dataset. Feature vector sizes for every model are also listed in Table 3. It can be interpreted as the amount of information that can be used to determine the exact class. However, the correlation between the size of the feature vector and accuracy is not apparent. The most accurate model is ConvNext – CNN architecture. XciT (ViT architecture) achieved a similar result with a significantly smaller size feature vector.

Table 3
Results of the artist classification

Architecture	CNN			ViT	
	BiT-M (ResNet101)	EfficientNet-B7	ConvNext-xL	Swin-L	XciT-L
Feature vector size	6144	2560	2048	1536	768
Accuracy, %	73	67	74	68	73

Experiment 2: Determining the qualitative difference between the two best models

Let me analyze the differences between CNN and ViT in similar image retrieval tasks. For this experiment, the two best architectures of each type were chosen: ConvNext and XCiT. Then, two random images from the dataset were picked. Feature vectors from the models were used to obtain the most similar images for the chosen two. In terms of vectors, the most similar vector means the closest by Euclidean distance. The results in Fig. 1–4 show that despite the similar accuracy of the models, their understanding of the similarity differs significantly. In the first case (Fig. 1 and 2), ConvNext correctly cited artworks by the same artist, while XCiT chose a few outliers.



Fig. 1. Similar images for XCiT for the Chagall example

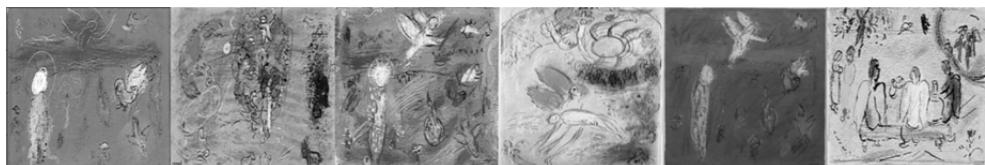


Fig. 2. Similar images for ConvNext for the Chagall example

However, luckily, XCiT found a sketch with a suitable composition that ConvNext did not find. In the second case (Fig. 3 and 4), both models found similar images, but XCiT was able to capture the similarity of faces in the portraits more accurately.



Fig. 3. Similar images for XCiT for the van Gogh example



Fig. 4. Similar images for ConvNext for the van Gogh example

Conclusion

Both convolutional neural networks and vision transformers are suitable for solving image classification tasks without fine-tuning. However, the recognition accuracy may be below the acceptable level, for what fine-tuning may be required. The most accurate models for use in real-life tasks are ConvNext-xL and XCiT-L. However, the considered differences in image processing of CNNs and ViTs didn't lead to the distinctive visual characteristics. Both models are able to effectively capture abstract concepts like genre, or style of painting.

Further work can be aimed at the analysis of the interpretability of feature vectors and the study of classification algorithms without fine-tuning.

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Классификация поверхности с использованием полностью подключенных нейронных сетей

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Исследована проблема классификации поверхностей с использованием полностью связанных нейронных сетей. Рассмотрен принцип работы нейронных сетей, методы оптимизации с использованием метода обратного распространения и градиентного спуска. Предложенная нейросетевая модель классификации поверхностей протестирована на основе открытых данных измерительных систем с датчиками IMU и предварительно выбранных показателей качества. Полученные результаты были проанализированы в заключительной части статьи.

Ключевые слова: машинное обучение, модель классификации, нейронной сети, показатели качества электрической энергии, модели матрицы ошибок, функция активации нейронного сетевого уровня

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Surface Classification Using Fully Connected Neural Networks

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This paper has investigated the problem of surface classification using fully connected neural networks. The principle of operation of neural networks, optimization methods using back propagation technique and gradient descent have been considered. The proposed neural network model of surface classification has been tested based on the open data of measuring systems with IMU sensors and pre-selected quality metrics. The results obtained were analyzed in the final part of the paper.

Keywords: machine learning, neural network classification, model quality metrics, model error, matrix activation, function neural network layer

Introduction

Currently most navigation methods of unmanned vehicles and aircraft are based on external sources of information such as GPS (Global Positioning System) or GLONASS (Global Navigation Satellite System). Such external sources of information are needed not only to track their location in space but also for the stable operation of other systems used in control systems.

However, the accuracy of navigation can be improved by using autonomous sources of information that are not directly related to the location of the position. INS (Inertial Navigation System) and IMU (Inertial Measurement Unit) are examples of such sources of information [1].

Since modern maps using segmentation and spectral analysis algorithms can contain information about the types of surfaces [2], GPS data can be made more reliable by placing autonomous information sources that will detect transitions to other types of surfaces, thereby fixing the location on the map. To detect such transitions, it is necessary to solve the problem of surface classification.

Another example of the practical application of the surface classification problem which we are solving is the problem of marking the type of surface, where it cannot be done in different ways.

Artificial neural network

An artificial neural network is a program code that, using various mathematical transformations, is able to simulate the work of the brain and self-learn from its mistakes. To put it more strictly, an artificial neural network is a sequence of differentiable parametric transformations. Just like a biological neural network, an artificial neural network consists of separate, interconnected neurons, but with a simpler structure.

Fully connected neural network

A fully connected neural network is an artificial neural network consisting of the simplest blocks (layers) (Fig. 1).

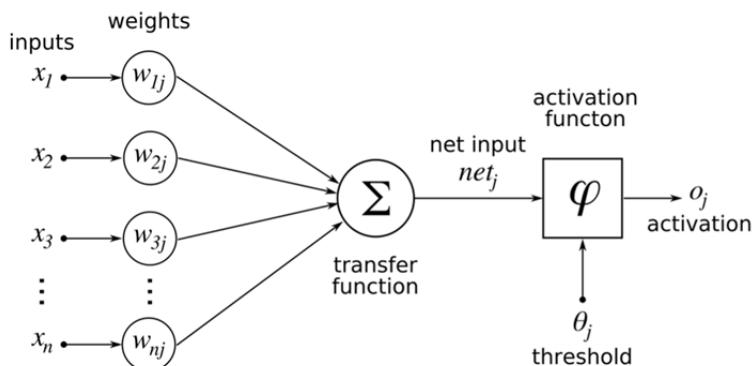


Fig. 1. Architecture of a fully connected neural network

- A linear layer is a linear transformation of the input data, where the training parameters are the weight matrix W and the shift vector b ($x \rightarrow xW + b$)).
- The activation function is a nonlinear transformation that is applied piecemeal to the input data. Thanks to activation functions, neural networks are able to generate more informative feature descriptions transforming data in a non-linear way. Rectified linear unit $ReLU(x)$ or the sigmoid $\sigma(x)$ are often used as an activation function [3].

Back propagation technique

Back propagation is a way of training a neural network. The goals of the error back propagation method are very simple: to optimize each weight in proportion to how much it affects a pre-selected loss function (MSE or MAE in case of regression and Cross Entropy or Log-loss in case of classification). When iteratively optimizing the weights of the model by gradient descent and reducing the error introduced into the total loss function by each weight, we get a set of weights at which the loss function will come to a local minimum and, as a consequence, to good forecasts.

The method of back propagation is used for effective training of a neural network using the so-called chain rule (the rule of differentiation of a complex function). In other words, after each pass through the network the back propagation performs a pass in the opposite direction and adjusts all parameters of the model parameters (weights and bias). In modern frameworks for creating neural networks the method of error back propagation is performed automatically using computational graphs called *Autograd*.

Experiment

In the experimental part of this research, we implemented a fully connected neural network and trained it in python using the Pytorch framework.

The simulation data was taken from open sources and consists of data records from the IMU-XSENS MTi-300 sensor, which is mounted on a robot moving on different surfaces [4]. The data set contains information about the orientation, angular velocity and linear acceleration of the robot, which moves on 9 different types of surfaces. An example of the data obtained from the IMU on which the model was trained is shown in (Fig. 2).

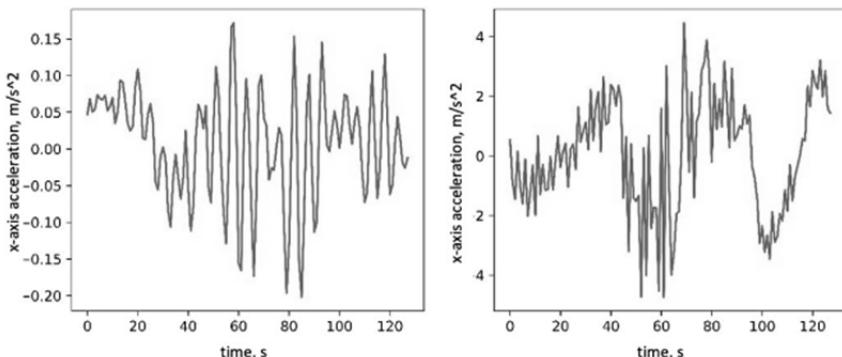


Fig. 2. Example of data with IMU

Since the data is balanced, we will use a quality metric such as Accuracy to assess the quality of the model. Accuracy is a metric that characterizes the quality of the model aggregated across all classes. For a more visual representation of the simulation results we constructed error matrix (Fig. 3).

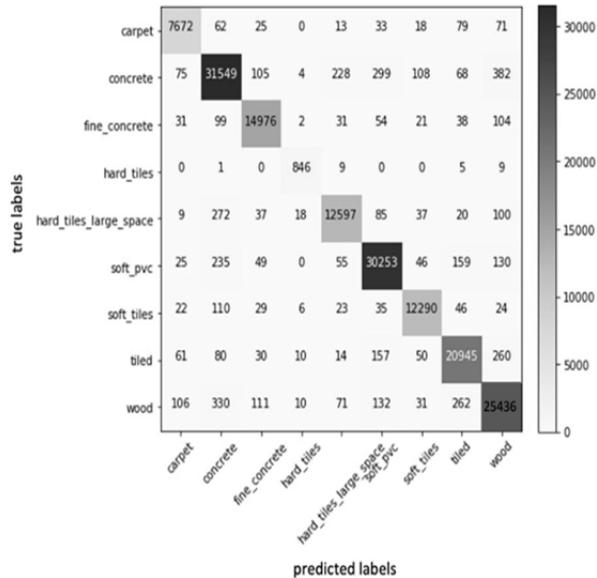


Fig. 3. Error matrix

The diagonal elements of this matrix show the number of correctly classified objects. It can be seen that the model classifies surfaces fairly accurately and rarely makes mistakes.

Conclusion

The analysis of the simulation results showed that fully connected neural networks are able to classify surfaces with sufficiently high accuracy and can be used to solve the problem. It should be emphasized that despite its simplicity fully connected neural networks have a high speed of operation and the ability to work in conditions of data heterogeneity. This fact makes fully connected neural networks an effective solution in tasks where high speed and reliability of systems are needed.

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УДК 004

Перспективы применения технологии PWA

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Рассмотрены предпосылки появления технологии прогрессивного веб-приложения (PWA), ее отличия от нативных приложений и веб-сайтов. Дано определение PWA, выделены преимущества перед другими типами приложений. Выявлены принципы, которыми должно обладать PWA приложение. Приведена информация о Service Worker, технологии, которая обеспечивает работу приложения в автономном режиме. Рассказано об обслуживании файлов из кэша и различных стратегиях кэширования, что также используется для обеспечения автономности приложения.

Ключевые слова: PWA, Service Worker, fetch, прогрессивное веб приложение, кэширование

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Prospects for Application of PWA Technology

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The prerequisites for the emergence of progressive web application (PWA) technology, its differences from native applications and websites are considered in the paper. The

definition of PWA is given, the advantages over other types of applications are highlighted. The principles which PWA application should have are identified. Information about the Service Worker, a technology that allows the application to work offline, is given. It is also said about serving files from the cache and various caching strategies, that are used to ensure the autonomy of the application.

Keywords: PWA, Service Worker, progressive web application, caching, fetch

Introduction

In the last few years there has been exponential growth in the number of mobile phone users. As of March 2023, 58.43% of all website traffic comes from people using mobile devices [1].

Obviously, the reasons include portability, cheap hardware, easy access to the internet and the increased number of services on the internet. With more users on mobile, the optimization of user experience on the phone is essential [2].

This trend has raised the bar for what users expect from websites, including fast loading and seamless browsing on their devices, regardless of brand, size or capacity.

An intermediate technology between sites and native mobile applications has become PWA technology — a web development technology that adds the capabilities of applications for mobile devices to sites. This technology allows you to solve the problem of traffic and mobility, and also allows you to work without the Internet.

Main part

Progressive Web Apps (PWA) are hybrid web pages which can be downloaded to your device just like a native APP and are designed to mimic native APP user experiences [3].

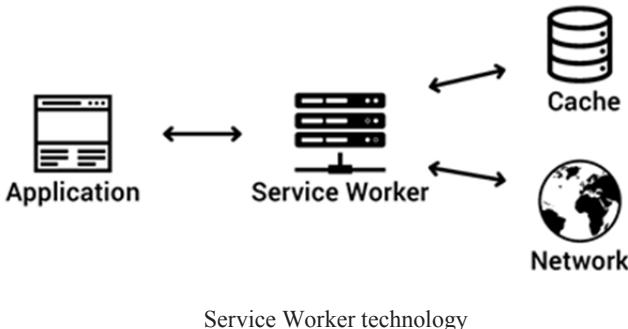
Once a user Installs or Adds to their Home Page — PWA's behave just like APPs. While the number of mobile users is growing each day — slow connections are an everyday problem for many and result in a frustrating user experience. PWA's are a great solution thanks to faster loading speeds and since they can even work while offline [4].

There are some key principles a web app should try to observe to be identified as a PWA. It should be [5]:

- discoverable, so the contents can be found through search engines;
- installable, so it can be available on the device's home screen or app launcher;
- linkable, so you can share it by sending a URL;
- network independent, so it works offline or with a poor network connection;
- progressively enhanced, so it's still usable on a basic level on older browsers, but fully-functional on the latest ones;
- re-engageable, so it's able to send notifications whenever there's new content available;
- responsively designed, so it's usable on any device with a screen and a browser — mobile phones, tablets, laptops, TVs, refrigerators, etc.
- secure, so the connections between the user, the app, and your server are secured against any third parties trying to get access to sensitive data.

The process of installing a web application is possible due to the loading of information into the cache and the support of Service Worker technology. Service Workers are a virtual proxy between the browser and the network. The Service Worker technology is a script that runs in the browser in the background. A key feature of the Service Worker technology is that this script can intercept and modify navigation and resource requests, flexibly cache

resources to provide full control over the behavior of the application in certain situations, for example, when the network is not available (Figure).



The fetch event lets us intercept every network request made by the PWA in the service worker's scope, for both same-origin and cross-origin requests. In addition to navigation and asset requests, fetching from an installed Service Worker allows page visits after a site's first load to be rendered without network calls.

The handler receives all requests from an app, including URLs and HTTP headers, and lets the app developer decide how to process them.

Serving files only from the browser cache doesn't fit every use case. For example, the user or the browser can evict the cache. That's why you should define your own strategies for delivering assets for your PWA. For example, you can have one strategy for the minimum UI assets, another for API calls, and a third for image and data URLs.

The most common strategies are [6]:

- Cache First — searches for a cached response first and falls back to the network if one isn't found.
- Network First — requests a response from the network first and if none is returned, checks for response in the cache.
- Stale While Revalidate — serves a response from the cache, while in the background requests the latest version and saves it to the cache for the next time the asset is requested.
- Network-Only — always replies with a response from the network or errors out. The cache is never consulted.
- Cache-Only — always replies with a response from the cache or errors out. The network will never be consulted. The assets that will be served using this strategy must be added to the cache before they are requested.

PWA applications have been actively used on the Internet for several years. Many large companies have made themselves progressive applications in addition to the usual ones that can be downloaded from marketplaces.

Based on statistics about the cost savings and productivity gains from Progressive Web Applications [7]:

- Google found that Progressive Web App install banners convert 5-6x more often than native install banners;
- the Forbes Progressive Web App's home page completely loads in just 0.8 seconds;
- the Weather Channel saw an 80 % improvement in load time after shipping Progressive Web Apps in 62 languages to 178 countries.

Conclusion

The use of PWA technology on the websites of popular brands indicates great prospects for the development of the technology. Many even call it the technology of the future. Advantages such as the small size of the application, efficient use of browser capabilities, instant installation of the application, cross-platform, make PWA technology very useful for the needs of companies, as it will ensure audience coverage even with a low Internet connection speed or a temporary lack of connection.

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УДК 611.08

Исследование способов решения проблем lifestyle-медицины с помощью применения методов машинного обучения

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Рассмотрены методы и приемы машинного обучения для решения задач lifestyle-медицины. В настоящее время тенденции распространности сердечно-сосудистых заболеваний, а также заболеваний, связанных с избыточной массой тела, вызывают серьезную обеспокоенность в научном сообществе. Подходы фармакологической медицины зачастую показывают меньшую эффективность, чем изменение образа жизни участников эксперимента. Машинное обучение может в значительной степени ускорить прогресс в этой области.

Ключевые слова: медицина образа жизни, отслеживание фаз сна, машинное обучение, мультиомный анализ, здоровье, образ жизни

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Research on Lifestyle-Medicine Problems Solution Using Machine Learning Approach

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The article describes the methods and techniques of machine learning for solving problems of lifestyle medicine. Currently, trends in the prevalence of cardiovascular diseases, as well

as diseases associated with overweight, are of great concern in the scientific community. Pharmacological medicine approaches often show less effectiveness than changing the lifestyle of the participants in the experiment. Machine learning can greatly accelerate progress in this area.

Keywords: *lifestyle-medicine, sleep phase tracking, machine learning, multi-omics analysis, health, lifestyle-medicine*

Machine learning and big data analysis are widely used both in the field of biomedicine in general and in lifestyle medicine in particular. The current state of these areas already makes it possible to alleviate the symptoms of many chronic diseases through the use of lifestyle therapies rather than regular medications.

Further development of technologies in this direction will be a gradual progress towards the synthesis of a digital twin of a person and, on its basis, providing a person with recommendations regarding a healthy lifestyle, including diet, exercise, daily routine, medication, etc.

The main objective of machine learning is to identify correlations among big data. The focus in the biology, biomedicine, and behavioral sciences is currently shifting from solving forward problems based on sparse data towards solving inverse problems to explain large datasets. Machine learning allows us to systematically preprocess massive amounts of data, integrate and analyze it from different input modalities and different levels of fidelity, identify correlations, and infer the dynamics of the overall system [1].

Lifestyle medicine is a growing area, some of the problems of which are successfully solved using machine learning methods and big data analysis. Some experts see the end point of this development as the emergence of a digital copy of a person to analyze and predict the state of his health based on population data, depending on his genetics, lifestyle, environmental conditions, social ties and other factors. The use of such a digital "twin" will provide real-time recommendations to the patient regarding his lifestyle [1].

One of the promising areas of research is the processing and analysis of data obtained from the study of one or more «omics»: genome, epigenome, transcriptome, and proteome. This direction has received particular development after the successes in the field of genome sequencing, as well as the development of computer technology and data processing techniques. Machine learning is used to detect non-obvious, including non-linear, correlations in data, study cellular mechanisms, recognize molecular signatures, and predict clinical outcomes on large data sets [2].

In this area of research, machine learning mechanisms face certain challenges. For example, the number of parameters can be many times greater than the number of samples, which leads to overfitting of the model. There are two ways to solve this problem: extract or select options. Parameter extraction methods can be linear (for example, Principal Component Analysis) and non-linear (for example, using an autoencoder). Among the methods for choosing parameters, there are filtering methods, wrapping methods and methods with built-in definition of key parameters [2].

The next significant problem in multi-omic studies is data heterogeneity. Reasons for this heterogeneity include, but are not limited to, a significantly different number of variables, different distributions and scaling, different data modalities, i.e. continuous signals, discrete counts, intervals, etc.

The use of classifiers in such studies is hampered by the rarity of certain classes or by the imbalance of classes represented in the data. This also leads to overfitting. Most

classifiers, including random forest, support vector machines, and artificial neural networks, are more likely to ignore instances of a rare class that represent the main value of the study. The problem is solved by randomly eliminating instances of the dominant class or by applying algorithms that give more weight to rare specimens [2].

There are also studies of the gut microbiome, when using machine learning methods, based on biome data, recommendations are made to the patient about foods that he should or should not consume. Among the most common applications of machine learning are: classification and recognition of microbial taxa, i.e. microbial classification and taxonomic assignment; predicting the host phenotype by associating microbial populations with phenotypes and the ecological environment, i.e. predicting diseases; and the use of microbial communities to understand the mechanisms of the disease and further application in personalized medicine, i.e., the search for biomarkers [3].

Motor activity and the quality and duration of sleep can be assessed using the sensors of the patient's wearable devices: heart rate sensor, gyroscope and accelerometer. With this data and machine learning methods, the type of movement can be classified: walking, walking upstairs, walking downstairs, running, sitting, lying down. In addition, using the same sensors, it is possible to determine the phase of sleep or awakening. Based on these data, it is possible to form a set of recommendations for the physical activity required by a particular user, taking into account his basic level of training and the amount of physical activity that he performs on a daily basis.

Over time, more and more studies appear, the result of which is a direct correlation of a person's lifestyle with the presence or absence of chronic diseases. Thus, lifestyle therapy is gaining more and more popularity, as opposed to the traditional approach of pharmacological medicine.

Among the main areas of lifestyle medicine, most often distinguished are: proper nutrition, regular moderate exercise, avoidance of alcohol and nicotine, sound and healthy sleep, as well as positive social interaction. Chronic stress is also a one of the negative lifestyle factors [4].

The 2021 study by a group of European scientists summarizes a total of 110 previous studies on the correlation of malnutrition with a predominance of carbohydrates, refined and processed foods and various types of breast, lung, prostate and other cancers. In the majority, it was possible to identify one or another dependence of the risk of developing a fatal disease with a variety of factors of malnutrition. The predominance of macronutrients in the diet, animal products, especially red meat, saturated and unsaturated fats were studied [4].

In addition, many studies confirm an increased risk of developing type 2 diabetes, diseases of the cardiovascular system in connection with certain negative eating habits. Obese mothers have been shown to have an increased risk of having a child with type 1 diabetes. In addition, there are studies proving that excessive consumption of sugar and refined industrial products cause chemical dependence on such foods, which leads to an increase in the amount of food consumed and has a negative impact on human health [5].

Moderate physical activity is also a must for a healthy lifestyle. It has been proven that physical activity can reduce the negative impact of stress on the body, exercise stimulates the self-renewal of stem cells in the brain, muscles and other tissues, and stimulates cognitive functions [4].

Regular quality sleep also has a significant impact on a person's physical well-being. Sleep optimizes processes at all levels of human life: cellular, tissue, the level of individual organs and their systems, regulates the ability to know and emotional state. Sleep and wakefulness exist within 24-hour rhythms regulated by major circadian genes.

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Технологии генерации контента для разработки мобильных игр. Обзор

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Видеогames давно стали распространенным видом досуга и важной частью рынка цифровых услуг. В последние годы идет бурное развитие мобильной отрасли. Мобильные устройства менее производительны, чем персональные компьютеры и консоли, поэтому не могут полностью соответствовать стандартам графики 3D-игр. Чтобы иметь наибольший охват пользователей, разработчики мобильных игр облегчают требования к производительности устройств, уходя от 3D-графики к 2D. Такой подход требует очень много художественной работы, в особенности это касается игр, в основе которых лежит коллекционирование. Коллекционные игры, в которых присутствует механика гачи, являются наиболее эффективными с точки зрения монетизации. Для поддержания конкурентоспособности своего продукта разработчикам приходится расширять и без того большой поток коллекционного контента. Над созданием такого количества контента трудится большое число художников и при тенденции к увеличению производства контента работников может не хватить. Помочь в создании контента могут глубокие генеративные модели. Приведен краткий обзор технологий, которые могут быть применены к данной задаче.

Ключевые слова: мобильные игры, генерация изображений, оптимизация, обзор

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Content Generation Technologies for Mobile Game Development. A narrative review

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Video games have long been a common form of leisure and an important part of the digital services market. The mobile industry has been developing rapidly in recent years. Mobile devices are less productive than PCs and consoles, so they cannot fully meet the standards of 3D game graphics. In order to have the greatest user reach, mobile game developers are easing device performance requirements by moving away from 3D graphics to 2D. This approach requires a lot of artistic work, especially for games based on collecting. Collectible games with gacha mechanics are the most effective in terms of monetization. To maintain the competitiveness of their product, developers have to expand the already large flow of collectible content. A large number of artists are working on the creation of such a large amount of content, and with a tendency to increase the production of content, there may not be enough workers. Deep generative models can help in creating content. This article provides a brief overview of the technologies that can be applied to this task.

Keywords: mobile games, image generation, optimization, review

Introduction

Video games have long been a common form of leisure and an important part of the digital services market. A large share of this market is focused on game consoles and personal computers, but in recent years there has been a rapid development of the mobile industry. This area has become especially profitable after the appearance of inexpensive smartphones on the market and an increase in the number of users, especially in the Southeast Asian segment. Over the past two years, the mobile gaming sector has grown significantly due to the impact of the coronavirus epidemic on leisure. The results of an analysis by the Financial Times newspaper showed that at the beginning of 2020, Chinese users made more than 212 million downloads in app stores [1]. For a developer, this is a profitable niche with greater development potential and lower risks than when developing an AAA project for PCs and consoles.

Mobile devices are less productive than PCs and consoles, so they cannot fully meet the standards of 3D game graphics. In order to have the greatest reach of users, mobile game developers are easing the performance requirements of devices, moving away from 3D graphics to 2D and simplified types of gameplay. This approach, however, requires a lot of artistic work, especially for games based on collecting.

Collectible games with gacha mechanics are the most effective in terms of monetization. Gacha (derived from the Japanese gachapon slot machines) is a game mechanic, the essence of which is to encourage the player to spend an internal or external monetary resource on in-game roulette, from which the player can get a valuable gaming resource. To successfully introduce mechanics into the game, several conceptual elements are required, one of which is a large and diverse set of content [2]. To maintain the competitiveness of their product, developers have to expand the already large flow of collectible content, offering the player more collectible resources or opening new options.

Modern popular gacha games are focused on collecting characters — in the game these are most often combat units. The task of developers and artists is not only to make

the unit desirable because of its combat power, but also to make the character characteristically and visually cute for the player, encouraging him to spend resources on favorite ones. The so-called waifu gaming (from the Japanese term waifu, which in turn originated from wife, implying a fetishized character) can encourage a player to spend ridiculously huge amount of money to strengthen his favorite one and collect everything related to them. Related to this phenomenon, the game element can be considered the presence of cosmetic items for the unit, which most often do not give gaming advantages, but change its visual component — change the color scheme or replace the character's costume.

A large number of artists are working on the creation of such a large amount of content, and with a tendency to increase the production of content, there may not be enough workers. Deep generative models can help in creating content. This article provides a brief overview of the technologies that can be applied to this task.

Perspective technologies application opportunities

“Image Generation from Sketch Constraint Using Contextual GAN” [3] explores the generation of images based on a manually drawn sketch. In previous technologies, the generation of the output image relies too much on the edges of the sketch, which can lead to a deterioration in the quality of generation when the sketch is made roughly. The authors of the work proposed their own method of generation, in which a rough sketch becomes a weak support and context for the output transformation. In the normal generation of the final image, the corrupted part of the input image is completed using the surrounding image content as context. By analogy, in the authors' approach, the “corrupted” part of the image is the entire image, while the context is a sketch [3]. One of the advantages of the technology is the possibility of obtaining different shapes and poses of the object in the output image from those described by a rough sketch. The application of technology to the task of generating content will reduce the time for drawing objects, individual parts of the illustration and will allow you to quickly create a basis for a character.

Another interesting approach to image generation is the work “Image Generation from Layout” [4]. The authors propose a new approach to image generation, which consists in creating an image with specified objects in the right places of the image. The representation of each object is divided into a specified part (category) and an undefined part (appearance). Based on this representation and the specification of the object's bounding box, a feature map is constructed for each object. These maps are then folded into a hidden feature map for the entire image, which is subsequently decoded into the output image. This approach is good for its flexible mechanism for controlling the formation of images. By dividing the representation of objects into categories and appearance, the model is able to generate a diverse set of images from the same layout [4]. The technology has a great potential for development, and applicable to our task will allow the illustrator to reduce the time to create such game elements as backgrounds (game locations). The approach is good because it allows you to increase the specifics of the request. When there is a specific idea, this approach will allow you to quickly create the basis of an illustration.

In the work “Deep Image Spatial Transformation for Person Image Generation” [5], an improved model of human image generation is proposed, taking into account the target pose. The presented model first calculates global correlations between sources and targets to predict flow fields. Then flowed local patch pairs are extracted from feature maps to calculate the coefficients of local attention. Finally, the source features are deformed using

a content-based sampling method with the resulting local attention coefficients. The network is divided into two parts: Global Flow Field Estimator and Local Neural Texture Renderer. The Global Flow Field Estimator is responsible for extracting global correlations and generating flow fields. Local Neural Texture Renderer is used to sample bright source textures for target objects in accordance with the received flow fields [5]. The model shows good practical results in the experiments of the authors, and also has other practical applications besides the main one: using the model, you can animate images (for example, object rotation or facial expressions). In the games discussed in our article, it is often necessary to prepare several images of the same character in different poses or with different facial expressions — this practice replaces the full-fledged animation that is used in games with three-dimensional graphics. If the characters are the main valuable resource of the gacha game, their number can be measured in three digits, and then the process of preparing images can be very delayed. In such a situation, this technology will come in handy more than ever. Having a ready-made illustration of the character, the artist can find an image with the necessary pose or make a rough sketch, and, depending on the quality of generation, make the basis for subsequent illustrations or almost ready-made ones.

Equally interesting is the work “Dressing in Order: Recurrent Person Image Generation for Pose Transfer, Virtual Try-on and Outfit Editing” [6], using similar methods as in the work above. The system supports pose transfer, virtual fitting and several clothing editing tasks. The key is the recurrent generation pipeline, which allows you to consistently put on clothes, so that fitting the same clothes in different order will lead to different images. The system can recreate the interaction of garments, as well as the layering of several garments of the same type. As the authors write, their system clearly defines the shape and texture of each garment, allowing you to edit these elements separately [6]. In gacha games, the main resource of which are characters, it is common practice to create a «skin» for a character — a cosmetic resource that changes the illustration from the point of design. As in the previous example, the process of creating additional illustrations can be greatly complicated by the constantly increasing number of characters. The technology will greatly facilitate the illustrator's task by creating the basis of an existing character in a different pose and in different clothes.

Conclusion

The mobile games sector is an extremely lucrative area, but gradually increasing competition pushes developers to endlessly increase content amount, heavily loading the illustrators of the project. The project manager can expand the staff or facilitate the work of existing employees by integrating deep learning technologies into the workflow.

This article is intended to draw the attention of developers of mobile games with two-dimensional graphics to promising approaches to content generation and help to cope with the growing demands of the market without excessive burden on the company's employees. In addition, these technologies can facilitate the production process for new companies with a small staff, where creating a large amount of content in a short time is impossible in principle.

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УДК 004.5

Использование дневникового метода исследования пользовательского опыта в юзабилити тестировании

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Рассмотрен дневниковый метод исследования пользовательского опыта, который при использовании в юзабилити тестировании позволяет выявить реальные проблемы пользователей, возникающие во время их работы с приложением. Метод может быть полезен для понимания поведения пользователя при работе с программным продуктом. Представлены понятия пользовательского опыта, юзабилити тестирования и дневникового метода, описаны типы дневников и их выбор в зависимости от целевой аудитории, приведены этапы проведения юзабилити тестирования с использованием дневника. Сделан вывод о том, что использование дневникового метода в юзабилити тестировании позволяет получить обширное представление о поведении, опыте, мотивации пользователя, а также о его взаимодействии с программным продуктом несмотря на то, что данный метод требует большие трудозатрат, чем другие методы исследования пользовательского опыта.

Ключевые слова: метод ведения дневника, юзабилити, пользовательский интерфейс, пользовательский опыт, разработка программного продукта, тестирование юзабилити

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Using the Diary Method of User Experience Research in Usability Testing

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This article discusses the diary method of user experience research, which allows you to identify real user problems that arise during their work with the application, when used in usability testing. The method can be useful for understanding user behavior when working with a software product. The article presents the definitions of user experience, usability testing and the diary method, describes the types of diaries and their choice depending on the target group, shows the stages of usability testing using the diary. In conclusion, it was concluded that the use of the diary method in usability testing allows you to get a broad understanding of the behavior, experience, motivation of the user, as well as his interaction with the software product, despite the fact that this method requires more labor than other methods of user experience research

Keywords: diary method, usability, user interface, user experience, software product development, usability testing

Introduction

At the moment, there are many different methods of user experience research when conducting usability testing of a software product. In this case, the methods can be divided into two main types, depending on the direct interaction with the user. Some methods involve interaction with the end user, and some involve only the study and analysis of data. The choice of a particular method of testing user experience depends on various reasons, for example, on the degree of readiness of the software product (whether it is the minimum viable version of the product or already a full-fledged product operating on the market), the type of software product (mobile application, web application, desktop application) or the target group.

One of the types of user experience research methods in usability testing, involving interaction with the end user, is diary research or research using a diary.

User experience and usability testing definitions

User experience is what experience/impression the user gets from working with a software product [1]. Does the software product solve his problem or pain, does it help him, does it have any value for him, and most importantly, how easy or difficult it is for him to use the software product. In order to answer all these questions, a software product developer needs to conduct usability testing.

Usability testing is one of the methods for verifying the functionality of a product by researching and observing real users of a software product while interacting with it [2]. The main goal is to identify user problems when working with a software product, that is, to study the user experience of the user, and as a result to determine possible improvements in the product. Usability testing is really valuable because it reduces uncertainty about what users really want and need [1]. When conducting usability testing, direct interaction with real users is important, which helps to understand the thoughts of users without any external factors.

In general, all usability testing methods can be divided into qualitative and quantitative [3]. Quantitative usability testing methods are based on numerical data collection or

metrics. With the help of such methods, you can evaluate the popularity of using a particular functionality, for example, put a click counter on the submit button in the form. And qualitative usability testing methods are deeper in user research and help answer the questions «Why did the user not perform the target action?» or «What barriers did the user encounter on the way to the target action?» based on a detailed study of user experience and collecting feedback from end users [4]. One example of qualitative user research is the diary method or diary research.

Diary research definition

Diary research is a qualitative usability testing method used to collect qualitative data on user behavior, actions, and experiences over time [5]. In most cases, when conducting a diary study, a simple notepad is used as the main tool, in which the user writes down all his problems and pains that arise when interacting with the software product for a certain period of time (week, month). In this case, the notebook can be both electronic and physical. At the end of the study, the user passes the notebook to the researcher for detailed study and drawing conclusions. Also, during this usability testing, sometimes the user is reminded of the need to fill out a diary or make a note in it (for example, using push notifications in the application itself) [5].

In particular, researchers are interested in the problems and pains that users experience when working with a software product. A more accurate version of the diary method may also include a quantitative indicator with which the user himself can assess the severity of the problem.

Also, the diary method is well suited for researching the user experience of a prototype or a minimum viable version of a software product, which in turn can be developed to test product hypotheses or, in other words, to test the value of an idea and its business viability. Thanks to the use of the diary method, you can really understand what problems the user is facing, what errors and barriers arise in his way, and as a result form a list of necessary improvements and improvements for the final version of the product or a future release.

For example, a developer of a mobile application of an online plant store needs to conduct usability testing. At the first stage, it selects users who really plan to make an online purchase of a plant in the near future. At the second stage, it gives users diaries or accesses to them (if the diary is in electronic format) and asks them to record all aspects that affect their impression of visiting a competitor's software product, or, if available, an existing prototype/minimum viable version of the product. At the third stage, users record their impressions in a diary. At the end of the study, researchers can analyze and understand both the positive aspects of using the product and the problems of users when interacting with the product based on the data obtained.

The context and time period during which data is collected for a diary study make them unlike other common usability testing methods, such as surveys (which provide observational information about a specific moment or a planned set of limited interactions in the laboratory) [6].

Types of diaries and the choice of type depending on the target group

There are various forms (means of presenting information) of diary research [5]. According to the form, the following methods are most common: pen and paper; social media/email; online form/website; specially designed application; notes made using an

electronic device (computer, laptop, smartphone or tablet); photo documentation (usually in combination with notes, an application or an online form); video documentation.

It is worth noting that in a classic diary study, participants simply record information using a pen and notepad.

By time, there are the following diary entries:

1. Complete recording of each event.

2. Brief notes with details added later (for example, a research participant pays attention to some interface elements, photographs them, and then after a while he describes his impressions in detail through, for example, an online form).

The researcher can also add structure to this method and thereby make it easier for the study participants to record by providing forms to fill out [6]. For example, a form for each individual record may include fields such as day, time, location/usage situation, description, feelings, etc.

It is also worth choosing the form of a diary depending on the target audience of the software product. For example, if the target audience is elderly people, then it is worth using a classic form, that is, a pen and notepad, or video recording (as easy to use as possible), and it is also necessary to remind them that they need to fill out a diary, since they can simply forget. If the target audience is teenagers, then the best solution would be to use notes or an application on mobile phones. This will also allow you to quickly collect the results after the study, and, if necessary, launch an additional study.

Stages of usability testing using a diary

The study of user experience using the diary method includes the following stages:

1. First you need to determine the purpose of the study. An important stage of testing is setting goals and defining tasks. Here it is necessary to decide what is really necessary to get from this study, what points are important for it, and also what are its hypotheses?

2. Determine the category of users to participate in the study. For a diary study, as for any user study, you need to think about the criteria that the researcher will use to select participants. For example, age, gender, marital status, place of residence, profession, income, certain devices/products that are used by future study participants.

3. Determine the duration of the study. At this stage, it is necessary to define a list of research questions so that they fit well into the structure of the diary. Determine the period of the study, as well as set the start and end dates.

4. Choose the form of the diary and the time of the diary entry corresponding to the purpose of the study, budget and deadlines.

5. Hold a meeting with users and explain to them the basic rules of keeping a diary. At this stage, you can also write detailed instructions for completing the diary. At a meeting with users, it is necessary to answer all their questions, as well as fix them and take them into account when conducting future research.

6. Constantly be in touch with the participants of the study and observe them during the research process, correcting the forms for writing and diary questions. During the study, frequent feedback from participants contributes to obtaining detailed answers. An important point is to send timely reminders to the study participants about the need to fill out their diaries, otherwise they may forget to make notes and remember about them by the end of the study, which may cause key moments or events associated with each entry to be missed [7]. The researcher should provide recommendations on tasks that may not be as intuitive as it may seem at first glance.

7. Analysis of the results. After the study, it is necessary to evaluate all the records received from the study participants. If some points in their record are not clear, it is worth an additional interview to discuss the diary entries in detail. The researcher can ask questions to the participants to reveal the specific details needed to complete the recording.

8. Evaluation of results. Usability testing with the help of a diary ends with a more or less detailed summing up, that is, a final discussion. At the end of the diary study, it is necessary to evaluate your results. In order to effectively and correctly evaluate the results of the study, it is necessary to answer the questions posed at the beginning of testing, as well as to test research hypotheses. Sometimes the results of the study may not be unambiguous or generate new questions, in which case it is worth analyzing the results in more detail and forming additional usability testing using a diary, which will include the necessary clarifying questions.

Conclusion

The diary research method allows you to get a broad understanding of the user's behavior and experience, about his interaction with the software product over time, despite the fact that this method requires more time and effort than other methods of user activity research. However, this research method is also suitable for researchers who do not have experience in conducting research in this format. A beginner can start with a little research on paper or using any application convenient for him. Diary research provides useful results that are especially important in the early iterations of the project.

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Адаптивная сетевая балансировка с использованием динамического алгоритма Weighted Round Robin

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Рассмотрена проблема адаптивной балансировки сетевой нагрузки. Цель исследования — реализация и проверка эффективности работы алгоритма *Dynamic Weighted Round Robin* посредством программного моделирования. Приведен обзор литературы по предмету исследования, осуществляется гибридизация алгоритмов, накладывается ограничение на входной поток сетевых запросов, осуществляется программное моделирование и анализ полученных показателей. Результатом исследования является программная модель процесса адаптивной балансировки нагрузки. Научная новизна заключается в оригинальном подходе при решении задачи адаптивной балансировки с использованием эволюционного подхода. Проведенный в данном исследовании эксперимент продемонстрировал эффективность реализованного алгоритма, которая заключается в сокращении среднего времени обработки сетевых запросов, поступающих в систему.

Ключевые слова: программная модель, адаптивная балансировка нагрузки, сетевой запрос, входной поток вычислительных задач, *dynamic weighted round robin*, генетический алгоритм, целевая функция

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Adaptive Network Load Balancing Using Dynamic Weighted Round Robin

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The paper discusses the problem of adaptive network load balancing. The scientific novelty of the approach to solving the problem of adaptive balancing using an evolutionary approach is discussed. The possibility of the approach to implement and verify the effectiveness of the Dynamic Weighted Round Robin algorithm through software modeling is focused on. Literature on the subject of the research is reviewed. Hybridization of algorithms is carried out. Software modeling and analysis of the obtained indicators is presented. The results of the research are discussed. The experiment conducted demonstrates the effectiveness of the implemented algorithm.

Keywords: software model, adaptive load balancing, network request, input stream of computational tasks, dynamic weighted round robin, genetic algorithm, objective function

Introduction

Modern computing systems are sets of computing nodes connected by a network and functioning as a single whole. Computing systems can be either homogeneous (consisting of identical nodes) or heterogeneous (consisting of nodes of different configurations and, as a consequence, nodes of different capacities) [1].

One of the main tasks solved within the framework of the operation of a computing system is the distribution of load between its nodes. The load between nodes is balanced using a set of special methods. The efficiency of the system directly depends on how optimally such a distribution is carried out [2].

Load balancing can be performed using both hardware and software tools. Load balancing technologies are actively developing and are now of great interest from the point of view of the IT industry.

Literary review

In the field of information technology, the concepts of vertical and horizontal scaling are common. They are applied both to physical resources and to software systems that are operated on them [3, 4]. Moore's law has lost its relevance [5], which makes horizontal scaling of systems more preferable [6], and the problem of load balancing more relevant.

Load balancing is carried out using a set of approaches and methods that correspond to the levels of the OSI model: network, transport and application [2].

In the case of network-level balancing, the load balancing function is performed by means of IP addresses. It is assumed that several physical machines can be responsible for one IP address at once.

When balancing at the transport layer, load distribution is carried out through proxy servers. Unlike the network layer, the transport proxy server acts as an intermediary and can add additional headers to the request.

Application-level load balancers analyze the contents of requests and redirect them to system nodes depending on the content and type of operations required. Well-known examples of solutions for applied balancing are Nginx and PGpool [2].

There are many different load balancing algorithms. Choosing a specific algorithm, you need to proceed, firstly, from the specifics of a particular project, and secondly, from the tasks that need to be solved. Among the goals that can be pursued within the framework of solving the balancing problem, we can distinguish: uniformity and determinism of distribution, minimum processing time, scalability.

The most well-known, frequently used and simple balancing algorithm is Round Robin. Requests are sequentially transmitted to servers from a looped list. This algorithm is widely used, in particular, in the DNS system [2]. The simplicity of the algorithm also entails some disadvantages: for effective operation, it is necessary that each server has the same set of resources available. In modern practice, these conditions in most cases turn out to be impossible [2].

Weighted Round Robin (WRR) is an improved version of the Round Robin algorithm. Depending on the performance and power of the server, each of them is assigned a weighting factor. This contributes to a more even distribution of the load: servers with more weight process more requests. For the WRR to work effectively, it is necessary to choose the right weights.

For adaptive balancing, WRR weights must be selected dynamically. The concept of such an algorithm is known and is called Dynamic Weighted Round Robin (DWRR). There are a number of researches that offer a variant of the implementation of such an algorithm, but they often deal with a particular solution to the adaptive balancing problem. For example, the research [7] suggests the use of various mathematical heuristics in conjunction with periodic reading of the state of the entire system (using feedback in real time), which is not entirely applicable to the modern web, where, due to the distribution of systems, the data transfer time is usually many times longer than the time of direct requests processing, which does not allow the effective use of metrics.

As part of the ongoing research, the implementation of DWRR is proposed, which involves the selection of weights in the background. This selection ultimately comes down to solving an optimization problem. To solve this class of problems, there are many methods, one of which is the method of evolutionary modeling.

Evolutionary modeling (EM) is a stochastic-heuristic method for solving optimization problems that uses the conceptual apparatus of population genetics [8] and the idea of “soft computing” [9].

A special place in EM is occupied by the genetic algorithm (GA). During the GA operation, a parallel analysis of different areas of the solution spaces is performed. Unlike machine learning, GA uses the absolute value of the objective function (CF), not its increment. The search process can continue until all points of the investigated space have been considered. The optimum criteria, the limit of the number of generations, the threshold of the CF increment, etc. can be used as a limitation [10].

Operators [8] are used to obtain the next set of solutions in GA: they are also called stages, because they are performed sequentially at each iteration. The following operators are used in the standard GA: selection operator (selection); crossover operator (recombination of genes); mutation or inversion operator.

The selection operator is of the greatest interest here. It is used to determine based on the fitness function candidates whose genes will be used to form the next generation. There are many selection schemes and their modifications. The most famous of them are: truncation selection, elite selection, exclusion selection, Boltzmann selection method [11].

Research results and their discussion

As part of the research, a software model of a distributed heterogeneous computing system was implemented, while a restriction was imposed on the input stream in the form of atomicity and independence of network requests. These limitations made it possible to fully concentrate on the subject of research without the need to additionally work out a solution to the problem of the uncertain nature of the input stream of requests [12].

Let the nodes of a computing system be a set $P = \{P_1, \dots, P_n\}$. The nodes are interconnected with each other and have some configuration characteristics, such as CPU, RAM, ROM, etc. Then let each P_i be a tuple of the form $\{p_1, p_2, \dots, p_k\}$, the elements of which embody various characteristics of the computing node. Let there be a set of network requests $X = \{X_1, \dots, X_m\}$, where every X_j is a tuple $\{x_1, x_2, \dots, x_k\}$, the elements of which embody various parameters of a request.

Also, for each node P_i given its characteristics to some network request X_j is some time to complete this request X_j on node P_i , which can be formalized in the form of $T = E(P_i, X_j)$, where E is the function whose value is defined for each possible pair P_i and X_j . The determination of P_i from the set of nodes of the system on which the request X_j , will be performed is carried out by the balancing function: $P_i = B(X_j, P)$.

Then the final task of load balancing can be formalized in the form of minimizing the total execution time of network requests X on sets of nodes P . To do this, you need to choose the type of function B : $T_{\text{sum}} = \sum_{\forall X_j \in X} E(B(X_j, P), X_j) \rightarrow \min$.

The load balancing function B is represented by the Weighted Round Robin algorithm. The optimization problem, which consists in the selection of weighting coefficients for the Weighted Round Robin algorithm, was solved using a standard genetic algorithm.

To form the input flow of requests, an ML model was developed for predicting the characteristics of a request by its various parameters. An example of a fragment of the list of a request parameters, presented initially in the form of an HTTP request, is illustrated in Table 1, and the most significant request characteristics are presented in Table 2.

Table 1
Parameters (dependent variables) of a network request

Parameter	Type	Description
Node	Nominative	Execution node
Size	Quantitative	Size of the HTTP request in bytes
Endpoint	Nominative	http://<ip>:<port>/<endpoint>

Table 2
Characteristics (independent variables) of a network request

Characteristic	Type	Description
Execution time	Quantitative	Task execution time on a node
Occupied memory	Quantitative	Occupied memory when executing

The prediction of the characteristics of a computational task by its parameters is carried out using linear regression. Depending on the features of the functioning of a particular computing system, the feasibility of using each of the machine learning models will vary from case to case [13].

Thus, during the development of the model, 3 software modules were implemented: a module for generating an input stream of tasks based on linear regression (Python) using pandas, numpy and sklearn libraries; a load balancing module (Golang), including a naive implementation of WRR; a WRR configuration module (Golang) based on GA with 3 operators [14].

The experiment consisted of sequential execution of the following stages: construction of a linear regression model based on the metrics of the computing system; carrying out the process of evolutionary modeling; reconfiguring the balancing algorithm.

Suppose there are only 3 computational nodes (node) and 2 types of computational tasks (edp), 1 quantitative metric of the query parameter (request_size) and 2 quantitative metrics of the query execution characteristics (execute_time, memory_use). Then the data for building a linear regression model can be presented in Table 3.

Table 3
Data format for building multiple regression

No.	Execution time	Memory use	Request size	node 2	node 3	edp 2
1	27.214	346	126	0	0	0
2	30.345	403	126	0	0	1
3	20.029	672	126	0	1	0
4	18.182	504	126	1	0	0
5	53.192	201	179	0	0	1
...

The node-1 and edp-1 classes are excluded from the table in order to eliminate redundancy. As a result, we obtain a regression model with coefficients for each of the dependent variables (Table 4).

Table 4
Multiple linear regression coefficients

Parameters	Intercept	req size	node 2	node 3	edp 2
Execution time	27.82097639	0.06818165	-17.29081112	60.37713004	12.73380641
Memory use	44.19622851	1.87571081	176.04401313	105.32098757	1.73683651

The operation of an unconfigured balancing algorithm is shown in Fig. 1.

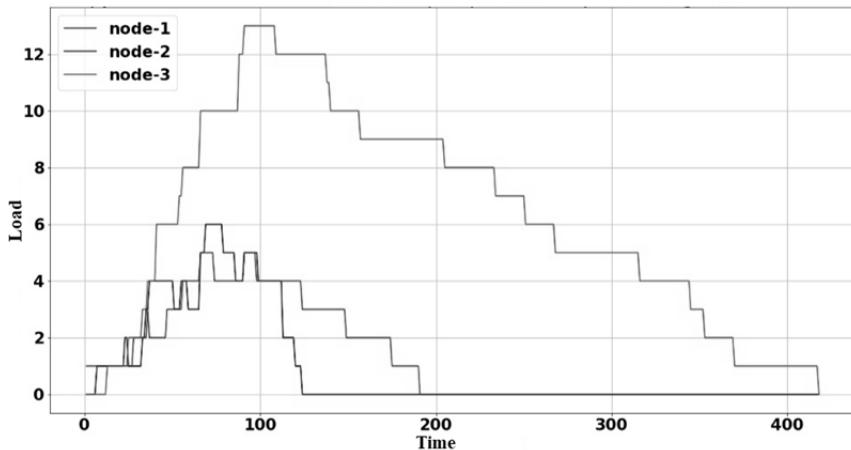


Fig. 1. Operation of an unconfigured balancing algorithm

The process of the genetic algorithm is illustrated in Fig. 2 and 3. Fig. 2 shows how the weights changed. Fig. 3 shows how the total amount of time spent on all tasks changed.

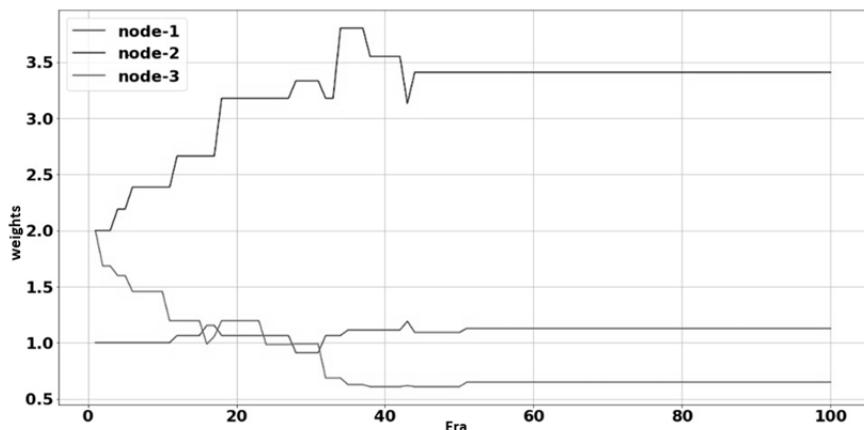


Fig. 2. Process of the genetic algorithm (weight)

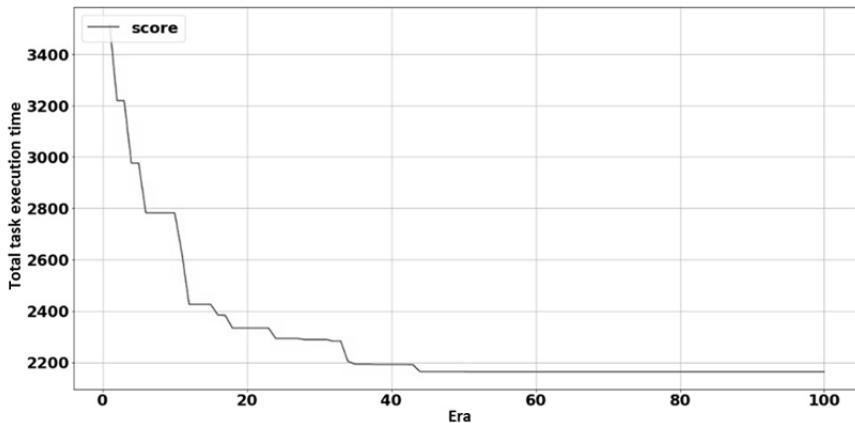


Fig. 3. Process of the genetic algorithm (total amount of time)

After completing the evolutionary process and setting the weights on the balancing algorithm, a more optimal distribution of computational tasks was obtained, as shown in Fig. 4.

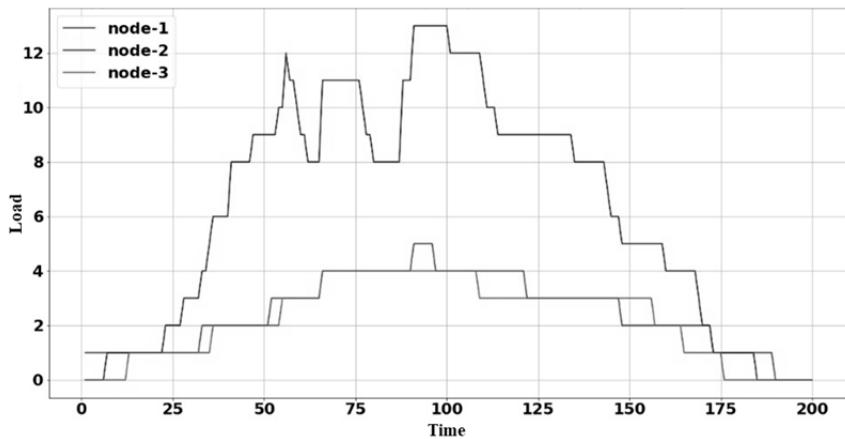


Fig. 4. Optimal distribution of computational tasks

The input task stream was generated for the first 100 seconds. Figure 1 clearly shows the load imbalance between the nodes. This is also evidenced by a strong spread in the completion time of processing tasks by nodes (120 seconds, 190 seconds and 420 seconds, respectively). The node-3 node showed itself the worst.

From Fig. 2 and 3 it is noticeable that the evolutionary process has reached a suboptimal niche at about 50 iterations (epochs) of the GA operation. The values of the weights have changed significantly. As expected, the weight of node-3 decreased and became the minimum of 3. The total task processing time has been reduced by approximately 35 % (Fig. 3).

According to the graph in Fig. 4, it can be concluded that the working nodes of the system not only completed their work at about one point in time, but also did it 200 discrete steps (seconds) earlier than in the case of an unconfigured algorithm in Fig. 1.

Conclusion

In the process of experimental modeling of adaptive load balancing, it was possible to reduce the total amount of task processing time by 35%. The increase in balancing efficiency was achieved through the use of a genetic algorithm. Also, the use of this algorithm made it possible to achieve the following balancing goals: fairness, uniformity, minimum processing time.

It is worth noting that the effectiveness of the adaptive balancing method presented in this article largely depends on the correctness (optimality) of the initial configuration of the Weighted Round Robin scales. The optimality of the initial setup is significantly affected by the size of the system and the heterogeneity of its hardware and software: the more hardware and software elements are included in the system and the more diverse these elements are, the harder it is for system administrators to choose the optimal configuration. The software model developed within the framework of this research demonstrates the possibility of solving this problem by using an adaptive balancing approach.

The developed software model has a margin of versatility: it is possible to use various balancing algorithms, an arbitrary number of network request parameters, any number of nodes with different characteristics from each other. However, there are also limitations: network requests must be atomic (cannot be divided into subqueries) and independent (requests are not related to each other by order relations).

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Биомедицинские технологии

**Biomedical
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Исследование годовой динамики изменения концентрации хлорофилла «а» и биогенных элементов в Яченском водохранилище в г. Калуге

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Представлены результаты годового эксперимента по изучению динамики концентрации хлорофилла «а» и биомассы фитопланктона в рекреационно-нагруженном водном объекте Калужской области. Актуальность обусловлена всевозрастающей тенденцией к эвтрофированию зарегулированных водных объектов. Диапазон изменения концентраций хлорофилла «а» варьируется от $1,48 \pm 0,49$ мкг/л в апреле до $117,97 \pm 4,47$ мкг/л в сентябре, при этом биомасса фитопланктона меняется от $0,59 \pm 0,07$ до $47,2 \pm 5,57$ мкг/л. Взаимосвязи концентрации хлорофилла «а» и других показателей на данный момент не выявлены.

Ключевые слова: хлорофил «а», биогенные компоненты, водохранилище, фитопланктон

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Research of the Annual Changes Dynamics in the Chlorophyll "A" and Biogenic Elements Concentration in the Yachenskoye Reservoir in Kaluga

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The paper presents an annual experiment the results to study the dynamics chlorophyll "a" and phytoplankton concentration biomass in a recreational-loaded water body in the Kaluga region. The relevance is due to the ever-increasing eutrophication tendency to regulated water bodies. The range concentrations chlorophyll "a" varies from 1.48 ± 0.49 mcg/l in April to 117.97 ± 2.47 mcg/l in September, while phytoplankton biomass varies from 0.59 ± 0.07 to 47.2 ± 5.57 mcg/l. The relationship between the chlorophyll "a" concentration and other indicators has not been revealed at the moment.

Keywords: chlorophyll "a", biogenic components, reservoir, phytoplankton

Reservoirs, ponds and lakes located within the city limits are popular recreation the population areas and are recreational-loaded water bodies. In this regard, an urgent task of modern research is to analyze the ecological wellbeing water bodies recreation-laden and socially significant. [1]. The entry amount pollutants a large into water bodies leads to the degradation of both individual the ecosystem components and entire groups of reservoirs [2]. At the same time, the main impact factor is chemical components origin biogenic entering the water body both during authorized and unauthorized discharges, as well as biotic the ecosystem components of the water body and adjacent territories. A large contribution of biogenic components can lead to excessive phytoplankton productivity and, as a consequence, to eutrophication body water.

In this regard, the purpose of this work is to study the dynamics concentration chlorophyll *a* (*Cl_a*) and phytoplankton biomass in the Yachenskoye reservoir in Kaluga. Additionally, to identify the dependence load the influence biogenic on the primary production community the phytoplankton, the main biogenic components of the water body were identified: nitrates, phosphates, ammonium, BOD (biological oxygen demand) — as an indicator of aerobic biochemical oxidation of organic matter by microorganisms, methane — a product of the vital activity of living organisms [1].

The Yachenskoye reservoir, located in Kaluga, was chosen research as the object. This is a man-made reservoir on the riverbed of the Yachenka River for sports and cultural purposes built for the Olympics-80. Morphometric the reservoir characteristics: length — 2,5 km, maximum width — 800 m, maximum depth — 7 m. The Yachenskoye reservoir and its embankment, located on the left bank, are a continuation of the ensemble of the K.E. Tsiolkovsky State Museum of the History of Cosmonautics. Reservoir on the right bank there is a monument of nature of federal

significance “Kaluga forest”. Thus, the selected object is a place both natural and anthropogenic accumulation influence factors.

The study subject is to study the changes dynamics in phytoplankton biomass and chlorophyll *a* concentration.

The chlorophyll *a* content is an internationally recognized most important eutrophication indicator and water pollution. For example, the ecological state assessment and this indicator monitoring in the Baltic Sea are provided for by the Maritime Strategy and the Water Directive of the European Union.

The chlorophyll *a* study is a convenient procedure for assessing the phytoplankton biomass ecosystems aquatic, which, with a sufficient amount statistical data, will make it possible to predict the water bodies eutrophication by analyzing the increase in the primary phytoplankton community production. At the same time, it is worth noting that phytoplankton is an important organic matter producer and self-purification an agent, as well as an indicator state the reservoir ecosystem the ecological.

An observation point was identified at the object of the study — “release” (Figure).



Observation point at the research object

The total annual water runoff entering the reservoir in an average water year is more than 8 times greater than the reservoir bowl volume, which allows us to conclude that the water exchange of the Yachenskoye reservoir is good [3]. Therefore, the water selected at the “release” point will characterize the water body complex state.

To identify the changes dynamics in the chlorophyll *a* and biogenic components concentration, fieldwork was carried out from August 2021 to October 2022. Laboratory analysis of biogenic components was carried out in the accredited ecological and physico-chemical research laboratory of LLC firm “Ecoanalytica” according to approved methods.

Laboratory analysis concentration chlorophyll a was carried out in the accredited laboratory of LLC firm "Ecoanalytica" by the spectrophotometric determination method photosynthetic pigments of algae with their preliminary extraction with ethanol, in accordance with the methodology approved by Roshydromet [4].

The obtained results analysis and their processing were carried out using the statistical software package Microsoft Office Excel 2016. The results obtained are presented in Table.

Study results the water Yachenskoye reservoir

Date	Nitrates. mg/dm ³	Phosphates. mg/dm ³	Ammonium. mg/dm ³	BOD. mgO ₂ /dm ³	CH ₄ . mm ³ /dm ³	Cla. mcg/l	Raw phytoplankton mass (Bfs). mcg/l
25.08.2021	0.09±0.01	0.04±0.01	0.10±0.03	6.20±0.87	6.9±1.5	79.97±0.99	31.99±3.83
30.09.2021	0.28±0.05	0.09±0.02	0.14±0.04	5.66±0.79	16.0±3.5	117.97±2.47	47.19±5.57
16.11.2021	1.43±0.26	0.08±0.01	0.17±0.03	3.88±0.54	6.36±1.43	16.29±0.49	6.52±0.79
23.12.2021	2.97±0.53	0.12±0.02	0.49±0.10	4.42±1.15	-	8.56±0.87	3.42±0.42
17.02.2022	6.29±1.38	0.09±0.01	0.57±0.12	2.90±0.41	8.64±1.91	4.28±2.24	1.71±0.22
31.03.2022	6.14±0.74	0.29±0.05	0.17±0.03	6.51±0.91	15.8±3.4	5.43±0.49	2.17±0.27
29.04.2022	7.26±0.87	0.17±0.03	0.59±0.12	4.76±0.67	10.1±2.2	1.48±0.49	0.59±0.07
25.05.2022	1.41±0.25	0.13±0.02	0.21±0.04	4.39±0.61	10.7±2.3	2.96±1.14	1.18±0.14
14.06.2022	0.12±0.02	0.23±0.03	0.22±0.05	3.40±0.48	45.6±9.7	9.4±0.2	3.76±0.45
15.08.2022	0.40±0.07	<0.05	<0.10	6.14±0.86	8.5±1.9	23.2±4.3	9.28±1.09
10.10.2022	0.56±0.10	0.09±0.01	0.15±0.03	5.63±0.79	15.4±3.3	4.4±1.0	1.76±0.21
Average	2.45±0.39	0.12±0.02	0.26±0.06	4.90±0.74	14.40±3.11	24.90±1.33	9.96±1.12

Min, max — minimum and maximum concentrations detected during the experiment.

The minimum concentrations for nitrates, phosphates and ammonium are typical at the end of the summer period (August). The highest these components content was observed in spring (March — April) during the high water period. This indicates the enrichment of the reservoir with biogenic elements introduced by surface runoff. It should also be noted the maximum value of BOD detected during the spring flood. Obviously, this is due to the aerobic biochemical oxidation of organic matter received from the surface runoff.

The maximum values of the dissolved methane level are observed in the summer period. Whereas the autumn period is characterized by a decrease in methane levels. This may be the result of a decrease in the activity of microorganisms, as well as physical processes occurring in the reservoir.

The concentration of chlorophyll a varies quite widely — from 1.48±0.49 mcg/l in April to 117.97±2.47 mcg/l in September, which averaged 24.90 mcg/l over the entire period. At the same time, the raw mass of phytoplankton varies from 0.59±0.07 to 47.19±5.57 mcg/l. During the study period, there was no clear dependence of chlorophyll a on other indicators for the entire data set. In this regard, further research is required to study the dynamics and establish dependencies.

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УДК 004.94

Разработка системы по неинвазивному распознаванию динамики гормона дофамина по психоэмоциональному состоянию человека в рамках современных здоровьесберегающих технологий

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Рассмотрена разработанная авторами методика неинвазивного распознавания динамики гормона дофамина по психоэмоциональному состоянию человека на основе частотного и нейросетевого анализа биологических сигналов. Для оценки эмоционального состояния участников эксперимента производится одновременное измерение нескольких физиологических сигналов с помощью датчиков: фотоплетизмограммы, датчиков электрической активности кожи и электрокардиограммы, подключаемых к платформе Arduino. Полученные сигналы обрабатываются методом быстрого преобразования Фурье, выполняется анализ результатов с помощью сверточной нейронной сети.

Ключевые слова: электрокардиограмма, фотоплетизмограмма, быстрое преобразование Фурье, нейросеть, язык Python

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Development of a System for Non-Invasive Recognition of Dopamine Hormone Dynamics by Human Psychoemotional State within the Framework of Modern Health-Preserving Technologies

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The method developed by the authors for non-invasive recognition of dopamine hormone dynamics by psychoemotional state of a person based on frequency and neural network analysis of biological signals is described. To assess the emotional state of the participants in the experiment, several physiological signals are simultaneously measured using sensors: photoplethysmogram), sensors of electrical activity of the skin and electrocardiogram connected to the Arduino platform. The obtained signals are processed by the fast Fourier transform method, the results are analyzed using a convolutional neural network.

Keywords: *electrocardiogram, photoplethysmogram, fast Fourier transform, neural network, Python language*

The relevance of recognizing the dynamics of the dopamine hormone in a non-invasive way is due to the rapid growth rate of various external factors beyond human control in the modern rapidly changing world that can negatively affect human health and quality of life.

Hormones are biologically active substances produced by endocrine glands cells. In addition to controlling our mood, hormones also affect concentration, sleep, metabolism, pulse rate and blood pressure, immunity, motivation and many other physiological functions [1]. In turn, a person is able to influence the production of certain hormones in his body, and continuous tracking of their dynamics gives an instrument to achieve this goal.

When developing a technique for non-invasive recognition of dopamine dynamics, the authors drew up and partially implemented a plan for conducting an experiment and automated processing of its results.

At the first stage of the experiment, data were collected using electrocardiogram (ECG) sensors connected to the Arduino platform to assess the current emotional state of the participants [2]. During the experiment, 48 digitized ECG signals were recorded in the files. The recording was made while monitoring 12 participants while watching short video clips that evoke 4 basic emotions: joy, sadness, anger and relaxation.

Participants viewed video clips each on their monitor wearing headphones. To assess the degree of influence of the videos on the participant's emotions, their own opinion was recorded about the level of one or another emotion caused by the video viewed on a scale of 0 to 10. Data was recorded from an ECG pulse sensor connected to the Arduino. This used Python GUI software on a personal computer that was connected to Arduino via a serial usb port.

After collecting the data, the graph was output and analyzed in the time and frequency regions using the Python program developed by the authors. Fig. 1 shows the spectrogram

obtained by the fast Fourier transform of the ECG signal taken when watching a video for one basic emotion. The amplitude is significant at multiples of each other: 22 Hz, 44 Hz, 66 Hz, 88 Hz and 110 Hz. Thus, the method used revealed 5 fundamental harmonic components in the signal being processed.

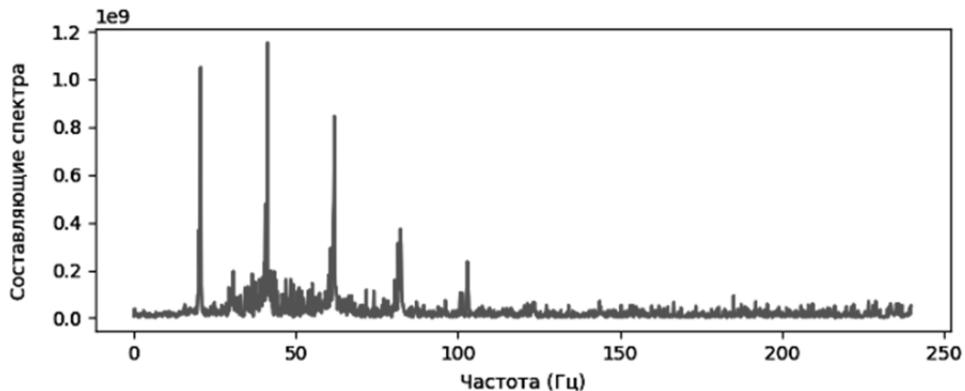


Fig. 1. Spectrum of processed electrocardiogram signal

When processing ECG signals by the selected method, the values of frequencies and amplitudes of harmonics will differ depending on the psychophysiological states of the person. By calculating the number of harmonics, their frequencies and amplitude ratios, it is planned to find a pattern of significant changes in the biological activity of the nervous system during various emotional states, by which it will be possible to track the dynamics of dopamine in real time.

Experience of similar experiments shows that the proportion of high-frequency (HF), low-frequency (LF) and very low-frequency (VLF) components of the ECG signal varies depending on emotional states [3].

To improve the practical and scientific value of this experiment, it is assumed to simultaneously measure several physiological signals. In addition to ECG, data from skin electrical activity sensors (GSR) and photoplethysmograms (PPG) in each of the participants should be recorded to obtain stable dependencies in tests for heart rate variability, and to determine the effect on emotions of heart performance parameters such as total power, standard deviation of NN intervals, and identification of low or high frequencies.

When recording the PPG signal, to compare the accuracy of measurements, you should use recording simultaneously from two sensors of different manufacturers (Pulse sensor and Max 30102), the combined use of which will reduce the possibility of obtaining an instrumental error, and will also allow you to conclude about the convenience of using each of them.

Emotion will be evaluated using a baseline emotional quadrant model (Fig. 2). It will show the degree of arousal along the ordinate axis, and the valence of emotions that are planned to be revealed during the study (joy, sadness, anger and relaxation) along the abscissa axis [4].

It should be noted that the degree of emotional involvement is regulated by neurotransmitters, including dopamine, and the brightness of the emotion experienced

depends on the so-called baseline dopamine level [1]. Thus, the greater the difference between the baseline dopamine level and its peak value at the time of watching the video, the greater the degree of excitement according to the model of the baseline emotional quadrant the participant will experience, which will reveal the dynamics of the dopamine hormone.

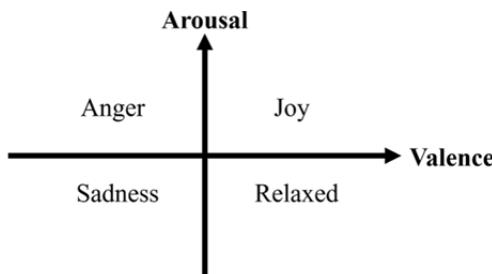


Fig. 2. Valence arousal dominant model

Further steps in the experiment involve the following steps:

1. Prepare a sample of data for training the artificial neural network [5].
2. Create a neural network to obtain emotion values according to the VAD model — “valence”, “arousal”, “dominant”.
3. Analyze the results using a convoluted neural network [6] to implement the classification of emotions by frequency spectra of signals taken using sensors.
4. Recognize the psycho-emotional state of a person and dynamic of the dopamine.

Conclusion

As a test of the use of software for the first stage of research, we have developed a program for processing measurements of biological signals. Based on the results of its work, input data were obtained for subsequent analysis in the frequency and time regions for training the neural network. In order to recognize the emotional state, according to the model of the basic emotional quadrant, it is also planned to determine the dependence of the dynamics of the dopamine hormone on emotional states. The results of the experiment can be used to create methods for managing emotional dynamics and improving involvement in the educational process, increasing motivation, improving mood, and therefore the quality of life of the individual.

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УДК 519.6

Оценка основного тона пульсовой волны сигнала фотоплелизмографии

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Рассмотрены различные методики частотного анализа сигналов фотоплелизмографии. Представлена последовательность выполнения интеллектуального анализа измеренных сигналов. Получены оценки мгновенной частоты. Цель данной работы — рассмотреть содержание последовательных этапов интеллектуальной цифровой обработки сигналов неконтактной фотоплелизмографии, методологии оценки мгновенной частоты квазигармонического сигнала пульсовой волны, а также применение данных методов на этапе разработки системы оценки состояния сердечно-сосудистой системы

Ключевые слова: фотоплелизмография, анализ данных, частота сердечных сокращений, пульсовая волна, интеллектуальный анализ данных

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Photoplethysmography Signal Pulse Wave Fundamental Tone Approximation

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In this paper, various methods of frequency analysis of photoplethysmography signals are considered. The intelligent analysis methodology of the measured signals is presented. Estimates of the instantaneous frequency are obtained. The aim of this research is to consider the content of intellectual digital signal processing of remote photoplethysmography signals, the methodology for estimating the instantaneous period of a quasi-harmonic pulse wave signal, as well as the application of these methods at the stage of the cardiovascular system diagnostic system development.

Keywords: photoplethysmography, data mining, heart rate, pulse wave, intellectual data analysis

Introduction

An important subject area of data mining is the development of medical decision support systems (DSS) for recognizing a patient's diagnosis based on a given set of symptoms [1, 2]. One of these promising areas of photoplethysmography is a remote photoplethysmography (rPPG). This method allows identifying abnormalities quickly in the physical state of a person and is also an effective methodology for remote express diagnostics in the telemedicine format. Its practical interest is the analysis of biological wave processes in the human body — pulse, respiratory, myogenic, etc.

In solving the problem of identifying biological wave processes, an important role is played by the space of informative features based on the measured initial data. The basis for solving this problem is the use of artificial intelligence methodology in the form of a natural symbiosis of methods for structural and spectral analysis of the dynamics of non-stationary time series (TS).

Remote photoplethysmography monitors changes in the intensity of light reflected from a subject's skin. An RGB video camera is used as a sensor, and the area of interest is most often the face, less often the palm or wrist.

The aim of this research is the intellectual analysis of heart rate variability (HRV) by various algorithms for processing photoplethysmography signals. It is important to note that

HRV analysis refers to the pre-medical stage, i.e. it does not diagnose the case, but forms the basis for its statement.

Photoplethysmography signal extraction

An area of the face is selected from the current frame — so-called face skin area of interest. Based on the results of measuring the degree of light scattering, the initial signals are formed as the time series. Each pixel in the image represents the red (R), green (G), and blue (B) color components. Thus, the face area can be shown as an array, with rows for representing frames, and columns for color components. To obtain a pulse signal, which, in turn, does not depend on the spectral characteristics of a stationary illumination source and its brightness level, it is necessary to normalize each color channel by dividing the TS realizations by their average values (trends). Extraction of pulse wave can be obtained by several methods.

Photoplethysmography signal processing algorithms

As the base for the study some algorithms are considered. The first one – CHROM was first introduced by the Eindhoven University of Technology (Netherlands) researchers in [3]. Mathematical model of Plane Orthogonal to Skin (POS) algorithm was invented in [4]. The main idea of the last one named Spatial Subspace Rotation — 2SR/SSR is to measure the temporal rotation of skin pixels subspace to extract the pulse wave [5].

The general algorithm for analyzing a photoplethysmogram consists of the following steps:

- for each frame, a face area is selected according to the Viola-Jones algorithm [6] and skin pixels according to the skin tone. The intensity value in each color channel is calculated as the average of the pixel intensity of the region of interest.
- structural decomposition of RGB non-stationary TS is performed using multiresolution analysis (MRA) in the discrete wavelet transform basis [7].
- the informative pulse wave frequency range from 0.667 to 4 Hz is identified according to the Analysis Mode Decomposition (AMD) method [8].
- the informative pulse wave signal is generated in the form of color signals combination according to the algorithms.
- estimation of the instantaneous phase and frequency of the pulse wave based on the Hilbert-Huang transform.
- assess the indicators of heart rate variability.

Singular Spectrum Analysis

Singular Spectrum Analysis with windowed estimation can be described as follows. Time series is divided into overlapped segments. SSA is applied to each segment so the set of TS reconstruction is carried out.

The result of two consecutive segments merging is prone to discontinuity due to edge effects. Similarly to the weighted sliding empirical mode decomposition (wSEMD) algorithm proposed by Faltermeir and colleagues [9], in sliding SSA analysis, discontinuities are prevented by combining the results with simultaneous smoothing. Each weighted segment is combined with the previous one so the time series is fully reconstructed.

Algorithm approbation on PPG dataset

As the initial data for the study, we took a database recorded by volunteers of the Eindhoven University of Technology (Netherlands), and designed to study the methods of photoplethysmography [10]. The database (DB) contains a set of video recordings, as well as reference HRV indicators, taken simultaneously with a photoplethysmogram. There are videotapes of the facial area of three subjects with different skin colors. For each participant in the experiments, a recording was carried out after physical activity, a set of recordings in a calm state, but under different lighting intensities, as well as recording with head turns (movement). Thus, based on this database, it is possible to study the operation of algorithms under various conditions, that is, their adaptability.

In this research, we analyze relatively short recordings of rPPG data — recording duration no more than 15 minutes at a frequency of 30 frames / sec.

Singular analysis is the final stage of the structural decomposition of the photoplethysmography signal, therefore, an extracted pulse wave is applied as the input signal. As a result of the SSA application, a smoothed time series presented in Fig. 1 is obtained. The gray lines show the results of the SSA decomposition inside the individual frame that form the ensemble. The time series obtained as a final result is shown in red.

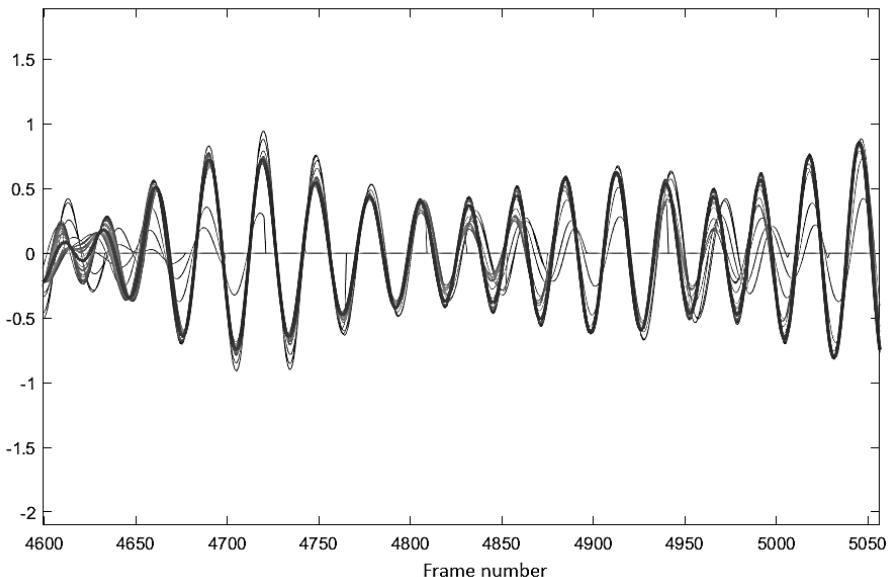


Fig. 1. SSA application results

An instantaneous period was formed by the method based on phase portrait. To verify the compliance of the results with the actual heart rate, the approximated results are compared with the RR intervals distribution histogram of the electrocardiogram (Fig. 2).

Histograms show correlation between obtained results and pulse wave RR intervals distribution. There is a predominance of 1 second interval, which corresponds to the normal heart rate of 60 beats/min.

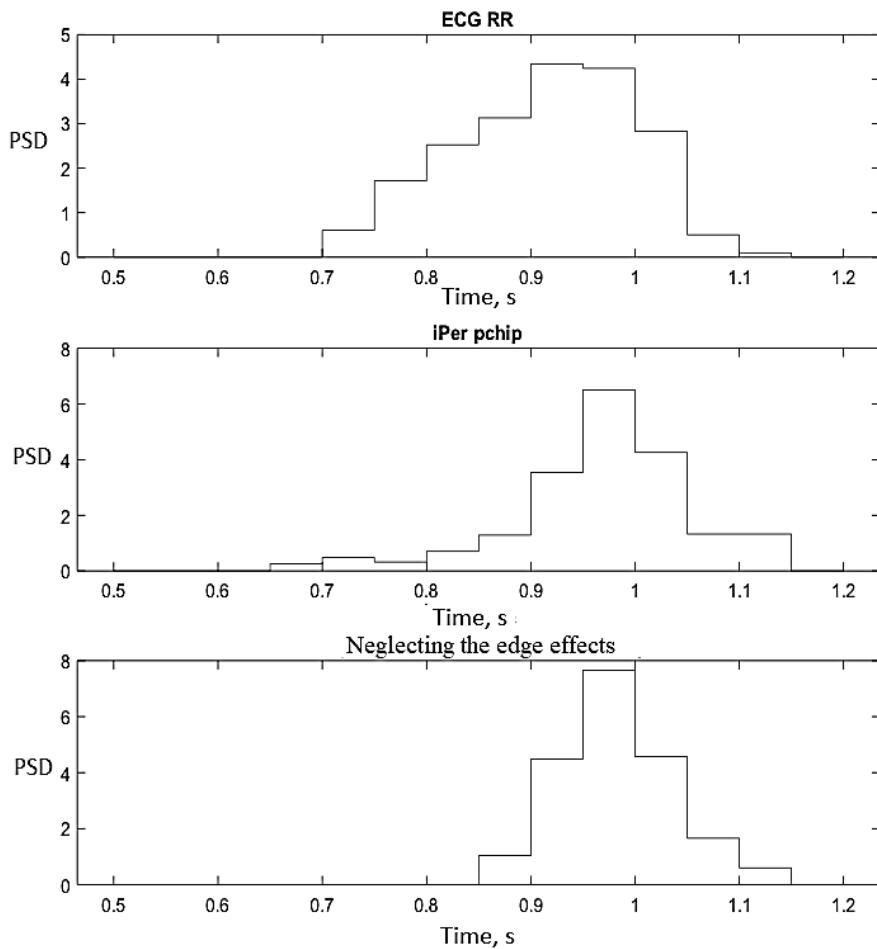


Fig. 2. Instantons period histogram distribution for the TS P1LC1 (upside down):
1 — RR intervals of ECG; 2 — edge effects included; 3 — after neglecting the edge effects

Conclusions

In this research the theoretical aspects of the techniques used for the instantaneous signal period extraction were studied. Hilbert transform, piecewise cubic interpolation by Hermite polynomials, exponentially weighted estimation were reviewed. The description of the developed algorithm was given.

A methodology for conducting a moving SSA and estimating instantaneous signal periods were developed, estimates of the PPG time series period were formed. The obtained results were compared with the evaluation of the RR intervals of the ECG.

Based on the results, it can be concluded that the considered algorithms are applicable to the analysis of photoplethysmography data with further modification as necessary. It is worth noting that the algorithm for selecting the instantaneous period is applicable only for selecting the period of the main harmonic.

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**Инженерный бизнес
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**Engineering Business
and Management**

УДК 334.012

Проблемы управления высокотехнологичными социальными предприятиями

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Высокотехнологичное социальное предприятие производит высокотехнологичную продукцию для решения социальных проблем. Основной целью исследования является разработка организационно-экономических методов управления высокотехнологичными социальными предприятиями для достижения позитивных изменений в высокотехнологичных социальных предприятиях с долгосрочным эффектом, определяющим позитивность, устойчивость и измеримость достигнутых социальных результатов. Рассмотрены примеры таких предприятий, их особенности как специфической формы предпринимательской деятельности. Анализируется управление высокотехнологичными социальными предприятиями, рассматриваются проблемы управления, финансирования и государственной поддержки.

Ключевые слова: высокотехнологичное социальное предприятие, инновации в управлении, государственная поддержка социальных предприятий, новые технологии в управлении, государственно-частное партнерство

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Problems of Management of High-Tech Social Enterprises

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High-tech social enterprise produces high-tech products to solve social problems. The main purpose of the study is to develop organizational and economic methods of management of high-tech social enterprises to achieve positive changes in high-tech social enterprises with long-term effect, determining the positivity, sustainability and measurability of the achieved social results. The article considers examples of such enterprises, their features as a specific form of entrepreneurial activity. The article analyzes the management of high-tech social enterprises, discusses the problems of management, financing and state support.

Ключевые слова: high-tech social enterprise, innovations in management, state support of social enterprises, new technologies in management, public-private partnership

Introduction

The article highlights the following issues/aspects: the definition of a high-tech social enterprise, examples of such enterprises, analysis of management problems and proposals for improving the efficiency, development and scaling of enterprises of this type [1–19]. A high-tech social enterprise is an enterprise that produces high-tech products designed to solve social problems. The purpose of the study is to develop organizational and economic methods of managing high-tech social enterprises to achieve positive changes (including in the infrastructure of the corporate system) that have a long-term effect, determining the positivity, sustainability and measurability of the achieved social results. The methods and procedures of scientific research were applied in the work: analysis of theoretical sources,

analysis of normative legal acts of the Russian Federation, causal analysis, classification, structural and functional analysis. As theoretical methods, description, statistical method. Examples of such enterprises and their products are shown in Table.

Examples of high-tech social enterprise products

No	Product Name	Company
1	Prosthetic hands with haptic feedback unit, components for prosthetic and orthopedic products, knee units for orthopedic devices	MIOLIMB LLC
2	Mobile neurointerface headsets based on hybrid technology for recording bioelectric activity and non-invasive stimulation of brain structures for people with impaired motor functions	NEUROIT LLC
3	NUST MISIS Robotic Lower Limb Rehabilitation System	NUST MISIS
4	RoboScan(ultrasound robot)	MAI
5	Robot for searching for people under the rubble	MAI
6	Organization of emergency data recovery in the network of medical clinics	KORP SOFT JSC
7	Highly intelligent systems for monitoring fatigue of drivers and equipment operators based on machine vision technologies	OKO Systems LLC
8	Development and creation of a prototype of a universal rehabilitation complex for restoring walking skills with the function of electrostimulation	LLC A-MEGA, [7]
9	Development of information accessibility for older people, as well as consistent integration of all types of social services.	Sistema Zabota LLC, [7]
10	Development and production of wheelchairs (all-terrain vehicles) and related equipment to provide a «barrier-free environment» for disabled	Observer LLC

The Faculty of Engineering Business and Management at Bauman Moscow State Technical University is launching a new master's program «High-tech social entrepreneurship. The program is implemented jointly with the Foundation for Regional Programs „Our Future“, a leading nongovernmental center for the development of social entrepreneurship in Russia. The Fund was established to implement long-term socially significant programs and projects in which the principles of social entrepreneurship can be applied. The Fund for Regional Social Programs „Our Future“ is a nonprofit organization that aims to promote quality social change. It identifies, trains and supports (through loans and grants) social entrepreneurs. By early 2020, since its founding in 2007, the „Our Future“ fund has provided interest-free credit support to 255 social enterprise projects from 58 regions of the Russian Federation. In accordance with the above, it is useful to discuss the problems of development and management of high-tech social enterprises (hereinafter referred to as **HTSE**).

Methods and procedures

To identify priority areas of HTSE support, the author used the GAP analysis methodology (diagnostic audit). The article applies a causal analysis of the factors constraining the development of high-tech social enterprises in the Russian Federation.

Structural and functional analysis of internal and external obstacles to the development of HTSE as high-tech small enterprises. Description of the level of initial integration of institutions, with the dominant role of the state and the state of innovation activity in the Russian Federation, the dynamics of developed and used advanced production technologies. The possible directions of further improvement of corporate governance of high-tech social enterprises in Russia are studied.

HTSE, as a new and in-demand direction in business, HTSE mission

We will briefly discuss the components of the term HTSE.

High-tech enterprises are enterprises that produce high-tech products [5]. As a rule, innovative. However, not all innovations are knowledge-intensive. Works [16-18] are devoted to modern approaches to the management of high — tech enterprises.

As emphasized in [4], social enterprises differ from commercial ones „primarily in motivation. The merchant seeks to make a profit, while the social entrepreneur aims to solve or mitigate social problems, and the use of an entrepreneurial approach and methods for building a sustainable business model serves to achieve its goals. Profit in social entrepreneurship is a source of funds for increasing social impact from activities and for business development [4, p. 11]“.

HTSE's mission is not to generate profit, but to » solve or mitigate social problems." Innovations and the economy as a whole should have a humanistic orientation [14, 15]. This approach to enterprise management is thoroughly justified in the works of employees and dissertation of the Faculty of Engineering Business and Management of Bauman Moscow State Technical University (see [3, 6, 10] and others). Profit is not a goal, but a means of ensuring the successful operation of the HTSE [11].

Here is a brief overview of some areas of development of high-tech projects in the social sphere aimed at improving the quality of life of senior citizens, disabled people, people with limited mobility and other socially vulnerable groups of the population (see also Table 1): Means of ensuring accessibility of social infrastructure and services for senior citizens, disabled people, people with limited mobility and other socially vulnerable groups of the population.

Hardware and software complexes and technical means for improving the quality of life and ensuring the safety of life of elderly citizens, disabled people, low-mobility and other socially unprotected groups of the population.

Systems and equipment for improving the availability and quality of education, training and ensuring access to information for older citizens, disabled people, people with limited mobility and other socially vulnerable groups of the population.

Medical devices for rehabilitation for senior citizens, disabled people, people with limited mobility and other socially unprotected groups of the population, including technical means of rehabilitation.

High-tech social entrepreneurship is a new and popular area not only for Russia, but also for most countries in the world. HTSE is aimed at solving acute social problems that have serious negative consequences for society in the medium and long term. HTSE differs from traditional charity, which is also aimed at solving acute social problems, in several important ways. Especially:

- HTSE produces high-tech products designed to solve social problems. uses advanced technologies, applies methods of artificial intelligence and «big data» in management, helps to increase labor productivity in the context of digital transformation of the enterprise;

- HTSE is focused not on helping specific people, but on creating conditions under which the social problem itself, which has put people in a difficult situation, will be solved;
- GSP is aimed at achieving self-sufficiency or even making a profit, i.e. high-tech social enterprises do not depend or depend much less than traditional charitable organizations on a constant flow of donations.

Let's discuss the essence and features of HTSE. High-tech projects in the social sphere (for example, improving the quality of life of elderly citizens, disabled people, people with limited mobility and other socially vulnerable groups of the population) are a specific form of entrepreneurial activity, which differs from others in that its essence is the development and implementation of a high-tech product to meet social needs. Let's highlight the following VSP features:

1. A combination of a socially significant result (high-tech product /social orientation/business process feature).
2. Ambiguity of performance criteria: satisfaction of public needs vs profitability.
3. Often a business is built around an innovative idea, which entails high risks and shows similarities with venture capital business.
4. As a rule, at the initial stages (the stage of origin and growth) of HTSE – subjects of small and medium-sized businesses (as a result, HTSE inherits the attributes of small and medium-sized businesses [1, 9]).

HTSE is characterized by qualification limitations (weak audit of business processes, insufficient ability to promote the product), lack of experience, low level of access to investment and borrowed capital.

HTSE management under conditions of uncertainty has its own characteristics. HTSE is not a legal term, but a type of enterprise with common features. As a result, there are problems of methodological support (the experience of HTSE development is specific, often developers of socially significant ideas do not have such experience) and interaction with stakeholders (including investors, credit organizations, and the state). According to the specifics of its activities, HTSE has related features with: a small innovative firm (to a greater extent), a social enterprise in the narrow sense (to a lesser extent), and a small business in the broad sense. Of great importance is the support of HTSE from the Fund for regional programs «Our Future», the Fund for promoting innovation, the fund for promoting the development of small forms of enterprises in the scientific and technical sphere (the Bortnick Foundation).

Purpose and objectives of HTSE development as a new scientific, practical and educational direction

The main goal of the new direction is to develop organizational and economic methods for managing high-tech social enterprises in order to achieve positive changes in the HTSE (including in the infrastructure of the corporate system), which have a long-term effect, determine the positivity, sustainability and measurability of the achieved social results. These changes should include the following mandatory elements: knowledge-intensive products, self-sufficiency, financial stability, innovative and high-tech approaches used, and their social significance. It is necessary to develop organizational and economic methods for managing high-tech social enterprises in order to achieve positive changes in the HTSE in the infrastructure of the corporate system, which have a long-term effect, determine the positivity, sustainability and measurability of the achieved social results. Changes should include the following mandatory elements:

knowledge-intensive products, self-sufficiency, financial stability, innovative and high-tech approaches used, and their social significance.

It is necessary to identify the features of HTSE as a specific form of entrepreneurial activity, which differs from other forms in its goal, which consists in developing and implementing technological solutions to meet social needs, and to consider the impact on HTSE activities of a predominantly favorable or unfavorable state of market conditions in the social sphere. It is advisable to develop and test a set of recommendations aimed at changing the situation of the emergence and functioning of HTSE in the Russian Federation, by influencing the state of the legal environment, support mechanisms, availability of financial and information resources, as well as improving the level of managerial competencies of management focused on the production of high-tech products.

Results and discussion

We provide information on the financial and economic activities of HTSE, information about which is given in Table 1.

NEUROIT LLC and MIOLIMB LLC are financed by the founders' own funds and grants. Companies have not reached the stage of business activity growth, and revenue is insignificant.

For KORP SOFT JSC, the social direction is not the main one. Financing is based on own funds, loans, and grants. From 2011 to 2021, revenue grew gradually, and in 2021, profit is shown for the first time.

Microenterprise LLC «OKO Systems» is financed from its own funds, loans, grants. Initially, the developer owned all of HTSE's capital, later new co-founders were attracted, but the founder retained control over 51 % of the capital. From 2018 to 2021, revenue grew, and profit was made in 2020 and 2021.

As already noted, one of the most popular areas of activity: Medical services, in particular rehabilitation, are a priority, but the market capacity is low. The social result of the projects of A-MEGA LLC and Sistema Zabota LLC is relatively high, but the solvency of potential consumers of the product / service is low. The gap between market capacity / solvency and business payback can be closed by government agencies, extending social insurance conditions to HTSE activities, providing grants [7].

According to the Federal Tax Service, for 2017, the revenue of Observer LLC amounted to 34.2 million rubles, and net profit — 1.16 million rubles. In 2018, revenue increased to 48 million rubles, but there was a loss of 1.23 million rubles.

Thus, HTSE receives financial resources from government authorities, basic enterprises, foundations and other organizations that distribute grants, as well as in the form of donations. In some cases, HTSE switch to self-sufficiency and even make a profit, which is spent on statutory purposes.

In comparison with other types of enterprises, HTSE management has its own characteristics. The initiator of a business is usually more of *an innovator* developing his idea than *an organizer* (manager, manager). The product (or service) produced is usually unique, and therefore there is no experience of market promotion. As the innovation process develops [8], the problems of changing the organizational model during the transition to the growth stage (from survival to routine), scaling the business, and «blurring» control over the business when new investors enter are revealed. The problems of the internal management circuit are important: concentration on the product, but not on

business processes; limited marketing competencies, inability to move from the birth phase to the growth phase; complexity of scaling [2, 13].

HTSE faces significant management challenges when moving from the creation stage to the growth and maturity stages. Enterprises with a low contribution of innovations to the product (service) and higher profitability (as more understandable for investors and creditors) are more likely to receive investments not from HTSE. Enterprises with a high level of innovation, which are not high-tech, are more likely to lose out to GSP, since the risk fee on the part of capital owners will be lower in this case.

It is not uncommon for HTSE business projects to pass the stage of attracting investment (after the prototype is presented), but do not pass into the growth stage, i.e. the innovation process remains incomplete [8].

HTSE management issues in the commercialization of socially significant innovations are important. HTSE has a higher payback risk compared to other types of small businesses (including small innovative firms), which is manifested in competition for investment and debt capital. HTSE has higher costs compared to social enterprises. HTSE's access to a stable growth trend is limited, in particular, due to the fundamental limitation of the volume of the consumer market. As a rule, the owner of a HTSE at the stage of a business idea does not have sufficient capital and management experience, in particular, the ability to assess risks. As a result, when competing for investments, HTSE lose both exclusively to social enterprises (which have higher social results) and to innovative firms without a social component (which have a more «understandable» image for investors [7]).

This analysis allows us to formulate our vision of the key issues of supporting the HTSE in the Russian Federation.

First, it does not seem entirely appropriate to combine them, along with other social enterprises, into one group as potential recipients of state support in the absence of an explicitly designated mechanism for rating / selecting recipients of support (within the framework of Article 24.1 No. 209-FZ).

Secondly, it is controversial to ignore among the declared measures of state support (within the framework of Article 24.1 No. 209-FZ) the system of state and municipal procurement, access to which would make it possible to compensate for one of the most significant restrictions in the HTSE's activities – the problem of finding a sustainable sales model.

Third, there is still a significant problem (which is also evident in structured databases of social enterprises) with the blurring of criteria for classifying them as HTSE subjects. This not only hinders their unambiguous characterization as an object of state support, but also hinders the process of institutionalization of the HTSE sector at the national level.

Taking into account the specifics of the mechanism of state support for activities of any orientation (its contours are set by the corresponding set of sources of law), a number of identified problems (as well as ways to solve them) should be attributed specifically to the sphere of rule-making activities. In fact, the provisions of Article 24.1 of Federal Law No. 209-FZ, when listing potential recipients of state support in various forms, ignore the condition of knowledge intensity, high-tech products as the subject of HTSE activities. At the same time, this condition is clearly defined, for example, in the regulations on the competition for grants of the Innovation Promotion Fund (among the types of economic activity of the applicant enterprise must be the type of activity corresponding to OKVED 72.19). However, the conditions of the FSI grants do not allow them to be profiled under the support of the HTSE due to the weight criteria of the level of knowledge intensity of the product (the prospects for commercialization of HTSE products in the social goods markets

are less significant than for enterprises focused mainly on profit), as well as the exclusion of all non-small businesses from the list of support objects. Thus, further development of the practice of supporting GSP requires unambiguous definition of the boundaries of such business structures as the side of interaction with the state, modernization of the system of criteria for providing grant support to small innovative enterprises (introduction of additional weight criteria), and promotion of institutionalization of communication of GSP with each other, with the state, and business.

Conclusion

The mission of the HTSE is aimed at improving the quality of life of the citizens of the Russian Federation. Therefore, HTSE activities must be supported by the state and society, business and the public.

The challenges arising in the management of HTSE are determined by the complexity of their mission. The production of high-tech (i.e., science-intensive) products requires a significant expenditure of resources, and the social function of HTSE, as a rule, is focused on a relatively narrow layer of potential consumers, whose financial situation does not allow to provide HTSE with the necessary resources.

Let's repeat: the mission of HTSE is not to make profit, but to solve or mitigate social problems. Innovations and economy as a whole should have a humanistic orientation. Therefore, the support of the state, business and population, including subsidies, grants, credits and donations, is necessary for development of HTSE activities. Changes in legislation are also needed.

We hope that the discussion of HTSE problems initiated in this article will contribute to the successful development of this new scientific and practical and educational direction.

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Системы поддержки принятия решений для реализации инвестиционно-строительного проекта

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Системы поддержки принятия решений (СППР) приобретают все большее значение в строительной отрасли, предоставляя профессионалам в области строительства ценный инструмент для улучшения процесса принятия решений и повышения эффективности. Двумя рассматриваемыми типами СППР являются системы, основанные на правилах, и системы, основанные на precedентах. Системы, основанные на правилах, используют правила «если-то» для принятия решений на основе заранее определенных знаний, в то время как системы, основанные на precedентах, полагаются на прошлый опыт и предыдущие случаи для принятия решений. Данный материал направлен на выявление пригодности СППР на основе правил и на основе конкретных случаев для реализации строительных проектов, изучение их теоретических основ и практических приложений. Путем сравнительного анализа тематических исследований и научных статей в этой работе оцениваются преимущества и ограничения каждой системы, а также их потенциал для интеграции с другими технологиями, такими как искусственный интеллект и машинное обучение. Определяя факторы, которые способствуют эффективности СППР на основе правил и конкретных случаев, эта статья дает ценную информацию для исследователей и специалистов, стремящихся использовать технологии для улучшения процесса принятия решений в управлении проектами.

Ключевые слова: система поддержки принятия решений, строительная отрасль, управление проектами, база знаний, принятие решений, оптимизация процессов

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Decision Support Systems for the Implementation of an Investment and Construction Project

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Decision Support Systems (DSS) are becoming increasingly important in the construction industry, providing construction professionals with a valuable tool to improve decision-making and efficiency. Two types of DSS are rule-based and case-based systems. Rule-based systems use "if-then" rules to make decisions based on predetermined knowledge, while case-based systems rely on past experience and previous cases to make decisions. The purpose of this paper is to compare the suitability of rule-based and case-based DSS for construction projects, to explore their theoretical foundations and practical applications. Through a comparative analysis of case studies and scholarly articles, the thesis evaluates the advantages and limitations of each system, as well as their potential for integration with other technologies such as artificial intelligence and machine learning. By identifying factors that contribute to the effectiveness of rule-based and case-based DSS, this work provides valuable information for researchers and professionals seeking to use technology to improve decision-making in project management.

Keywords: Decision Support System, construction industry, project management, knowledge base, decision-making, process optimization

Introduction

Decision Support Systems (DSS) are becoming increasingly important in the construction industry, providing decision makers with access to data-driven information and knowledge to improve project outcomes. The choice of DSS is critical to project success, and it is important to understand the potential advantages and limitations of different types of DSS [1]. The purpose of this paper is to compare the two main types of DSSs: rule-based and example-based systems and their suitability for construction projects. The paper discusses the advantages and disadvantages of both approaches and discusses situations in which each type of DSS may be most effective. The conclusions of this article may help decision makers in the construction industry make an informed decision about which type of DSS to use for their specific project needs [2].

Data and methods

This article utilizes a comprehensive review of the literature to evaluate the benefits and limitations of rule-based and case-based DSS in construction projects. The review includes a variety of sources, such as case studies and research articles. The sources were selected based on their relevance to the topic and their potential to contribute to the comparative analysis of rule-based and case-based DSS. A qualitative analysis of the sources was conducted to identify the key factors that contribute to the effectiveness of each type of DSS in construction [3].

To compare the effectiveness of decision support systems (DSS) based on rules and specific cases in construction projects, a thorough literature review of existing studies and reports was conducted. The available data on both types of DSS are analyzed, including their characteristics, advantages and disadvantages. Case studies and real-life applications of both systems in the construction industry are reviewed to assess their practical effectiveness [4].

The data analysis was conducted using a comparative approach to identify the differences between rule-based and case-based DSS. The focus was on their ability to handle complex data, provide accurate recommendations, and adapt to changing project requirements. Potential limitations of each approach are also considered, such as the potential for inaccuracies in rule-based systems or the difficulty of obtaining relevant cases for case-based systems [5].

To better understand the suitability of each type of DSS for specific project needs, a matrix has been created, comparing their characteristics and applications. The matrix includes criteria such as the size and complexity of the project, the availability of relevant data, and the level of certainty required in the decision-making process. This approach made it possible to identify situations in which rule-based or case-based DSS would be most effective.

Results

An analysis of rule-based and case-based decision support systems (DSS) in construction projects revealed a number of key differences in their characteristics, advantages and disadvantages.

Rule-based DSS are based on a set of predefined rules and logic that allow for fast and efficient decision-making. They are relatively simple to implement and maintain, and are well-suited for tasks that require repetitive and well-defined decision-making processes. However, rule-based DSS can be limited by their inability to handle complex and uncertain data, and may not be able to provide accurate recommendations in situations where the rules are not well-defined or when there is limited data available.

In contrast, case-based DSS rely on the analysis of historical cases to provide recommendations. They are better suited for handling complex and uncertain data, and can adapt to changing project requirements. However, case-based DSS require a significant amount of data to be effective, and may be limited by the difficulty of obtaining relevant cases.

A review of case studies and real-life applications of both systems in the construction industry revealed that both rule-based and case-based DSS have been used successfully in various projects. For example, rule-based DSS have been used to optimize project scheduling, while case-based DSS have been used to identify potential safety hazards (Table 1).

To compare the practical effectiveness of these two systems, we created a matrix that compared their characteristics and applications. The matrix includes criteria such as the size and complexity of the project, the availability of relevant data, and the level of certainty required in the decision-making process.

Based on this matrix, it can be concluded that rule-based DSS are better suited for simple and repetitive tasks, deterministic decision-making processes, and situations where complete and structured data sets are available. On the other hand, case-based DSS are more effective for complex and unique projects, decision-making processes with

uncertainty or risk, and situations where incomplete or unstructured data may be present. Though case-based DSS may require more resources and expertise to develop and maintain.

Table 1

Rule-based and Case-based Decision Support Systems Comparison Matrix

Criteria	Rule-Based DSS	Case-Based DSS
Size and complexity of the project	Best suited for simple and repetitive tasks	More effective for complex and unique projects
Availability of relevant data	Requires structured and complete data sets	Can work with incomplete or unstructured data
Level of certainty required in decision-making process	Suitable for deterministic decision-making processes	More appropriate for decision-making processes with uncertainty or risk
Adaptability to changing circumstances	Limited adaptability to new or unexpected situations	Better adaptability to new or unexpected situations
Potential for inaccuracies	May produce inaccurate results due to oversimplification or lack of flexibility	Less prone to producing inaccurate results due to its ability to draw on past experiences
Ease of implementation and maintenance	Easier to implement and maintain due to its standardized rules and processes	Requires more resources and expertise to develop and maintain

However, it is important to note that the effectiveness of each approach ultimately depends on the specific project requirements and the available data. In some cases, a combination of both rule-based and case-based DSS may be most effective.

The analysis also revealed potential limitations of both rule-based and case-based DSS (Table 2). Rule-based DSS may be limited by the potential for inaccuracies in the predefined rules and logic, while case-based DSS may be limited by the difficulty of obtaining relevant cases and the potential for inaccuracies in the analysis of historical data.

Table 2

Comparison of rule-based and case-based DSS in construction projects

Criteria	Rule-Based DSS	Case-Based DSS
Decision-making context	Highly structured	Less structured
Knowledge representation	Predetermined rules	Past cases and experience
Suitability for cost estimation	Effective	Limited
Suitability for scheduling	Effective	Limited
Suitability for quality control	Effective	Limited
Suitability for risk management	Limited	Effective
Potential for integration with AI/ML	Limited	Promising

Overall, the analysis using a comparative approach and the matrix allowed us to identify the strengths and weaknesses of each type of DSS and their practical applications in the construction industry. By considering the specific project requirements and available

data, project managers can make informed decisions about which type of DSS to use to achieve optimal project outcomes.

Discussion

The findings of this paper suggest that both rule-based and case-based DSSs have potential advantages and limitations when applied to construction projects. Rule-based DSSs are best suited for situations where the decision-making process is highly structured, while case-based DSSs are better suited for situations where the decision-making process is less structured and there is a need to use past experience and knowledge to make informed decisions.

One potential limitation of rule-based DSSs is that they cannot capture the complexity of real-world decision-making processes. Rule-based DSS rely on predefined rules and procedures that may not always be applicable to every situation. On the other hand, case-based DSSs may be more effective in capturing the complexity of real-world decision-making processes, but may require more time and resources to develop and maintain.

Overall, the results of this paper show that the choice of DSS for construction projects should be based on the specific needs and characteristics of the project. A rule-based DSS may be more appropriate for projects that have well-established rules and procedures, while a case-based DSS may be more appropriate for projects that require more nuanced decision-making based on past experience and knowledge.

Conclusion

In conclusion, decision support systems have the potential to significantly improve decision making and efficiency in the construction industry. This paper compares rule-based and case-based DSSs and their suitability for construction projects. The results show that both types of DSSs have potential advantages and limitations, and that the choice of DSS should be based on the specific needs and characteristics of the investment and construction project. Future research may explore the potential for integrating rule-based and precedent-based DSSs to create hybrid systems that take advantage of the strengths of both approaches.

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Перспективы интеграции целей устойчивого развития в стратегию предприятий промышленности

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Цифровая трансформация секторов экономики является приоритетной стратегией развития общества. Ключевую роль в процессе цифровизации занимают промышленные предприятия. Рассмотрены цели устойчивого развития. Представлены принципы устойчивого развития промышленных предприятий. Охарактеризован алгоритм выбора методики интеграции целей устойчивого развития в стратегию. Определены перспективы интеграции.

Ключевые слова: инновационный потенциал, промышленность, промышленные предприятия, устойчивое развитие, цифровая трансформация, цифровизация, цифровая экономика, цели устойчивого развития

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Prospects for Integrating Sustainable Development Goals into the Strategy of Industrial Enterprises

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Digital transformation of economic sectors is a priority strategy for the development of society. Industrial enterprises play a key role in the process of digitalization. The article discusses the goals of sustainable development. The principles of sustainable development of industrial enterprises are presented. The algorithm of choosing the methodology for integrating sustainable development goals into the strategy is characterized. Prospects of integration are defined

Keywords: innovation potential, industry, industrial enterprises, sustainable development, digital transformation, digitalization, digital economy, sustainable development goals

The formation of a new stage of economic development – the digital economy – has become a decisive factor in the economic growth of industrial enterprises [1]. The introduction of digital technologies into enterprises allows to increase the level of their innovation and competitiveness in the market, expands the possibilities of ensuring their sustainable development.

The formation of a sustainable development strategy in the context of the digital transformation of the economy is a key aspect of the activities of modern industrial enterprises. The essence of sustainable development is the development and modernization of financial mechanisms, the reorganization of production processes in accordance with digital technologies, the development and implementation of innovative solutions in the economic activities of the enterprise to ensure the growth of economic potential.

The Sustainable Development Goals are a set of 17 key interrelated goals aimed at solving certain global problems. These goals were named in the General Assembly resolution «Transforming our World: the 2030 Agenda for Sustainable Development» [2].

The goals and objectives are complex and indivisible and ensure the balance of all three components of sustainable development: economic, social and environmental (Fig. 1).



Fig. 1. Sustainable Development Goals [3]

The implementation of the Sustainable Development Goals makes it possible to reorganize enterprises in accordance with modern market conditions. The sustainable development of industrial enterprises is based on the following principles:

- Adaptation to structural changes in all spheres of economic activity of the enterprise;
- Preservation of the integrity of the enterprise in the conditions of digitalization;
- Continuous development of enterprises, growth of innovation and investment attractiveness;
- Balance of elements of sustainable development at the enterprise;
- Ensuring environmental responsibility and improving labor safety;
- Providing timely high-quality information in the required volume in accordance with the level of access to information;
- Continuous improvement of processes within the enterprise.

Following the presented principles contributes to increasing the level of maturity of industrial enterprises, as well as ensuring the sustainability of their development [4].

Digital transformation is being carried out at an increasing pace, which creates new conditions for conducting economic activities both within the enterprise and in the external environment. The main goal in the current conditions for industrial enterprises is timely adaptation to structural changes to ensure and maintain the sustainability of development. The level of adaptability is determined by the dynamic abilities of industrial enterprises that form competitive advantages in the market [1].

The process of integrating the Sustainable Development Goals into the strategy involves choosing the correct methodology (Fig. 2).

As a result, the prospects for integrating the Sustainable Development Goals into the strategy of industrial enterprises are based on the following capabilities of industrial enterprises:

- Timely response to structural changes in the external environment through the use of digital analysis methods;
- Obtaining timely and reliable information based on digital document management technologies for management decision-making;
- Increasing the level of innovation potential through the development and implementation of digital innovations;
- Increasing the level of human resources through the use of digital technologies to ensure continuous training and development of both highly qualified personnel and the enterprise as a whole;
- Increasing the level of investment attractiveness for investors by ensuring sustainable development based on ESG indices.

The presented prospects, based on the dynamic capabilities of the enterprise, correlate with the degree of digitalization [5]. Digital transformation affects not only the production sector, but also the management system of enterprises in the industrial sector of the economy [6, 7].

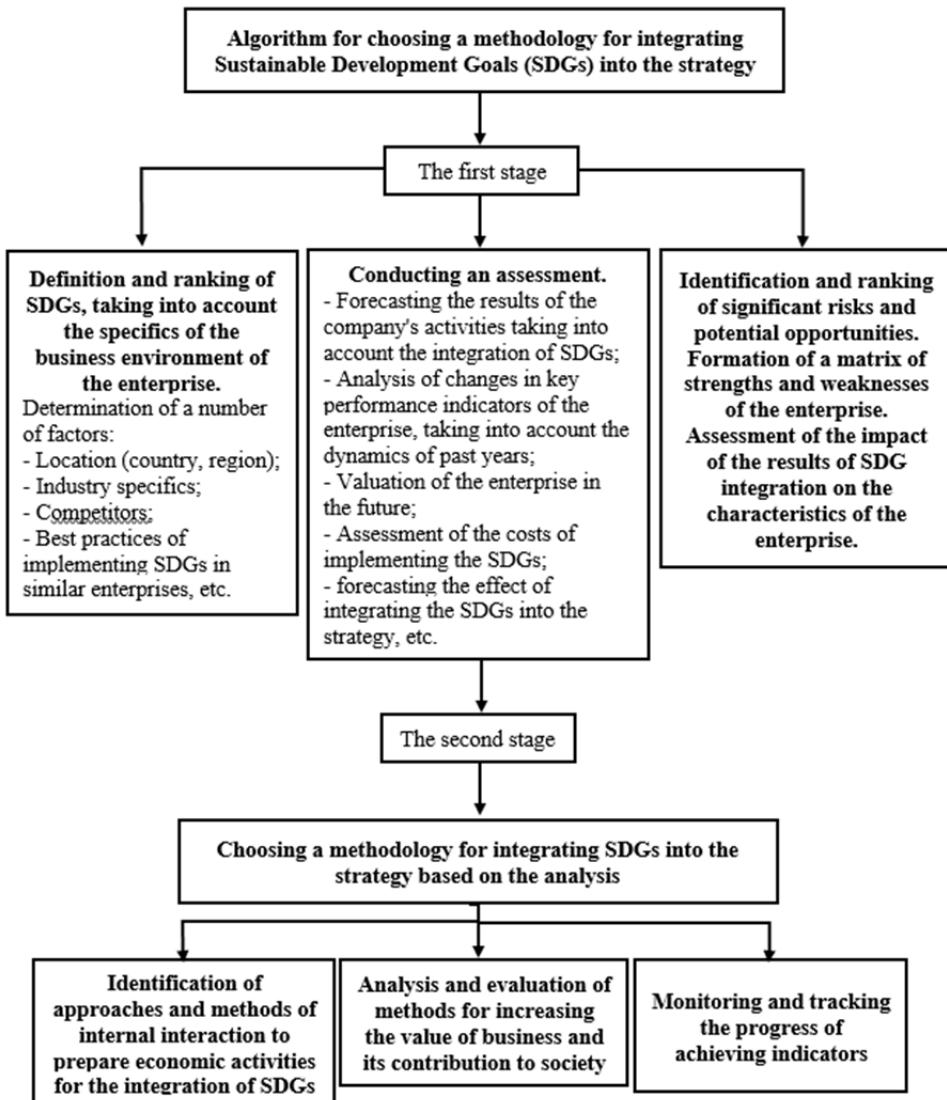


Fig. 2. Algorithm for choosing a methodology for integrating sustainable development goals into the strategy

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Ценообразование научно-исследовательских проектов

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Рассмотрены способы установления цены на научно-исследовательские проекты, факторы влияющие на этот процесс, а также взаимосвязь научно-исследовательских проектов и научно-исследовательских и опытно-конструкторских работ, что позволяет вникнуть в механизм установления начальной (максимальной) цены контракта. Рассмотрены данные о факторах трудоемкости научных исследований и опытных разработок. Приведены формулы для расчета начальной (максимальной) цены контракта. Сделаны выводы, что ценообразование научно-исследовательских проектов является сложным процессом, зависящем от множества факторов, в большей степени от величины трудоемкости.

Ключевые слова: ценообразование, установление цены научно-исследовательских проектов, научно-исследовательские и опытно-конструкторские работы, научно-исследовательская работа, опытно-конструкторская работа

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Pricing of Scientific Research Projects

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This article discusses the procedure for setting the price of research projects, the factors affecting this process, as well as the relationship of research projects, research and experimental development, which allows to penetrate into the mechanism of setting the initial (maximum) price of the contract. The data on the factors of labor intensity of scientific research and experimental development are considered. The formulas for calculating the initial (maximum) price of the contract are given. During the analysis of the data it is concluded that the pricing of research projects is a complex process, which depends on many factors, primarily on the value of labor intensity.

Keywords: pricing, pricing of the research projects, research and development, scientific researches, experimental and design work

Introduction

Pricing of scientific research projects (SRP) is one of the important aspects of pricing at the enterprise, as normalizing SRP and establishing common pricing rules for them is quite difficult. Obviously, in order for manufacturing enterprises to enter new markets and expand the share in the already developed markets, they need to improve the competitiveness of their products [1]. One of the ways to improve the competitiveness of products is to conduct scientific research.

The following aspects organize the current study: the differences between SRP and research and development (R&D), factors of labor intensity of SRP, methods and formulas for calculating the initial (maximum) price.

The purpose of this article is to identify particular factors of labor intensity of scientific research (SR) and experimental and design work (EDW) and give the formulas for calculating price.

Data and methods

First of all, it is necessary to define the concept of the project. A project is a purposeful, time-limited activity carried out to meet specific needs in the presence of external and internal constraints and the use of limited resources [2]; In turn, SRP is a project which aims to conduct scientific research and solve urgent practical and theoretical problems of considerable importance for the life and functioning of society.

Implementation of SRP can be divided into several major interrelated blocks: feasibility study (FS) of scientific research, validation of the FS, methodological guidelines for the implementation of research, carrying out research and experiments, scientific and technical report. While, R&D have the following stages: basic research: theoretical and exploratory; applied research; engineering development; work performed at any of the preceding phases, which include experiments and tests. Thus, SRP includes R&D, but at the same time it has a feasibility study and contains the research methodology. Therefore, R&D is one of the stages of SRP.

To determine the cost of SR and EDW, which are part of the SRP, it is necessary to consider the basic economic indicators. Such indicators for the enterprise can be: average wages, overheads, profitability.

The main items of costs taken into account when estimating the cost of R&D: materials and components; costs of outsourced work; wage costs of workers directly involved in work performance; social insurance costs; cost of special equipment and special accessories; other direct costs immediately related to SR, EDW and technological work: travel expenses, other direct costs and general administrative (indirect) expenses not directly related to the performance of work on average 15 % of R&D costs [3].

The problem in the generation of evaluation indicators of SR is caused by the fact that the research is diverse and has a large number of factors that are difficult to be systematized. For example, novelty, sophistication of the work, the availability of qualified specialists.

Specific challenges carried out during various SR and EDW significantly differ from each other in the degree of novelty and frequency, which together are expressed in the level of labor intensity of R&D, to determine it consider such broadening factors as:

- the level of R&D uncertainty;
- complexity of R&D;
- novelty of R&D.

In order to provide a comprehensive and in-depth justification of the labor intensity of works, the generalizing factors are supplemented by a group of particular factors reflecting the organizational and technical conditions in which SR and EDW processes are implemented (Table) [4, 5].

Particular factors of labor intensity of SR and EDW

Factors for SR	Factors for EDW
Novelty for the researchers of the challenge and the way to achieve the goal	Existence of the scientific and technical information required for the EDW
Availability of information about the object of research	Reliability and completeness of the initial data
Intensity (urgency) of work performance	Sufficiency of time to carry out the full cycle of EDW
The appropriateness of the researchers' qualifications	Availability of human resources
The need to attract new specialists, which are almost or not present in the organization	Suppleness of the new materials and equipment base
Material resources	Suitability of the experimental base
Availability of computer resources	Achieved scale and potential level of automatization of research, design, engineering, experiment and testing
Presence of an appropriate experimental base	Suitability of the pilot production base
Organizational complexity of the work	Degree of independence in conducting EDW
The degree of independence in carrying out SR	Territorial integrity of the object of engineering and pilot development organization
Completeness of the management structure of the SR process	Improvement stimulation of specialists and workers
—	Completeness of the management structure of the EDW process

Factors affecting the value of labor intensity do not act in isolation, but in a certain interaction, which makes them to be considered together.

Results

At the present time there are variety of methods for determining the cost of SRP. However, the price of government contracts for SR and EDW should be determined and based on the methodology approved by Order No. 1788 of September 11, 2014. Ministry of Industry and Trade of the Russian Federation. This methodology implies the use of one of two methods: the method of comparable market prices or the cost method of calculating the initial (maximum) price of the contract (IMPC).

When using the method of comparable market prices at least three analogues are selected. The parameters of comparison are: the subject of work, type of work, object of research, result of work, amount (labor intensity) of work or any other parameters individually determined by the administrator of expenses (person or structural unit responsible for the SRP at the enterprise), in accordance with the agreed technical requirements of the contract, for which the initial (maximum) price is formed. The coefficient of variation of the prices of analogues is calculated, in order to determine the degree of homogeneity of the set of values used in the calculation. If the coefficient of variation is more than 33%, the combination is considered heterogeneous, it is required to increase the number of analogues under consideration.

The IMPC when using the comparable market price method is calculated according to the following formula:

$$IMPC^{\text{market}} = \left(\sum_{j=1}^{n_i} P_i \right) / n,$$

where P_i — price of work for i analogue; i — number of the analogue under consideration; n — number of items used in the calculation.

Determination of the price of the contract by the cost method is carried out by summing up the labor costs for work under the technical specifications, costs of materials, components necessary for the work, overhead and other expenses and profit.

The labor and time costs shall be determined by the expenses administrator in accordance with the specific features of the subject of the contract, with regard to the complexity and novelty of the work to be performed. Costs for materials and special equipment shall be calculated upon approximate budgets, which shall be attached to the calculation of the estimated cost of the contract.

Overhead costs are measured by expert evaluation, and their sum is set in % of the payroll. The prime cost is the sum of all cost items listed in the Methodology. Then the IMPC under the cost method is calculated as follows:

$$IMPC^{\text{cost}} = PS + Prof,$$

where PC — prime cost; $Prof$ — desired profit.

Furthermore, there is a comparison of the IMPC calculated by different methods and a choice of the optimal price. According to the discussed aspects of SRP pricing, it is possible to say that the more complex is R&D, the higher is the price of SRP.

Conclusion

The result of the SRP cost calculations should be the identification of the prime cost of R&D, the graphing of the cost increase in coordinates "time (R&D stages) — cumulative

costs” and graphs or diagrams characterizing the structure of R&D costs taking into account possible options for implementation [6].

At the current stage of scientific progress, engineering companies are facing complex tasks. This includes transformation to digital economy and industry 4.0. Large-scale national projects targeting the development of the state economy and domestic enterprises are created. In this regard, pricing at enterprises plays a key role. Pricing of SRP is a complicated process, which depends on many factors, mostly on the value of labor intensity of SR and EDW. There are a number of methodologies that allow you to choose a price for SRP, which are based on the calculation of the price by different methods, in order to set the price more accurately. Nevertheless, there is no methodology based on the classification of labor intensity of SR and EDW at the moment, its appearance will make the process of pricing of SRP more simple and systematized.

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УДК 338

Прогнозирование значений факторов, влияющих на развитие высокотехнологичных отраслей в Российской Федерации

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Для развития высокотехнологичной отрасли необходимо наличие доступных и дешевых в обслуживании финансовых средств в течение длительного периода НИОКР, а также квалифицированных кадров. Рассмотрены факторы, влияющие на развитие высокотехнологичных отраслей: нехватка финансовых средств, высокие ставки по кредитам, недоступность долгих кредитов, избыток устаревших производственных мощностей, дефицит компетентных кадров. Построение прогноза значений проводили на основе данных Росстата методом экстраполяции тренда, так как в исследуемых статистических данных не наблюдается сезонность. Временной ряд представляет собой ряд Фурье первого и второго порядка с коэффициентом достоверности $R = 0,87\ldots0,89$. Проведенное исследования указывает на стагнирование значений ряда факторов, малую привлекательность долгосрочных инвестиций в высокотехнологичный сектор, износ основных средств предприятий, что отрицательно влияет на темпы развития. Для преодоления имеющегося макроэкономического пробела требуется эффективное использование всех имеющихся ресурсов для развития и модернизации предприятий.

Ключевые слова: высокотехнологичная отрасль, инновационное развитие, высокотехнологичная экспансия, устойчивое развитие, национальная конкурентоспособность

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Forecasting the Values of Factors Influencing the Development of High-Tech Industries in the Russian Federation

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The development of a high-tech industry requires the availability of affordable and cheap-to-maintain financial resources over a long period of R&D, as well as qualified personnel. The article discusses the factors affecting the development of high-tech industries: lack of financial resources, high interest rates on loans, unavailability of long-term loans, an excess of obsolete production facilities, and a shortage of competent personnel. The construction of the forecast values was carried out on the basis of Rosstat data by the method of extrapolation of the trend, since there is no seasonality in the studied statistical data. The time series is a Fourier series of the first and second order with a reliability coefficient R = 0.87...0.89. The conducted research indicates the stagnation of the values of a number of factors, the low attractiveness of long-term investments in the high-tech sector, the depreciation of fixed assets of enterprises, which negatively affects the pace of development. To overcome the existing macroeconomic gap, the effective use of all available resources for the development and modernization of enterprises is required.

Keywords: innovative development, high-tech industry, high-tech expansion, sustainable development, national competitiveness

Introduction

Despite the transition of the world economy from the industrial to the post-industrial format, large-scale production remains the most important part of the macroeconomic cycle, since the

provision of services is based on these products. According to [1, 2], the degree of its efficiency directly affects the general economic development of the macrosystem.

According to [3–6], the development of high-tech industry requires available and cheap financial resources for a long period of R & D, as well as qualified personnel. The sources [7–9] note the significant role of the degree of wear and age of the necessary high-tech tools and equipment.

Thus, we can identify the following factors affecting the development of high-tech industries: lack of financial resources, high interest rates on loans, unavailability of long-term loans, excess of obsolete production facilities, shortage of competent personnel.

Methods and instruments

Statistical data from the Federal State Statistics Service (Rosstat) and the Analytical Center under the Government of the Russian Federation were used to analyze the data. One of the most common forecasting methods are trend extrapolation and smoothing methods (moving average method, exponential smoothing). These methods are based on trends in the development of the situation in the past, which are then extrapolated into the future. The group of extrapolation methods includes the simple exponential smoothing method, the Holt method, and the Holt-Winters method. When using the exponential smoothing method, the series smoothing coefficient is set manually and is in the range from 0 to 1. The greater is this coefficient, the stronger is the influence of recent periods on the forecast. The accuracy of the forecast result depends on the selected coefficient. The Holt-Winter method is used to account for the trend component in the forecast. The Holt-Winters method takes into account several forecast components, such as trend and seasonality.

Since there is no seasonality observed in the studied statistical data, the trend extrapolation method will be the most relevant for the model. The time series is a Fourier series:

$$a_1\varphi_1(x) + a_2\varphi_2(x) + \cdots + a_k\varphi_k(x) + \cdots,$$

where a_k — coefficient of the Fourier series of the function $f(x)$; φ_k — sequence of orthonormal functions on a segment, where $f(x)$ is continuous.

For long-term forecasting, it is necessary to find the values of the coefficients a_k using the minimum quadratic error condition, for each of the found coefficients, a delay matrix is built and its own forecast for the next period is built. Based on the predicted values of the coefficients, the values for the next period are found using the following formula:

$$y_{m+1}(t) = \frac{a_0^{m+1}}{2} + \sum_{k=1}^n a_k^{m+1} \cos(kx) + b_k^{m+1} \sin(kx),$$

where $y_{m+1}(t)$ — partial sum of Fourier series of order n function f .

The CurveFitting block of the MatLab environment was used to build the forecast.

Forecasting the values of factors affecting the development of high-tech industries

The share of products of high-tech and science-intensive industries in the gross domestic product [10–12] is an indicator of the level of development of high-tech and science-intensive industries. Data on the dynamics of this parameter in the Russian Federation are provided in Fig. 1 (according to Rosstat).

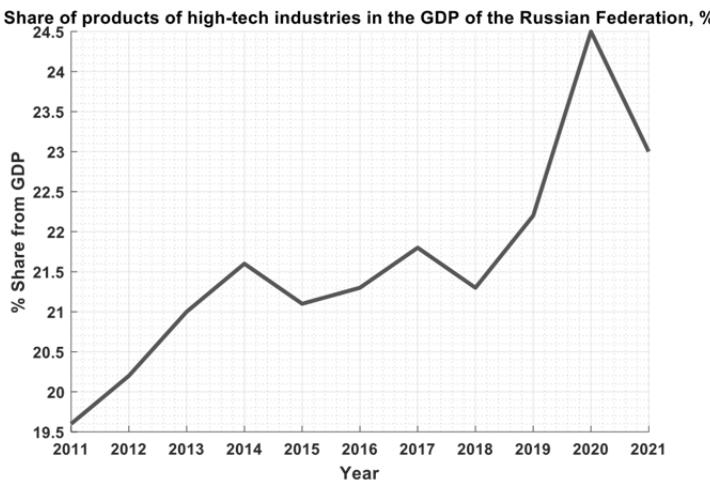


Fig. 1. Share of products of high-tech industries in the Russian Federation

The most relevant for the forecast by extrapolation of data from the results of an empirical study was the Fourier time series, a partial sum of a second-order series with the highest reliability coefficient among others $R = 0,87$, where t – numbered time period (year):

$$f(x) = 21,51 + 1,23\cos(0,45x) - 0,39\sin(0,45x) + 0,79\cos(0,9x) + 0,62\sin(0,9x). \quad (1)$$

The forecast of changes in this parameter according to model (1) for a ten-year period is shown in Fig. 2.

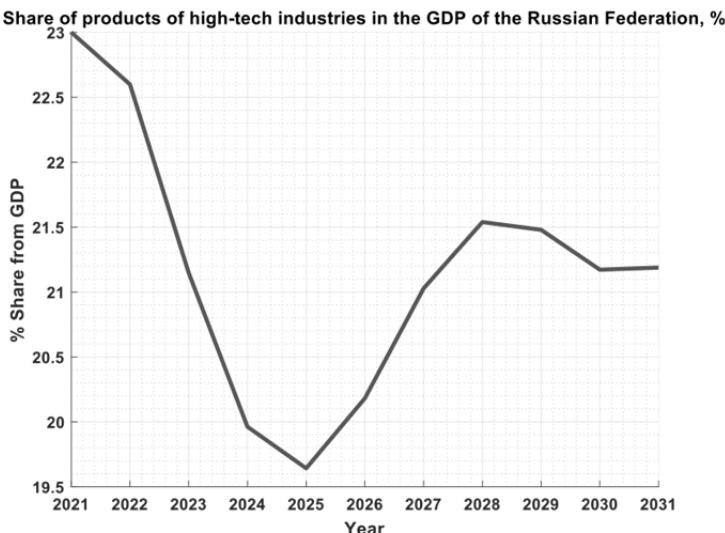


Fig. 2. Projected dynamics of changes in the share of products of high-tech industries in the Russian Federation for a ten-year period

Analysis of the graph indicates the stagnation of the considered value at around 21 % after a ten-year period.

Another problem is the lack of funds for a long period of development. This forces the company to use long-term and short-term loans. The factor of their attractiveness is the interest rate on loans for non-financial organizations (NFOs).

Graphs and values of the interest rate on loans on a time scale in the US and China (according to TradingEconomics) are presented in Fig. 3 and 4.

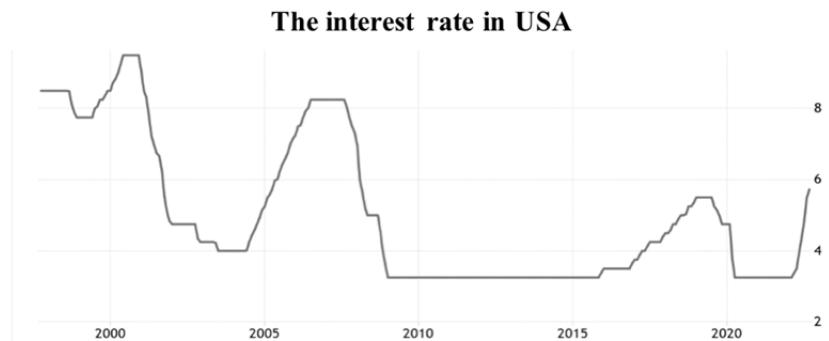


Fig. 3. Dynamics of the interest rate on loans for NFOs in the USA

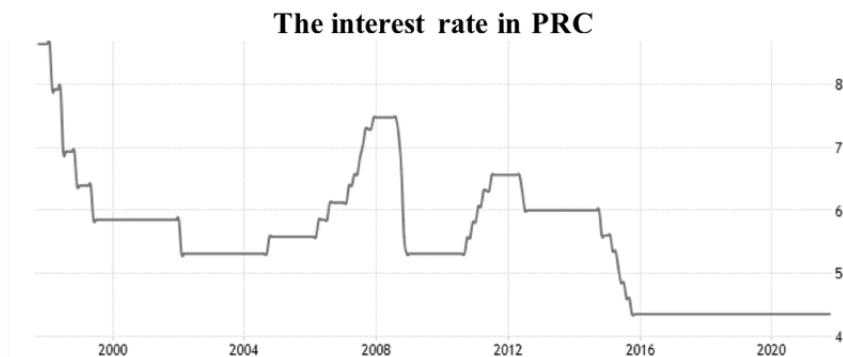


Fig. 4. Dynamics of the interest rate on loans for NFOs in China

Graphs of the dynamics of interest rates for similar loans in the Russian Federation based on the Central Bank of the Russian Federation data from January 2019 are shown in Fig. 5.

Thus, an analysis of the graphs in Fig. 3–5 shows that the volatility and average values for a 10-year period of lending rates in the USA and China are lower than in the Russian Federation for both long-term and short-term obligations, which makes risky long-term projects unattractive.

Another factor influencing the development of the high-tech industry is the degree of depreciation of fixed assets of high-tech organizations. Fig. 6 shows the dynamics of the degree of depreciation of fixed assets of high-tech sectors of the economy in the Russian Federation (according to Rosstat).

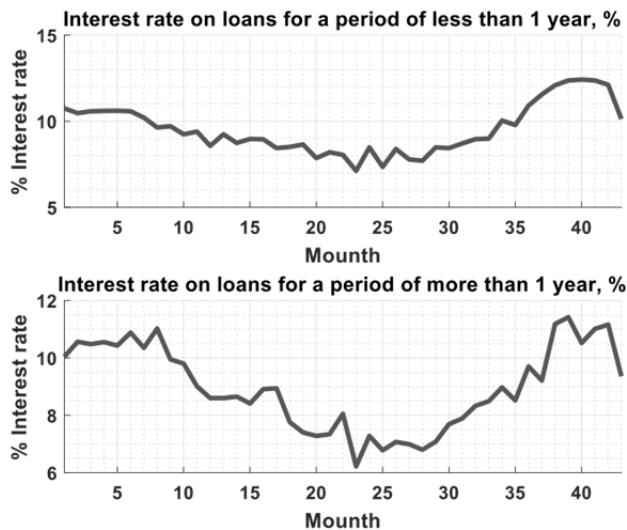


Fig. 5. Dynamics of the interest rate on long-term and short-term loans for NFOs in the Russian Federation since 01.2019

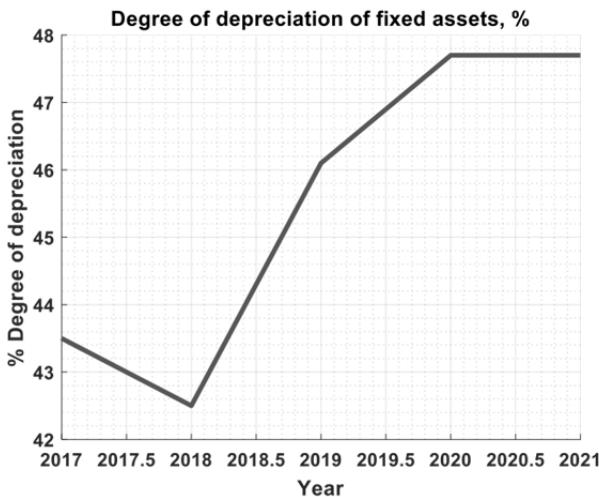


Fig. 6. The degree of depreciation of fixed assets of high-tech industries in the Russian Federation

To predict the indicator under consideration, the Fourier method of the first order is used with a reliability coefficient $R = 0.89$, where t – numbered time period (year):

$$f(x) = 45.49 + 0.85\cos(1.16t) - 2.71\sin(1.16t). \quad (2)$$

The forecast of changes in this parameter according to model (2) for a ten-year period is shown in Fig. 7.

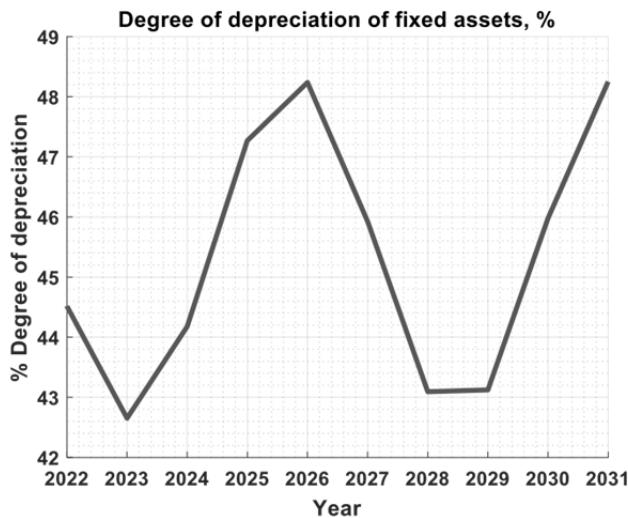


Fig. 7. Forecast of the degree of wear of fixed assets of high-tech industries in the Russian Federation

Another indicator reflecting the state of high-tech production facilities is the weighted average age of fixed assets. It allows assessing the state of the material and technical base of the industry. Fig. 8 shows the dynamics of this indicator, the calculation of which is carried out according to the method presented above (according to Rosstat).

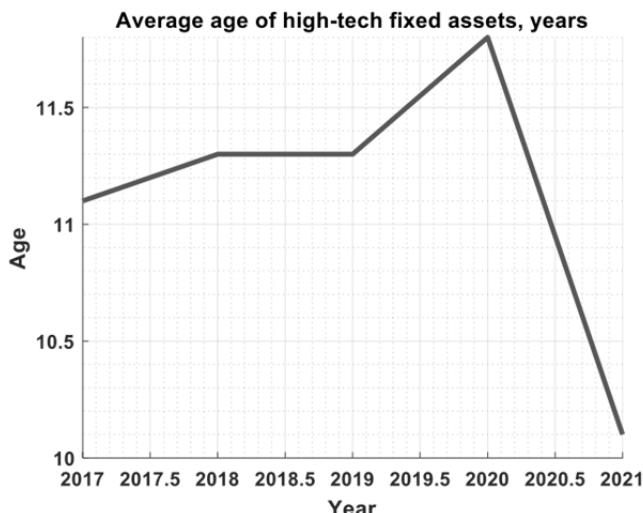


Fig. 8. Graph of the dynamics of the weighted average age of fixed assets of high-tech and knowledge-intensive industries in the Russian Federation

Thus, the analysis of the forecast (Fig. 7) and assessment of the current state of fixed assets (Fig. 8) allows us to conclude that they are critically obsolete and worn out. The

forecast indicates the volatility of depreciation of fixed assets of enterprises of high-tech industries in the Russian Federation at around 46 %, which also has a significant impact on the pace of its development.

Another important factor determining the degree of development and expansion of the high-tech industry is the increase in high-performance jobs, the dynamics of which is shown in Fig. 9 (according to Rosstat).

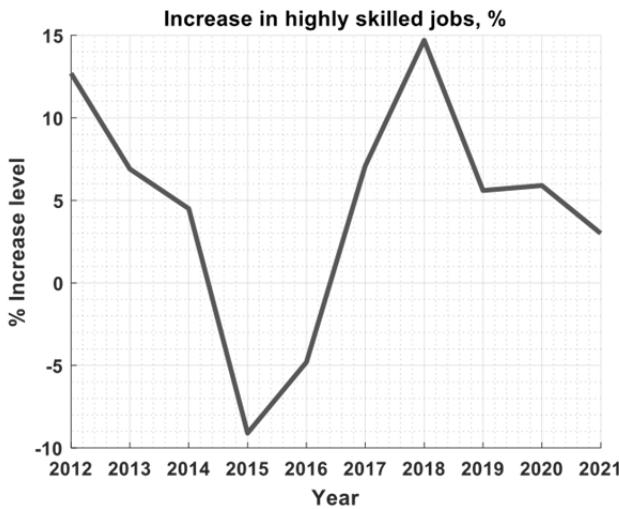


Fig. 9. Graph of the growth of highly qualified jobs in high-tech sectors of various sectors of the Russian economy

An analysis of the graph in Fig. 9 indicates a stagnation in the number of high-tech jobs in all sectors of the Russian Federation, which indirectly reflects the stagnation of the further introduction of high technologies in them.

Another important indicator is the release of highly qualified personnel, which reflects the situation with the mutual interest of workers and the employer in the functioning and maintenance of high-tech jobs in various industries. Graph 10 (Fig. 10) shows the dynamics of this indicator based on data on the annual output of highly skilled workers [13].

The decrease in the release of highly qualified personnel to the labor market also confirms the assumption made earlier about the stagnation of the industry.

Thus, a causal relationship is observed: the high cost of a loan and its volatility do not allow enterprises to take risks and renew stable functioning fixed assets, which leads to a decrease in the hiring of highly qualified personnel for their maintenance and use, which leads to a drop in the release of those same personnel due to low interest employers in them. This leads to stagnation in all sectors, which affects the entire economic complex of the country. A small share of the high-tech industry, combined with low growth rates in the industrial/post-industrial era, leads to a general stagnation of the macrosystem.

Consequently, the share of high-tech industries in developed countries in the total GDP of 50 % provides the entire economic complex with technologies and methods of production and organization of labor, which allow pushing forward all other industries and achieving leading world positions.

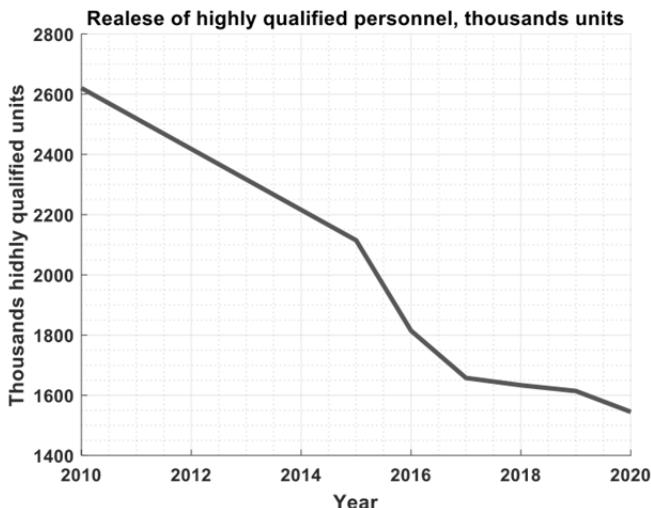


Fig. 10. Graph of changes in the number of graduates of highly qualified specialists of various categories in the Russian Federation

Conclusion

The conducted research shows that there is a huge gap in the high-tech sectors of the Russian economy. This aspect together with modern tendencies of deglobalization suggests that to overcome the existing macroeconomic gap it is necessary to use all available resources effectively to develop and modernize existing enterprises and concerns in high-tech industry. Due to the complex geopolitical and economic situation the possibilities of direct import of innovative technologies and productions are small, which requires the search of internal opportunities and integration of lean production and development processes. At the same time, it should be noted that the idea of blind copying of developments and achievements of the world economy is a dead end, since the dynamics of innovation and new ideas in the high-tech sector is extremely high. This leads to a situation of constant time delay in the macroeconomic system, associated with significant time and material costs to develop and organize production of already obsolete by this time.

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Гуманитарные науки

Humanities

УДК 81'33

Особенности перевода терминов-эпонимов с русского на английский язык в параллельных текстах

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При переводе эпонимов с русского языка на английский имена ученых часто изменяются. Для того чтобы рассмотреть такие случаи, решено проанализировать английские и русские эпонимы в предметной области «Космонавтика» и изучить способы передачи русских эпонимов на английский язык. Для этого выбраны эпонимы из параллельных текстов и проведено сравнение этих терминов. По результатам найденных терминов было обнаружено, что фамилии в эпонимах были изменены или включали иностранные символы того или иного языка, так как сохраняли культуру стран ученых.

Ключевые слова: эпонимы, параллельные тексты, терминология, структурные трансформации

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Peculiarities of Translation of Eponymic Terms from Russian into English in Parallel Texts

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The names of scientists often are changed when eponyms are translated from Russian into English. To consider such cases, we decided to analyze English and Russian eponyms in the area of Cosmonautics and to study the ways of transferring Russian eponyms to English. For this purpose, we manually selected eponyms from parallel texts and compared these terms. Based on the obtained results we discovered that the surnames in the eponyms were

changed or they included foreign letters of a particular language, as they retained the culture of the scientist's countries.

Keywords: eponyms, parallel texts, terminology, structural transformations

Introduction

Terminology deals with the study of special vocabulary, examining it in terms of typology, origin, form, meaning, functioning, use, ordering and creation.

A term can be either a word or a phrase or an abbreviation. The inner form of a term carries the attribute of the concept to be terminated and its terminological information, there are processes of transition of terms from one sphere to another, which is called reterminologicalization. Researchers of various fields during the study of special vocabulary have found that there are also other special lexical units, in particular nomens — the names of single concepts or mass products, which are reproduced according to one pattern set by a certain number of times. There are also sub-terms used as terms for naming new concepts that do not yet meet the basic requirements unlike terms. Subterms can often be found in descriptive clauses, conjunctive phrases, participles and deuteronomies, and so on.

Eponyms, i.e. terms derived from proper names, traditionally are used in the language of science and date back to the earliest periods of their formation. The peculiarities of the eponyms are determined primarily by the fact that they are based on different proper names, i.e. the names of our contemporaries and the names of scientists, political and public leaders who lived in the past. Consequently, eponymic names become «monuments» of their time, and that is their great value [1]. Eponymies reflect the anthropocentric nature of scientific knowledge. Discoveries and scientific and industrial developments are made by people whose names become memorialised in the names of the relevant phenomena, objects or phenomena, carrying a large number of associations and allusions in their semantics through which we can understand the scientific concept, e.g: Diesel — the internal combustion engine was named after its inventor Rudolf Diesel or the Pegu Loop. Pegu was a French pilot, famous for his show, who immediately performed a dead looper after Pyotr Nesterov , but Nesterov was a Russian military pilot who performed a dead loop on his plane for the first time in the world but he was little-known abroad [2].

The formation of eponymic terms does not differ from the formation of ordinary terms, but it has a certain number of peculiarities. Scientists argue about the meaning of proper names in eponymic terms and their opinions are divided according two points of view on this matter [3]. The first ones assert that proper names are not related to concepts and have no lexical meaning (A.A. Reformatsky, N.D. Arutyunova, etc.), and the second ones state that proper names have a meaningful function in eponymic terms (L.V. Shcherba, S.V. Grinev) [4]. The goal of this review is to analyze eponymic terms in academic texts. In order to achieve this goal, the following tasks are to be solved:

1. To study the basic concepts of terminology on the basis of theoretical sources to identify the main difficulties in the translation of special vocabulary;
2. To analyze English and Russian eponyms in the area of Cosmonautics;
3. To explore the ways of translation of Russian eponyms into English.

Methods

In this research we have used a method of structural analysis to study the formal structure of the English and Russian eponyms relating to cosmonautics, as well as

a comparative analysis of Russian eponyms and their English equivalents. On the basis of the data obtained, eponymic terms that do not have scientific accuracy are identified. We have studied the eponyms, their origin, features of translation and what areas they are used in. Equivalents of eponyms collected from research papers on space and cosmonautics were considered and unique cases of translation from Russian into English were found.

Results

In the table you can see structural transformations in translation.

Structural Transformations in Translation

Russian	English
Форма Ми — Грюнейзена	Mie — Grüneisen form
Метод Соболя	I.M. Sobol's method (Sobol's method)
Квазиньютоновский BFGS (Broyden — Fletcher — Goldfarb — Shanno) метод	Quasi-Newtonian Broyden — Fletcher — Goldfarb — Shanno (BFGS) method
Векторные мнимые единицы Гамильтона	Imaginary Hamilton units
Матрица Гессе	The Hessian
Теории Штермера	Theory of Størmer
Лоскуты Безье	Bézier patches
Углы Эйлера и Крылова	Euler and Tait — Bryan angles
Частоты Брента — Вяйсяля	The Brent — Väisälä frequency

Having studied the parallel texts in Cosmonautics we found 9 terms with structural transformations. Table shows examples of eponymic terms in Russian and their translations. When translating a term «Mie — Grüneisen form» into English «Mie — Grüneisen form», German letters appears. This is due to the fact that the scientist was German and when he was included in the English-language article, his last name was left in German in order to preserve the linguistic identity of the scientist. When translating the term «Sobol's method» into English «I.M. Sobol's method (Sobol's method)» the initials of the scientist appear due to the type of specification of lexical transformations. The eponym «Quasi-Newtonian BFGS (Broyden — Fletcher — Goldfarb — Shanno) method couldn't be translated into Russian. When translating from Russian to a foreign language, the term „Hessian Matrix“ was omitted in the term „Matrix“ and in the article in English this term is listed as „The Hessian“. The term „Bézier patches“ is translated with a diacritical mark for a more accurate pronunciation of „Bézier patches“. In the eponym “Euler and Tait Bryan angles,” which has the translation «Euler and Tait Bryan angles,» we can notice that in the translation the surname «Krylov» was changed to «Tait Bryan,» the replacement of the unit occurred because the source language word had a less broad meaning than «Tait Bryan» in English language science.

Conclusion

In this paper we have found unique cases of translation of eponymic terms with substitutions of surnames from the source language with more famous surnames of the translated language. Besides, we described cases of retention of German signs in the surnames of scientists to indicate their linguistic affiliations.

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Сравнительный анализ акцентов на примере королевской семьи

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Приведены различные виды акцентов на примере королевской семьи Великобритании. Сравнивают британское нормативное произношение и стандартный южно-британский английский язык. Использованы методы фонетического исследования и объективные методы. Предоставлены особенности произношения Короля Чарльза и его сыновей, Гарри и Уильяма. Проведен сравнительный анализ дифференциации акцентов внутри одной семьи.

Ключевые слова: произношение, акценты, различие, британское нормативное произношение, стандартный южно-британский английский, гласные, согласные, дифтонги

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Comparison Analysis of The Royal Family Accents

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This article presents different accents in Great Britain by means of an example of the Royal Family. Received Pronunciation and Standard Southern British are compared. Methods of phonetic investigation and objective methods are involved. The case study of King Charles and his sons Harry and William pronunciation peculiarities is given. The comparison analysis of the accent differentiations is conducted.

Keywords: pronunciation, accents, difference, Received Pronunciation, Standard Southern British, vowels, consonants, diphthongs

Introduction

It would not be an exaggeration to declare that English has become a international language both in the field of live communication and on the Internet. Being official in various countries, such as the USA, Britain, Canada, Ireland, Australia, New Zealand, South Africa and several Caribbean countries, the English language is made a priority in a foreign-language teaching in many countries the world over. There exists a wide diversity of cases in which the degree of language proficiency of the communicants does not mean a lot (small talk in the street or conversations in some networks). On the other hand, an accent extremely affects speech representation Thus, the problems related to the study of different accents have been a key discourse point for many modern linguists. The present paper presents the study of different accent types in the modern English. The goals of this article are related to the present-day accents. The means of phonetic analysis of various speeches are exposed for differentiation.

It is essential to define the term "accent". The accent is a combination of phonetic, lexical and phraseological peculiarities of the speaker's pronunciation caused by the influence of the mother-tongue or the region the person comes from. It should be noticed that the linguistics sources emphasize that "the term refers to pronunciation only, and is thus distinct from dialect, which refers to grammar and vocabulary as well. The accent is a special way of pronunciation, which is characteristic of a group of people in any area. Regional accents are a part of the regional dialects [1].

The term accent has various meanings, but in speaking, an accent is an identifiable style of pronunciation, often varying regionally or even socioeconomically. There are about 40 different British accents [2].

Received Pronunciation, also known as «RP», is a British accent known as the «Standard British» accent. It is spoken mostly in London and South East England but it is also the accent most often used in formal education and the media (such as news broadcasts). It is also used for phonetic pronunciations in all British dictionaries [3, 4].

Standard Southern British (where ‘Standard’ should not be taken as implying a value judgment of ‘correctness’) is the modern equivalent of what has been called ‘Received Pronunciation’ (‘RP’). It is an accent of the south east of England which operates as a prestige norm there and (to varying degrees) in other parts of the British Isles and beyond [5].

If we take the aristocratic accent or the posh English accent, its name speaks for itself, because the *posh* word translated as «elite», «artsy». It is the language of higher social strata, a prestigious variant pronunciation. It becomes the determining factor in education and the media. It is distinguished by clarity and purity, all consonants are pronounced slowly and pretentious, as if your mouth plum. Of course, speaking with an accent *posh*, you need to carry on a conversation with a touch of arrogance, because you are better and more important than others [6].

The main differences between classic mid-twentieth-century RP and contemporary SSB are in the vowels. In terms of the phonemic inventory, SSB totally lacks the old FORCE diphthong /ɔə/, which still appeared in RP materials as recently as the 1977 English Pronouncing Dictionary, 14th edition, but which has been fully merged with the THOUGHT monophthong /o:/ . The old CURE diphthong /ʊə/ is also now mostly merged into THOUGHT /o:/ .

In terms of distribution, old RP allowed the short lax vowels /ɪ/ and /ʊ/ in word-final position, but in contemporary SSB schwa /ə/ is the only short lax vowel allowed finally.

Methods

We distinguish between subjective, introspective methods of phonetic investigation and objective methods. The oldest, simplest and most readily available method is the method of direct observation. Objective methods involve the use of various instrumental techniques (photography, cinematography, videos and so on). Mainly videos and videoclip are investigated. Measuring and analyzing the movement of the air in the terms of acoustics is investigated with the help of sound-analyzing techniques and also by means of speech-synthesizing devices.

The life of the Royal Family

The way people speak depends on the background, education, qualification they have and their social status. We are analyzing the speeches of the Royal Family members. Prince Charles' accent was taken after his mother Queen Elizabeth II, while her accent a more regal bearing [3]. Young people of a very privileged background have all shown a shift to a less stiff, formal mode of speech and a less polarized accent. In this sense, Charles is a relic among other relics and it is not constrained to his family. He was the first heir apparent to attend school rather than be educated by a private tutor. Charles is also a man who displays great anxiety traits. He has always been viewed as shy, socially awkward, and with a large number of anxiety-related nervous tics. He studied at the elite school in London and Cambridge University. Prince Charles has a posher-sounding accent than Harry and William. Harry and William also had the advantages of both public school and popular culture. Both princes attended the prestigious boys school Eton College. Their different accents also might have to do with Charles's personality.

If we compare King Charles's speech with the speech of his sons William and Harry, it would be clear that this is a comparison between RP, Received Pronunciation, and its modern equivalent SSB, Standard Southern British, spoken by William and Harry (Table). We may have wondered why these differences are so much bigger than the differences between King Charles and his late mother? Between Charles's childhood and William and Harry's, Britain saw huge social changes.

Being upper class changed rapidly from being prestigious to being a symptom of unfair privilege, and many in the upper classes shifted their pronunciation to sound less like posh RP. Even the Queen shifted her vowels a bit between the 1950s and the 1980s [7]. For example, the vowel in the word PRICE. King Charles has the RP vowel, beginning [a], [ai], whereas William and Harry have the SSB vowel, beginning [a], [aj] [8]. And in words like ‘while’ and ‘smile’, the vowel can be smoothed into just that first part, [a] and [a]. The vowel in the word DRESS was made with a closer mouth in RP, [e]. In SSB it’s more open, [ɛ]. The same is true of the vowel in FACE. The opposite applies to the vowel in CHOICE. King Charles has the more open RP sound [ɔɪ], while Prince Harry has the less open [oj] of SSB. This means that the start of the word ‘joy’ sounds like ‘job’ when Charles says it, but like ‘jaw’ when Harry says it [9]. In RP, the vowel in SQUARE was a diphthong, a changing vowel, [ɛə]. In SSB, it is a monophthong, with a steady, unchanging quality, [ɛ:]. So, they end very differently. And in RP, the unstressed vowel on the end of words like happy was the lax vowel of ‘it’, but in SSB, it’s the tense vowel of ‘tea’. Before we leave vowels, we have to mention the effects ON vowels of one particular consonant, dark L. Older speakers like King Charles and have pretty much the same vowel in ‘no’ and ‘soul’, but listen to how different they are for Prince Harry. And the smoothed-out PRICE vowel can get merged into a following L. Prince William often seems to be talking about the vegetable chard. This L-vocalization is a huge topic and it can be found in many accents and many languages. Okay, on to the consonant /t/. King Charles not do this: In other words, turn final /t/on the end of a word into a glottal when a vowel follows. Like the new Prime Minister, William and Harry do this lots [8].

King Charles’s speech and the speech of his sons William and Harry

Words	King Charles RP	Prince William SSB	Prince Harry SSB
Price	I > [aɪ]	I > [aj]	I > [aj]
Dress	E > [e]	E > [ɛ]	E > [ɛ]
Face	E > [e]	E > [ɛ]	E > [ɛ]
Square	UA > [ɛə]	UA > [ɛ:]	UA > [ɛ:]
Choice	O > [ɔɪ]	O > [oj]	O > [oj]
Happy	Y > ‘it’	Y > ‘tea’	Y > ‘tea’

While watching the video [9], Youtube’s automatic captioning algorithm is amazingly good, but it can be confused by this glottal stop, for example at the end of the word Charlotte.

The algorithm is more at home with American style /t/voicing, sometimes called flapping. We saw in the video that King Charles occasionally does this. But his sons, like many SSB speakers, do it quite a bit more. Of course, Prince Harry spends a lot of time in the United States, and this may well be why he does this even in words where most Brits would not. We saw in the video that King Charles sometimes uses yet another third kind of t-weakening, which moves it towards an s-sound. This could be ‘sing’, but is actually from the word fighting. And for once it is like father, like son. Here Prince William might almost be saying ‘see’ but it’s the second half of the word ‘city’: And this is almost ‘mass’ but it’s the first part of matters: Releasing the consonant t with a little s is called affrication and is absolutely the norm for SSB speakers, but William uses more than most. Some of his

pronunciations could have been lifted directly from Liverpool English, Scouse. And this leads us to the issue of so called mumbling, which some people have accused Charles of, but which is supposed to be a relaxed way of speaking. Occasionally Charles produces some of his words very quickly, or misses out a syllable or two though one can notice less of this in his speeches since becoming King. And then there is William.

It is quite hard to find speeches where William does not do this kind of thing. A lot. You might jump to the conclusion that he has it from his father, but in William's case it seems the opposite of relaxed, it sounds rushed, hurried. And away from the royals, there are some very successful public communicators who do the same thing as William [8].

We can end with three features that you can hear from SSB speakers. First, Uptalk, which is basically saying statements with rising intonation more like a typical question. It is often used to check that the person you are speaking to is following you. Next, TH-fronting, which includes pronouncing th as f. It is a general British phenomenon that can be heard increasingly from younger and not so younger speakers all over the country. That might have been just a slip, because 'faiths' is a hard word to say, and we can hear other examples of it from William or Harry. And finally ejective k, which sound like' this. And if you would like to know more about what ejectives are, how they are produced and who uses them, this is the video to watch.

Conclusion

Although it has been 70 years since a change of monarch in the UK, King Charles' accent is not very different from his mother's one. It is the sort of accent you could hear in the 1950s on the BBC: Upper Received <https://pronunciationstudio.com/upper-received-pronunciation/> and it is really only spoken now by ageing aristocrats. It is the accent that is supposed to be dying out. It is rare for people to encounter somebody in everyday life who sounds like Elizabeth II or Charles III. England's next monarch will bring a slightly more contemporary speech style to the throne.

William and Harry accents are signs of the time. William verbal dynamics deliver the true essence of a young British royal; a young British prince; a young man with high morals, high principles. Prince Harry spends a lot of time in the United States, and this may well be why he does this even in words where most Brits would not.

It is not so much that he has developed an American accent but more that he is adapting his. For example, dropping his Ts and use of Americanisms to 'fit in better and be liked', according to a speech expert [9]. That is a sign of the time.

More than that, as the analysis of factual materials demonstrates, accent can help people express their identity, capture attention of interlocutors, create a comic effect, break the ice. Thus, from the point of view of sociolinguistics, accent plays the role of a social marker that contributes to the individual features of a speaker or to giving any speech an expressive shade.

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Современные подходы к экстерриториальности в правовой системе США

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В статье рассматривается вопрос экстерриториального применения правовых норм на примере судебной практики США, который становится всё более актуальным ввиду интенсивных процессов глобализации. Исследуются пределы презумпции против экстерриториальности, установленной Верховным судом США, и анализируются три правовых стандарта: канон «Очаровательной Бетси» (*the Charming Betsy canon*), тест на поведение и последствия (*conduct-and-effects test*) и фокус-тест (*focus test*). Последний является недавним дополнением к прецедентному праву и подчеркивает важность анализа «фокуса» исследуемого права.

Ключевые слова: экстерриториальность в праве США, сфера применения правовых актов, анализ судебной практики, анализ прецедентного права США, US case law analysis, канон «Очаровательной Бетси», тест на поведение и последствия, фокус-тест

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Modern Approaches to Extritoriality in the US Law

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This article delves into the topic of extraterritorial application of legal norms in the US judicial system, which has become increasingly relevant due to globalization and international relations. It explores the limits of the presumption against extraterritoriality established by the US Supreme Court and analyzes three legal standards used in this context — the Charming Betsy canon, the conduct-and-effects test, and the focus test. The latter is a recent addition to case law and emphasizes the importance of analyzing the "focus" of the law being examined.

Keywords: extraterritoriality in the US law, scope of legal acts, analysis of jurisprudence, US case law analysis, the Charming Betsy canon, conduct-and-effects test, focus test

Introduction

Recently, against the background of intensive multilateral globalization processes, many legislators and academic scholars from various countries have concluded that the state can no longer effectively protect its interests on the basis of the territorial principle of law enforcement alone. The practice of extraterritorial application of laws exists and is actively developing, and therefore it is necessary to reach agreement on exactly what constitutes the extraterritorial application of national law and how exactly it can be carried out. In the United States, the doctrine of extraterritorial application of law is actively used and developed, which arouses scientific and practical interest in the study of this issue using the example of this country's jurisprudence. Modern legal science concludes that the action of normative acts is realized on the basis of territorial and extraterritorial principles. The territorial principle implies the action of a normative legal act within the borders of the state or the relevant administrative entity. The extraterritorial principle of normative acts action, being a phenomenon of globalization, involves the extension of the legal acts action beyond the borders of the issuing body jurisdiction.

Disputes over extraterritoriality arise when a domestic rule of law applies to a foreign person under the jurisdiction of the regulating State in respect of acts committed outside the territory of that State. Thus, the question of the extraterritorial application of the law hinges on whether the foreign individual or entity falls within the jurisdiction of the issuing State. Therefore, as Cohen-Tanugi points out, “the truly debatable issue concerns the degree of ties required with a State in order for that State to lawfully exercise jurisdiction. The weaker these ties, the less justified the application of extraterritoriality” [1, p. 3].

Research

In 1991, U.S. Supreme Court case law established a presumption that the U.S. law does not apply abroad unless the law itself clearly indicates to the contrary. Until then, courts had relied on Supreme Court case law, established prior to 1991, called the Charming Betsy canon, to decide such issues. In *Murray v. The Charming Betsey* of 1804 established the principle that an act of Congress shall never be construed to violate the laws of nations, if any other possible interpretation remains [2].

The approach to the issue of extraterritoriality was substantially expanded in 1991 when the Supreme Court articulated a presumption against extraterritoriality in EEOC v. Arabian American Oil Co [3]. In that case and subsequent cases, the Court argued that unless a statute contained a ‘clear indication’ that Congress intended it to apply outside the territorial jurisdiction of the United States, it did not apply extraterritorially. Specifically with respect to this case, the Supreme Court pointed out that Title VII of the U.S. Code does not apply extraterritorially to regulate employment practices in American companies, and that petitioners’ evidence in the case does not demonstrate a clear congressional intent to establish the extraterritorial application necessary to overcome the well-established presumption against statutory extraterritoriality. In F. Hoffmann-La Roche Ltd. V. Empagran, where the plaintiffs argued the applicability of extraterritorial application of antitrust law in their case, the U.S. Supreme Court noted that the purpose of the presumption was to avoid inadvertent conflict with the laws of foreign countries and cautioned courts against assuming that legislators in other countries necessarily consider the sovereign interests of other countries when they write laws [4]. An important precedent was set in Skiriotes v. Florida case, where it was held that in certain cases states may exercise extraterritorial regulation on the same terms as the federal government [5].

A particular difficulty in applying the extraterritoriality principle is the question of exactly what activities and to what extent must have been conducted within the state for the United States to exercise jurisdiction over the case. The watershed case of Morrison v. National Australia Bank [6]. Prior to it, the Supreme Court had not considered what, or to what extent, conduct should take place within the United States. As Austin Parrish [7] and Derek White [8] point out, until then, lower courts, in deciding whether the law was extraterritorial, generally applied the so-called conduct-and-effects test. Under this approach, the court was to ask two basic questions: 1) whether the wrongful conduct was committed in the United States, and 2) whether the wrongful conduct had substantial consequences in the United States or for U.S. citizens [9]. Courts evaluated the facts of each case to determine, as was stated, for example, in Bersch v. Drexel Firestone, Inc. case, whether Congress wanted the U.S. courts and law enforcement agencies to devote some of their precious time to resolving these issues, rather than leaving the problem to foreign nations to resolve [10]. If the answer was positive, the case was continued; if not, it was dismissed.

In the 2010 Morrison case [11], the Supreme Court rejected the possibility of using such a test, which meant that the court had to find a new solution to the question of how to determine state jurisdiction in cases of this type, and what conduct must take place in a state for the crime to be considered domestic rather than extraterritorial. In the Morrison case, the Supreme Court criticized the fact that Congress’s silence on the extraterritorial scope of the article at issue gave judges the power to determine what Congress would have wanted, and the correct approach, according to the Supreme Court, was to apply the presumption against extraterritoriality in all cases. The Court also pointed out that the courts’ approach based on the ‘conduct and effect test’ was inconsistent in application and led to unpredictable results, and formulated a new ‘focus test’ under which courts must assess which event or relationship is the ‘focus’ of the law, that is, as the Court specified, the object on which the law is directed to determine the necessary character of conduct that must take place in the United States for a suit to be heard by a United States court.

Methods

In the present study, the formal-legal method was applied, which allows to investigate individual legal concepts and to classify them using constructions and terms developed by

the legal science. To compare different approaches to the topic of extraterritoriality existing in the law of a particular country, the comparative legal method was used.

Findings

In the Morrison case, the securities fraud claim was based on conduct occurring both in the United States and abroad. The court determined that one element of the claim was decisive, based on the aforementioned ‘focus test’. It was ruled that a strict territorial nexus was present only in securities fraud cases involving “transactions in securities listed on domestic exchanges and domestic transactions in other securities”, and pointed out that the location where the fraudulent activity took place and where the harm arising from the fraud occurred were irrelevant.

Shortly after the Morrison case decision, however, Congress amended several securities laws to permit the Securities and Exchange Commission and the U.S. Department of Justice to prosecute violations where conduct within the United States constitutes significant steps in furtherance of the violation, even if the securities transaction occurs outside the United States and involves only foreign investors; or conduct occurring outside the United States that has a foreseeably substantial impact on the United States. These amendments apply only to securities fraud cases, and therefore they left in effect the rule articulated by the Morrison case for civil securities suits. This move was perceived as a limited reinstatement of the ‘conduct and consequences’ test.

The implications of the Morrison case for jurisprudence remain a hotly debated issue among researchers on the issue. Leah Brillmeyer, for example, is rather harsh in her criticism of the implications of this judicial decision saying that “in Morrison v. National Australia Bank case, the Court effectively threw overboard decades of established jurisprudential rules for such cases, cast doubt on the applicability of long-established practices of statutory interpretation, and instructed lower courts to ignore any indication that Congress intended a statute to be extraterritorial, other than an express indication thereof” [12, p. 1].

Discussion

The approach of U.S. courts to questions of extraterritoriality of law has changed dramatically over time, and there are still differing views in the doctrine as to whether these changes lead in the right direction. Either way, one can conclude that the main approach today in American law enforcement practice is the presumption against extraterritoriality, which can only be overcome, if Congress has expressed an intent to apply a law extraterritorially, and the main method used to determine whether such an intent has occurred is the ‘focus test’. The formulation and experience in applying this presumption and these tests may be useful both for the theoretical study of the concept of extraterritoriality and for the development of legislation in this area.

Conclusion

In conclusion, the courts initially relied on a general approach relying on the relationship between domestic rules and international law, known as the Charming Betsy canon, but it gradually became clear that deciding the extraterritorial application of the law required further specification. In certain types of cases, such as antitrust and securities law cases, jurisprudence has developed a «conduct and effects test» that has existed for a long

time, but in 2010, following the decision in the landmark Morrison case, the Supreme Court indicated that there was a need to create a new standard called the «focus test.» The U.S. courts' approach to the extraterritoriality of a law and how to determine whether a law can be applied extraterritorially has changed dramatically over time, individual cases have significantly altered enforcement practices, and there are differing opinions in the doctrine as to whether these changes are leading in the right direction.

In any case, it can be concluded that the main approach in American law enforcement practice today is the presumption against extraterritoriality, which can be overcome only if Congress has expressed an intention to apply a law extraterritorially, and the main method used to determine whether such an intention has taken place is the «focus test». The formulation and experience in applying this presumption and these tests may be useful both for the theoretical study of the concept of extraterritoriality and for the development of legislation in this area.

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Особенности образования новых английских фразовых глаголов

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Рассмотрена актуальная на сегодняшний день проблема – образование новых фразовых глаголов. Актуальность определяется тем, что на сегодняшний день в английском языке существует огромное количество фразовых глаголов, причём это количество неуклонно растет. Отметим, что наблюдается не только появление новых фразовых глаголов, но и увеличение частоты употребления уже имеющихся единиц. Фразовые глаголы придают речи особую выразительность и употребляются не только в разговорной речи, но и в официально-деловых текстах. Задача автора установить продуктивные способы образования фразовых глаголов. Материалом исследования послужили данные сплошной выборки на основе лексикографических источников и корпусов современного английского языка. Использованы следующие методы: анализ научно-методической литературы по выбранной теме исследования, метод сплошной выборки для выявления продуктивных способов образования фразовых глаголов, а также статистический метод, позволивший получить и проанализировать полученные количественные данные.

Ключевые слова: фразовый глагол, словообразование, неологизмы, трансноминации, мотивы образования, модель, семантическая группа, конверсия

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Features of the Formation of New English Phrasal Verbs

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The article is devoted to an urgent problem today – the formation of new phrasal verbs. The relevance is determined by the fact that today there are a huge number of phrasal verbs in the English language, and this number is steadily growing. Note that there is not

only the appearance of new phrasal verbs, but also an increase in the frequency of use of existing units. Phrasal verbs give speech a special expressiveness and are used not only in colloquial speech, but also in official business texts. The aim is to establish productive ways of forming phrasal verbs. The research material was the data of a continuous sample based on lexicographic sources and corpus of the modern English language. The article used the following methods: analysis of scientific and methodological literature on the chosen research topic, a continuous sampling method to identify productive ways of forming phrasal verbs, as well as a statistical method that allowed obtaining and analyzing the quantitative data obtained.

Keywords: *phrasal verb, word-formation, neologisms, trans-nominations, motives of formation, model, semantic group, conversion*

The formation of new phrasal verbs is an important process in modern English. From a structural point of view, a phrasal verb can be represented according to the Verb + Adverb (V + Adv) scheme. This format of the formation of new semantic units is the most productive, since the possibilities of affixation are somewhat limited by typological characteristics. It is important that the increase in the number of verbal units of the language is replenished at the expense of its own resources [1].

In the work of E. S. Kubryakova, devoted to the study of the cognitive foundations of word formation, it is said that the predominant part of new words arises in the language as a result of one or another word-formation act, which leads to the assumption that the conceptualization of the world is considered as a phenomenon of «verbalization» or «linguization» of conceptual structures existing in human consciousness [2].

The main motive for the formation of new phrasal verbs is the creation of language nominations, the meaning of which is focused on the description of spatial-temporal characteristics. As a result, we can say that such a word-formation model has strengthened the analytical tendencies of the language, reducing the importance of word-formation morphology. Polysemy or polysemy of phrasal verbs cannot be arbitrary.

Phrasal verbs can be conditionally divided into two large categories. A group of neologisms proper is distinguished, combining the novelty of the form with the novelty of the content. The second group is represented by trans-nominations — linguistic units that have a new form, but a well-known content realized in a different form [3].

The main reason for the emergence of phrasal verbs in the English language system is the desire of its speakers to create nominations that would differ from the existing ones in their shade meaning, suitable for describing the specifics of a particular action in accordance with the context of the situation.

Thus, the motives for the formation of phrasal verbs include:

– the need to give names to actions and operations related to the development of the scientific and technical sphere of human activity. For example,

to boot up – включить компьютер (начать загрузку);

to start up – начать работу (включить техническое устройство);

to cable up – подсоединить кабель к телевизионной системе;

– the need to give a name to the means of communication and daily interaction. For example,

to log in – залогиниться(ввестилогин);

to log off – удалить аккаунт;

to fax out – разослать большое количество документов при помощи факса;

– the need for the designation of terms related to the field of aeronautics and astronautics. For example,

to sock in – не давать разрешение на взлет;

– the need to identify problems and issues of a social nature. For example,

to trip out – испытывать галлюцинации;

– the need to identify the specifics of a person's behavioral characteristics. For example,

to beef up – совершенствоваться;

to gin up – совершенствоваться;

– the need to designate social relationships. For example,

to ask out – попросить уйти в отставку;

to suss out – понять, войти в положение;

– the need to create linguistic units denoting the psycho-emotional activity of a person.

For example,

to dream up – воображать, мечтать;

to nod off – дремать (неожиданно для себя);

to doze out / to doze away – задремать, заснуть;

to chill out – расслабиться;

to flip out – сойти с ума.

To sum up, the formation of phrasal verbs depends on a large number of factors. First, the motives for their occurrence are related to the fact that the language tends to develop and change every day, thereby causing the need to adjust existing linguistic norms.

The mechanism of phrasal verb formation consists of several stages. First, it is necessary to pay attention to the creation of a preverbal meaning. It is formed and correlated with the deep tier of meanings of the mental lexicon. It is important that in order to verbalize the constructed meaning, it is necessary to find the appropriate form, consider the word-formation and morphological possibilities provided by the English language at the time of the formation of new linguistic units, in particular, phrasal verbs.

According to the theory of conceptual integration, new conceptual content often does not require the creation of new forms of expression. The language contains all the grammatical forms necessary for the formation of almost any phrasal verb.

Phrasal verbs can be presented from the position of a new form of expression. It is in it that the model of word formation, which has become normative, comes out in the first place. It can be represented as follows: verb + particle. The advantage of this model lies in the specifics of the elements of which it consists. The totality of various models of phrasal verbs can be represented by the following examples:

- V + P = VP, i.e. a combination of a verb and a particle;
- N → V + P = VP, i.e. a combination of a converted verb (from a noun) and a particle;
- A → V + P = VP, i.e. a combination of a converted verb (from an adjective) and a particle.

The last two models include the following categories of phrasal verbs:

• phrasal verbs, the first component of which does not have free verbal functioning (for example, *to bliss out*),

• phrasal verbs in which the first component retains an obvious semantic connection with the meaning of the original noun or adjective and does not correlate semantically with the corresponding verb (for example: *to bottle out – to suddenly decide not to do smth because you are too frightened*).

For the study, we selected phrasal verbs presented in the Cambridge Dictionary [4], Dictionary by Merriam Webster [5] and Macmillan Dictionary [6].

Most of the phrasal verbs under consideration (80 % of the units from the total sample) are formed according to the following model: V + P = VP. The second in terms of the number of phrasal verbs is the following model: N → V + P = VP (which is 16% of the total sample). The model A → V + P = VP is the least productive (which is 4% of units).

The initial verbs involved in the formation of a phrasal verb according to the V + P = VP model belong to various semantic groups, of which the following can be distinguished:

- verbs of physical action (for example: *to log, to whack*) – 38 % of units. For example, *log out / off* – выйти из системы, *log in* – войти в систему;

- verbs of transformation of form or structure (for example: *to blast, to boil, to peel*) – 24 % of units. For example, *blast off* – взлетать, *startовать*, *boil up* – накаляться, *boil off* – испаряться, *boil away* – выкипать, *boil down* – сокращать, *boil out* – уваривать, *boil over* – перекипать, *peel away / peel off* – выходить из строя, *стаскивать одежду*, *peel back* – отогнуть край одежды;

- verbs of psycho-intellectual activity (for example: *to dream*) – 15 % units. For example, *dream on* – мечтать не вредно! *dream up* – фантазировать;

- verbs of psychoemotional activity (for example: *to psych*) – 8 % of units. For example, *psych out* – возбуждаться, *взвинчиваться*;

- verbs of speech activity (for example: *to ask, to talk*) – 6 % of units. For example, *ask back* – делать ответное приглашение, *talk away* – заговориться / выговориться, *talk out* – исчерпать тему разговора, *talkover* – обсудить;

- verbs of social action (for example: *to adopt, to deal, to let*) – 5 % of units. For example, *let by* – пропускать мимо ушей, *let down* – работать, не прикладывая усилий, *let in* – допускать, признавать, *let in for* – напрашиваться на неприятности, *let in on* – посвящать в свои планы;

- verbs of movement (for example: *to bound, to stomp*) – 4 % units. For example, *stomp on* – переписать что-то автоматически, *stomp off* – отправляться, потеряв терпение.

In the structure of new phrasal verbs formed according to the model N → V + P = VP, the original verbs are converted from the noun. The nouns that served as the source of the nominal verb conversion belong to the following semantic groups:

- a person (for example, *geek* – a person who knows a lot about computers and/or the Internet; *wimp* – a coward). For example, *geekout* – чудачить, проявлять энтузиазм в отношении чего-то, что вас интересует, и вы много об этом знаете, но остальные могут найти скучным, *wimp out* – струсить, слиться;

- psychological and intellectual properties of a person (for example: *beef* – inf., strength). For example, *beef about* – предъявлять претензии, *beef up* – подкреплять, наращивать, усиливать;

- social phenomena (for example: *gang* – a group of criminals working together). For example, *gang with* – водиться скем-либо;

- artifacts (for example: *mouse* – a small hand-held device which controls a cursor on a computer screen; *sack* – a bed). For example, *mouse out / about* – разнюхать, *mouse ahead* – бурить скважину малого диаметра, *mouse over* – навести курсор мыши, корпеть над чем-либо, *sack in / out* – отправляться спать;

- abstract concepts (for example: *bliss* – happiness). For example, *bliss out* – кайфовать, торчать.

Next, we will present examples of individual phrasal verbs. They were formed by conversion:

- *You'll have to butter them up a bit before they agree* [5].
- *Maybe he's trying to cool off out there in the rain* [5].
- *He accused broadcasters of contributing to the dumbing down of America* [5].
- *You need to man up and tell her to leave!* [4].
- *It was an article bigging up some new DJ* [5].
- *You could pretty up the room rather inexpensively simply by painting it* [4].

The following model A – V + P = VP is considered as the least productive. The total total index of phrasal verbs formed according to this model is 1.5% of units. This method is characterized by the use of the out particle (for example, *to bogue out – to become bogus*).

The results obtained suggest that the formation of phrasal verbs activates three word-formation models. Of these, the most productive is the V + P = VP model.

Among all phrasal verbs we have identified the following groups by structure:

- phrasal verbs with postpositive up – 32 % of the total number of units in the sample;
- phrasal verbs with the postpositive out – 61% of the total number of units in the sample;
- phrasal verbs with postpositive in – 7 % of the total number of units in the sample.

There are many ways to form new words from phrasal verbs, among which the following should be highlighted: word composition, conversion, and affixation. For example, lexical units such as *shoot-them-up* or *hand-me-up* are formed, respectively, from the phrasal verbs *shoot up* and *hand up* as a result of conversion from a stable phrase (holophrasis as a means of implementing the principle of saving linguistic economy):

- This is a Doom-style 3D *shoot-'em-up* that combines tough competition with amazing graphics [4].
- A father who is not so selective about fit or fashion wears the *hand-me-up* T-shirt of his son, declaring that it is 'like new'. A mother talks about her most fashionable outfit consisting of *hand-me-ups* from her oldest daughter [5].

Phrasal verbs formed by affixation can be represented in the following examples, emphasizing their specificity:

- Peter Morgan, screenwriter: «I'm a terrible *put-downer* and walker. So I hardly ever finish books or see out a movie. But I don't think I've ever pretended to read a book that I haven't» [6].
- She's not a mindless worker, she is a *startupper* [4].

Most often, when forming new words from phrasal verbs, conversion is used, for example:

- She was searching for a vicious suitable *put-down* [5].
- The whole concert was a bit of a *letdown* [6].

Based on the information received, it can be said that various models of phraseological units formation can be applied in modern English. According to the research materials, a number of the most relevant models can be identified: V+up', 'V+out', 'V+in', but they do not exhaust the variety of phrasal verbs that replenish the English language.

Based on the materials presented in the second chapter, it can be argued that the formation of phrasal verbs is determined by the formula Verb + Adverb (V + Adv). A significant part of phrasal verbs is formed due to special word-formation acts, which can be conditionally called the processes of «verbalization» or «linguization».

The phrasal verbs that exist today can be conditionally divided into proper neologisms and transnominations. The first are linguistic units that combine the novelty of the form and

the novelty of the content. The second category includes linguistic units that combine the novelty of the form, but the established content.

Among the motives for the emergence of phrasal verbs are the need to designate actions and operations related to the development of scientific and technical areas of human activity, the need to name means of communication and daily interaction, the need to designate terms in the field of aeronautics and astronautics, the need to designate social issues, the need to designate the specifics of human behavioral characteristics, the need to designation of nominations of social positions and social relationships, the need to create language units, denoting the psychoemotional aspects of the state of a person's personality and his psychoemotional activity.

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Эвфемизмы в китайском языке. Лингвокультурологический аспект

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Рассмотрены эвфемизмы в китайском языке как социокультурный феномен, описываются основные темы и сферы употребления эвфемизмов, особенности их функционирования в языке, а также то, как эвфемизмы в китайском языке координируют межличностные отношения. В ходе работы была проведена классификация китайских эвфемизмов, исследована и проанализирована с точки зрения лингвокультурного аспекта тематическая группа эвфемизмов "смерть".

Ключевые слова: Китай, Эвфемизмы, лингвокультурология, Смерть

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Euphemisms in Chinese: Linguocultural Aspect

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This research paper examines euphemisms in Chinese as a socio-cultural phenomenon, describing the main topics and areas of euphemism, the features of their functioning in the language, as well as how euphemisms in Chinese coordinate interpersonal relations. In the course of the work Chinese euphemisms were classified, the thematic group of euphemisms "death" was investigated and analyzed from the point of view of linguocultural aspect.

Keywords: China, euphemism, linguocultural aspect, death, socio-cultural phenomenon

Introduction

Euphemisms are a socio-cultural phenomenon that exists in different languages of the world and plays a coordinating role in interpersonal relations and in everyday communication. Euphemisms, as a mirror, reflect general and national features in culture, as well as general and specific development of a society as a whole. Thanks to euphemisms, it is possible to understand the life views and values of not only an individual, but also of a particular nation, they allow people to include taboo topics in their communication, to create a harmonious atmosphere for communication. Euphemisms coordinate interpersonal relations in the process of communication and are an important tool to implement communicative tasks. The research in this field is significant, because euphemisms are not only a purely linguistic phenomenon, they are also related to culture and society development.

In Chinese culture, a great number of taboos have survived since ancient times, most of them related to religion and faith. Linguistic taboos in Chinese culture are associated with respect for people of high rank, so in the past, people tried not to use the names of very distinguished people in conversation, in particular, the name of the great philosopher Confucius and the names of Emperors of China. People believed that by doing so they showed respect and reverence for the person. Euphemisms are divided into general-language and speech euphemisms. General-language euphemisms have features of stability and reproducibility. They are used in typical communicative spheres: linguocultural traditions, value-normative concepts, social environment, social status, etc. In contrast to the common language, they have the character of unstable nominations, but at the same time they have a number of advantages, in particular, their denotation is more camouflaged. Some author's euphemisms are codified and pass into common language [1].

There is a number of studies on euphemisms in the Russian and Chinese languages. These studies prove their very bright national and socio-cultural marking. The Explanatory Dictionary of the Russian Language, edited by D.N. Ushakov, gives a definition of «euphemism»: it's a word or expression that used to denote, cover up some object or phenomenon, which is inconvenient, indecent, not acceptable to call by its direct name in the given environment".

In modern linguistics, the term euphemism means a softening expression of what is untactful, indecent, rude to the interlocutor. An euphemism is the replacement of any undesirable word or expression in a given situation with a neutral or positively colored designation in order to avoid conflict in communication or to conceal unpleasant phenomena in reality. Euphemism is a unit that characterizes speech behavior, belongs to the phraseological fund of the language, therefore euphemism is a unit of linguoculturalism [2, p. 20–22].

Scholars study closely related linguistic, social, psychological aspects of euphemisms. The formation and development of euphemisms are always closely connected with historical events and socio-cultural discourse. Due to the different socio-cultural space and geographical location, the origins of the formation and a sphere of use of euphemisms by different people are also different. The famous linguist Lo Changpei said: «Language and writing are the highest expression of a nation's culture; they help the former culture of a nation to pass from mouth to mouth, and they help the future culture of a nation to move forward. Language is not only an important means of communication between different nations, but also an important carrier of the cultural content of different nations» [6]. Euphemisms inevitably have a trace of the culture of considered nations, their formation

was not without religious culture, social customs and national psyche and so on, so euphemisms have a deeper cultural meaning.

Many linguists have considered euphemisms through different angles of perception: social, religious, linguistic, political, and so on. Euphemisms serve as a kind of linguistic bridge, which is very relevant to human communication in the modern era.

The main criteria for the use of euphemisms are aesthetics and morality. They put a ban on the direct use in speech of the names of the processes of physiology, which are associated with the processes, for example, the excretory function of the body, about the sexual relations of people, about defects which are congenital. Target settings of the use of euphemisms are: the desire not to get into conflict situations related to the communication of people without creating feelings in their interlocutor which cause discomfort [2].

Euphemisms are so deeply embedded in our language that few of us can be proud to be outspoken and rarely a day goes by without using these expressions. In the Russian language scholars distinguish the following main topics and areas in which euphemisms are used:

- Illnesses, names of medical institutions;
- Death and related phenomena;
- The shortcomings and vices of people — deceit, stupidity, drinking, drugs, smoking;
- Physical characteristics of a person;
- Finances: position, actions connected with them, names of money;
- Punishment, vice;
- Curses, curses, nicknames;
- Names of certain body parts and related processes;
- Nudity;
- Physiological excretions;
- Sexual life;
- Politics, war [3].

The goal of the research is to define communication situations where euphemisms are used in Chinese. The field observation was manually conducted by using examples of Chinese euphemisms that are influenced by culture. Methods of research are collecting examples, separate them to the topics and analyze their meanings. Materials are academic papers of linguistic field, Chinese and English works about how culture influenced on language and how translate euphemisms correctly. Euphemisms in Chinese originate in ancient taboos. Taboo is a system of prohibitions common in pre-class society, the violation of which is supposedly punished by supernatural forces.

Methodology

This research presents the analysis of euphemisms from the point of view of areas euphemisms in Chinese language are mainly used. They are classified according to topics related to an everyday life. We reviewed about 200 units of the Chinese language selected from the dictionary of euphemisms.

Results

In this research we have classified the selected units into the following groups:

- politics (instead of «capitalist countries» (资本主义制度国家), «western countries» (西方国家));

- poverty (instead of «poor» (生活贫困) they say «is in dire circumstances» («experiencing material difficulties» (囊中羞涩), instead of «unemployed» (失业) they say «resigned» (下岗), «waiting for a job» (待业), instead of «poor» they say «thin man, like a stem» (干人);
- gifts (e.g., the phrase 送钟 song zhōng — «to give a watch» sounds the same as the syntagma 送终 song zhōng — «to see your father (mother) off to the last journey»;
- crime («to express gratitude» (表示感谢) is used in place of «to bribe» (行贿), «high wall» (高墙), «execution house» (班房) replaces «prison» (监狱), «three hands» (三只手) means «thief»);
- illness or injury (if someone has behaved strangely, they say «water in the head» (脑子进水), etc.

We have analyzed the most numerous group of euphemisms such as «death». The influence of religion on the Han national culture in comparison with the Russian one is less significant, so euphemisms in Chinese are less influenced by religion. Nevertheless, some euphemisms about death have a religious origin, for example 仙逝 «to become a celestial», 化鹤 «to become a crane», 驾鹤西游 «to ride a crane to the west». These euphemisms for death reflect Taoist thought: the followers of Taoism think that humanity is part of nature, eventually man will return.

During the research we found out that the meaning of «die» could vary according to different attributes [6]:

- a cause of death: ordinary death — 老了 («grow old»), 没了 («disappear»), 不在了 («stop being here»), 过世了 («live life»), 归天了 («return to heaven»); die of illness — 没治好 («not cured»), 没救过来 («not saved»). 瘫 or 夭折 — («to die early in life»);
- a name of death for different classes of people (only in ancient Chinese): 嗣 (death of a prince), 卒 (death of a dignitary), 不 祿 (death of an official).

In some cases of natural death, people in the village who believe in «endless reincarnations» say that death in a sense is happiness; it symbolizes the beginning of a new life. Therefore, they often call such a death 白喜 (white happiness), using such an expression as a euphemism can be used to comfort the relatives of the deceased.

Discussion and Conclusion

In everyday communication people tend to avoid expressions that may be misunderstood. The human desire to express their own thoughts and feelings tactfully has led to the emergence of euphemisms, metaphorical expressions and words that help make our speech pleasant. Euphemisms are widespread throughout the world, they are used by different peoples according to the peculiarities of a particular language. As a linguistic phenomenon, the term «euphemism» is used in various humanities: linguistics, psychology,

sociology and other areas. In everyday communication, the function of euphemistic statements is mainly communicative.

The subject of death has always been inconvenient, uncomfortable and accessible for people in China. In the actual communicative process, it has been noted that's the strictest taboo, the more difficult it is for communicants to choose the optimal words or way of responding. Breaking the strictest taboos can be followed by the cessation of a contact. This suggests that the basic function of such taboos is a protective one, and it also exists in the context of modern communication. Euphemisms as one of the varieties of stylistic means allows speakers to vary the speech depending on communicative conditions, if necessary to hide or veil their intentions, thereby avoiding conflicts in communication.

The study and use of euphemisms cannot be one-sided and abstract in isolation from language communication. The study of euphemisms is important for expanding the fields of language learning, for conscious intercultural communication, for preventing errors in language use, and for teaching foreign languages. Knowledge of euphemisms can help us to communicate successfully.

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Эволюция китайской иероглифической письменности

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Исследована периодизация этапов формирования письменности Китая с древнейших времен до нашего времени. Рассмотрены основные этапы развития китайской иероглифической письменности. Особое внимание уделено детальному описанию каждого периода становления иероглифической письменности в Китае. Представлена краткая характеристика каждого этапа формирования китайского письма, и раскрыты основные причины появления каждого из этапов.

Ключевые слова: китайский язык, иероглифы, китайская иероглифическая письменность, китайская письменность

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The Development of Chinese Characters

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The purpose of the study was to analyze the development of Chinese characters. The paper focuses on the features of the Chinese hieroglyphic writing, as well as the main stages of its development. Much attention is given to the description of each stage of the formation of the Chinese script. The main reasons for the emergence of each stage of the development of Chinese writing are explained in detail.

Keywords: Chinese characters, Chinese language, characters, Chinese writing

Chinese characters are one of the oldest forms of writing on the Earth, which has been preserved until today and occupies a prominent place among the most widely spoken languages in the world. The origin and evolution of Chinese characters have been crucial for the development of ancient Chinese culture, as well as for forming cultural values and customs all over the world.

One of the first historical documents to shed light on ancient Chinese orthography are called oracle bone script (Chinese: 甲骨文, pinyin: jiǎgǔwén), written on animal bones or tortoise shells. They were discovered by local farmers in the village of Suoyutun, Anhui Province, and sold as medicinal ingredients from traditional Chinese medicine called ‘dragon bones’ [1].

Today it is estimated that there are more than 150 000 oracle bone writings were found. Because of the combination of characteristics found in this writing from both pictograms and ideograms, some symbols can still be identified by modern people. At present, more than 1700 symbols have been identified [2].

The next stage in the development of Chinese characters is represented by the characters written on the bronze bells and vessels of the Zhou Dynasty (1066–256 BC). This writing is known as Chinese bronze inscriptions (Chinese: 金文, pinyin: jīnwén). During the Bronze Age in China (the Shang and Zhou dynasties) bronze items were cast to be used as sacrificial divination vessels to find out the outcome of such great events as sacrifices, battles, slave trade, etc. as well as the content of the inscriptions, in addition to the cult nature, was associated with the granting of lands and government posts for various kinds of services to the emperor, with the historical events of that time.

In the period of Warring States, also called Contending States, (475–221 B.C.), China experienced a civil war and therefore writing was not uniform. Xu Shen (c. 58 – c. 148 CE) who was a Chinese calligrapher, philologist, politician, and writer of the Eastern Han Dynasty (25–189), in his famous work The Shuowen Jiezi (Chinese: 说文解字) write about this issue that ‘statements and speeches began to sound differently’. After Emperor Qin Shi Huang (Chinese: 秦始皇) unified China, he immediately began unifying writing. A new style of writing emerged that received the name seal script (Chinese: 篆书, pronunciation: zhuànshù). It was used for writing on bamboo slips and paper cuts or stamped on stone. Thanks to its beautiful symmetry and neat lines, calligraphy considers it the most beautiful style of symbols in ancient China. This type of writing is still used today for writing names on printed labels or slips of silk or fabric. There are two types of printable handwriting: large seal script and small seal script.

The large seal script (Chinese: 大篆, pinyin: dàzhuàn) is a general term used to describe all varieties of writing used by the Zhou Dynasty (1118–249 BCE). It was widely used by many feudal states during The Spring and Autumn period (770–476 BCE). This type of paper, with more balanced and symmetrical characters than that on metal, was used for official documents.

The small seal script (Chinese: 小篆, pinyin: xiǎozhūàn) was the official style of characters used in the Qing dynasty, used for all government documents. This type of characters — the result of first extensive simplification and standardization of Chinese writing — was more simple than calligraphy on metal, as well as more structured than calligraphy on paper. Besides, each character had its limited amount of space allocated to it. However, lines forming the character were complex and curved; however, they were less similar to pictures.

A gradual need to write more simply and quickly developed in the third century B.C., when officials began using the clerical script (Chinese: 隶书, pinyin: lì shū), which

consisted of more formal characters than seal script. The clerical script was used only for official business communication and papers.

The final stage of standardization of Chinese writing was the development of a more sophisticated style, called regular script (Chinese: 楷书, pinyin: kǎishū) ,also known as “uniform script” and “real script”, as well as its variations — running hand (Chinese: 行书, pinyin: xingshū), cursive script (Chinese: 草书, pinyin: cǎoshū). These were created during the reign of Cao Wei but became widespread during the period leading up to the Jin dynasty, with various forms being developed for different purposes and levels of literacy. This system of writing is clearly structured, with each character having only one form that is determined by meaning and pronunciation. This prevents confusion over how characters should be read and renders it possible to speak about fully developed Chinese literacy at this time.

A new stage in the development of Chinese writing is associated with the proclamation of the People's Republic of China. In 1949, the Society for the Reform of Chinese Writing was formed; in 1952, a committee was established to study the issue of the reform of Chinese writing, which in 1954 was transformed into the Committee for the Reform of Chinese Writing under the State Council of the PRC. The main task of this committee was to study and systematize various projects for the reform of Chinese writing since the 17th century.

Note that the benefits of simplifying the writing in the spread of literacy among the population of the country are undeniable.

The need for reform arose due to the usage of a large number of words with the same sound and meaning, but different spelling, as well as the significant complexity of writing. So, for instance, 果 and 莓, are two characters that have the same pronunciation guǒ and the meaning of ‘fruit’, but due to the more complex spelling of the second, it was proposed to remove it from usage [3].

Thus, as a result of the reformation, the number of frequently used characters was reduced from 6–7 thousand to 5–6 thousand, which greatly facilitates the study of Chinese language [4].

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Использование англоязычных песен при обучении лексике

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Рассмотрена целесообразность использования текстов песен британских и американских авторов и исполнителей как одного из способов мотивации обучающихся при изучении английского языка. Очевидно, что музыка активизирует мозговую деятельность человека, снижает тревожность и стресс, тем самым создает необходимые условия для успешного овладения языком. Особое внимание уделяется обучению лексике на основе анализа наиболее популярных англоязычных песен. Приводятся типы заданий, способствующих расширению словарного запаса обучающихся.

Ключевые слова: англоязычные песни, обучение английскому языку, лексика, словарный запас

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Using Song Lyrics to Teach and Learn English Vocabulary

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The paper looks at ways of teaching and learning English vocabulary through listening to British and American songs and analyzing their lyrics. It is obvious that music boosts human brain activity, reduces anxiety and stress providing necessary conditions for successful language acquisition and serving as a powerful motivator for English language learners. The authors analyze some of the most popular song lyrics and show how to use them teaching vocabulary in the English classroom.

Keywords: English songs, song lyrics, teaching and learning English, vocabulary

Introduction

Music is currently perceived as an instrument that helps people not only feel better but also learn better. Music surrounds us everywhere; we hear music when we listen to the radio or when we watch television. Music can bring about multiple different feelings. Usually when people listen to songs, they feel energized, excited and optimistic about life. It is scientifically proven that as music enters our brain it activates pleasure centers that release dopamine. They trigger people to feel satisfaction and motivation to do something.

Research has shown that listening to music can reduce anxiety, blood pressure, and pain as well as improve sleep quality, mood, mental alertness, and memory [1]. All these factors are essential for successful language acquisition since they give a boost to the process of teaching and learning English by making it less stressful. Furthermore, using songs as a teaching tool allows students to feel safe since listening to music is part of most people's everyday life. It has an emotional appeal as students are personally engaged in the classroom activities and feel more comfortable speaking and sharing their thoughts and emotions.

Hilda F Israel points out that music is a means of communication. It crosses all barriers – language, culture, belief systems, age, gender and nationality. It is an innate part of a person's being. Used carefully in the learning situation, it can turn the beat of the learning process around [2]. As a matter of fact, according to Stephen Krashen's Affective Filter hypothesis, students with high motivation and a low level of anxiety are better equipped for success in second language acquisition. It explains why some students learn better and faster and some learn worse and more slowly. Those students who have a positive attitude towards learning, that is a weaker affective filter, are more likely to learn better [3]. It proves the fact that teachers are required to create a friendly and positive atmosphere in the classroom for a more effective learning process and songs can be one of the tools to help create such atmosphere as they have this exact effect on people.

Taking into account the benefits of using songs in the classroom, the focus in this paper is on the role of songs in teaching and learning vocabulary in advanced English classroom.

The role of vocabulary in foreign language acquisition is clearly pivotal. Students who learn English as a Foreign Language are required to possess enough knowledge when it comes to grammar, vocabulary and pronunciation. However, some researchers point out the significance of vocabulary over grammar and pronunciation. According to Michael McCarthy, “No matter how well the student learns grammar, no matter how successfully the sounds of L2 are mastered, without words to express a wide range of meanings, communication in an L2 just cannot happen in any meaningful way.” [4]. Consequently, knowing vocabulary is the key to successful communication. Inadequate vocabulary can lead to communication failure, that is to say students are not capable of not only expressing their own thoughts and opinions but also comprehending others’ words. This idea is supported by Wilkins: “Without grammar very little can be conveyed, without vocabulary nothing can be conveyed” [5]. In other words, knowing how to use grammatical structures correctly does not guarantee successful communication, whereas knowing lexical expressions even at the basic level can help achieve a better understanding for both the speaker and the listener.

Materials and methods

The paper is concerned with songs by American and British authors. The determining factor for choosing songs is the belonging of its vocabulary to a certain thematic group. The main idea is to use songs abundant with words of a particular semantic field, which would result in a better vocabulary acquisition. Since this paper deals with teaching advanced students of English, songs should contain advanced vocabulary. To sum up, song lyrics for an advanced classroom should be based on the same topic, preferably the one under study, should not be primitive or contain abusive vocabulary, let alone the requirement that songs should be popular with those who are in their early twenties, that is we looked into the matter from both linguistic and sociological points of view.

Results of song lyrics case studies

This section looks at some examples of using a song as a tool of presenting a new topic. Broadly speaking, the first song chosen is connected with mass media, more specifically it is limited to a theatrical play production and the song could be used as a lead-in to the corresponding class. The song by Kygo — *Stole The Show* feat. Parson James brings out the topic of a relationship that is heading downhill; even though everything was fine in the beginning, it is over now. When the couple started their relationship, it was great but there’s nothing between them anymore. The narrator underlines that it was a great experience back then but now there is nothing romantic left and it’s time to let go of each other:

Our debut was a masterpiece/ But in the end for you and me

Oh, the show, it can't go on/ We used to have it all, but now's our curtain call

So hold for the applause, oh/ And wave out to the crowd, and take our final bow

Oh, it's our time to go, but at least we stole the show

The song uses a show at a theatre as a metaphor for a great relationship ending. Subsequently, in the lyrics of this song there are many words united by the topic of a theatrical performance: *credits, villains, heroes, stage, debut, curtain call, final bow, applause, full house, steal the show, sold out*.

In the second example the song was no less known and popular (344 million watches on YouTube), it was *Shape of My Heart* by Sting, who wanted to tell the story of a «card player, a gambler who gambles not to win but to try to figure out something; to figure out some kind of mystical logic in luck, or chance; some kind of scientific, almost religious law.» [6]. From the point of view of semantics the song dominates the category of words connected with a card game: *deal the cards, spades, clubs, diamonds, hearts, play the jack of diamonds, to lay the queen of spades, king*. Surely, just listening to songs is unlikely to teach students how to speak the target language, it requires a substantial effort on the part of the teacher developing song lyrics-based tasks. Some of the tasks are given below.

The song *Beautiful People Beautiful Problems* by Lana Del Rey (feat. Stevie Nicks) can serve as a great tool for learning idioms that have colours as one of their components. According to the singer herself the song is about rejecting consumerism and the value of artists. She is talking about surrounding yourself with people who put their art and love first not just for money but for the right reasons [7]. Since there are a lot of colours mentioned in the song, it can serve as a lead-in to some idioms connected with colours, e.g. *feel blue, out of blue, blue blood, be in red, take the red eye, white lie, black sheep, be in the dark*.

Regarding tasks that can be used with these songs, staging of a listening lesson should be considered. Scrivener writes that listening can be divided into three stages [8]:

1. Pre-listening stage. It consists of things that students do before the listening in order to help students get the most of what they are going to listen to. It serves as a preparation stage when students are given some substantial pre-listening support. Pre-listening tasks can include a variety of activities, e.g.:

- Explaining words' meaning, giving synonyms or matching the words with their definitions (Fig. 1).

The same task can also be applied to the second song (Fig. 2). This song is abundant with words associated with cards game.

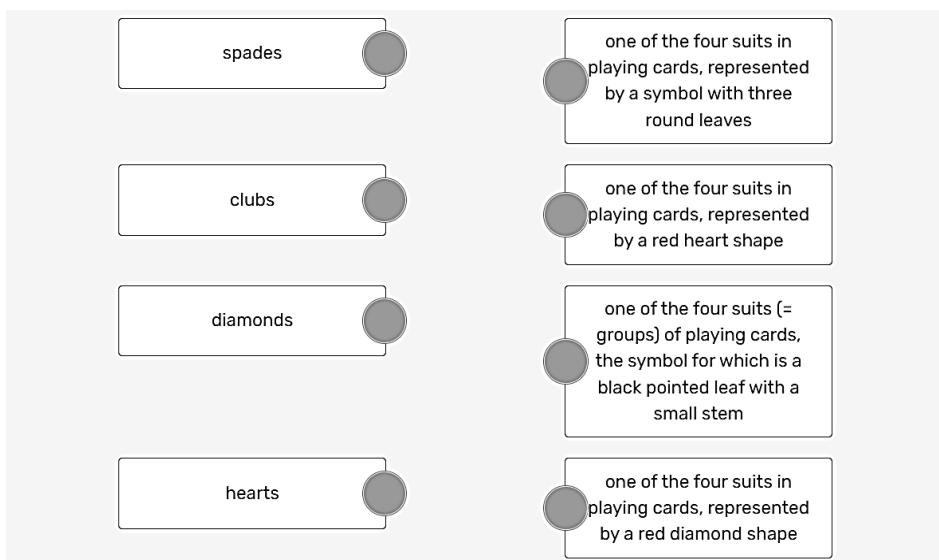


Fig. 1. A word-definition matching task for Kygo's Stole The Show

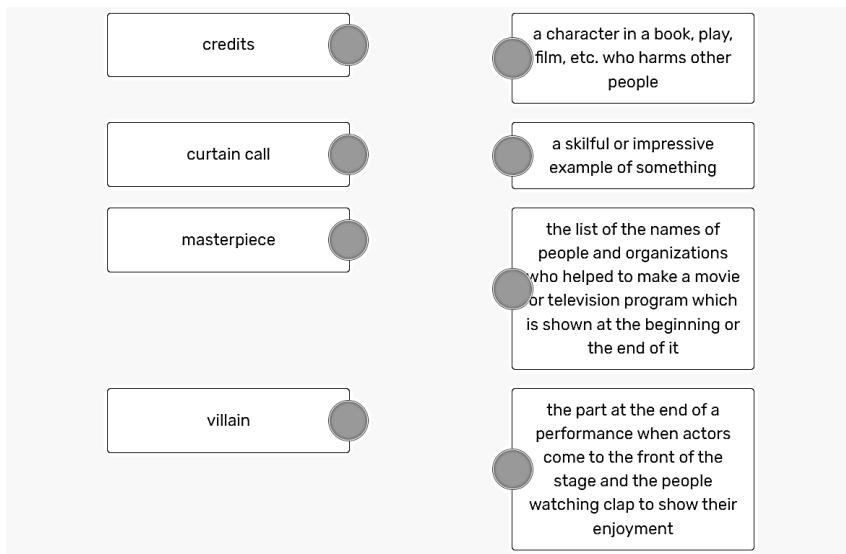


Fig. 2. A word-definition matching task for Sting's Shape of My Heart

As for the song *Beautiful People Beautiful Problems*, students can be asked to guess the meaning of numerous idioms connected with colours (Fig. 3).

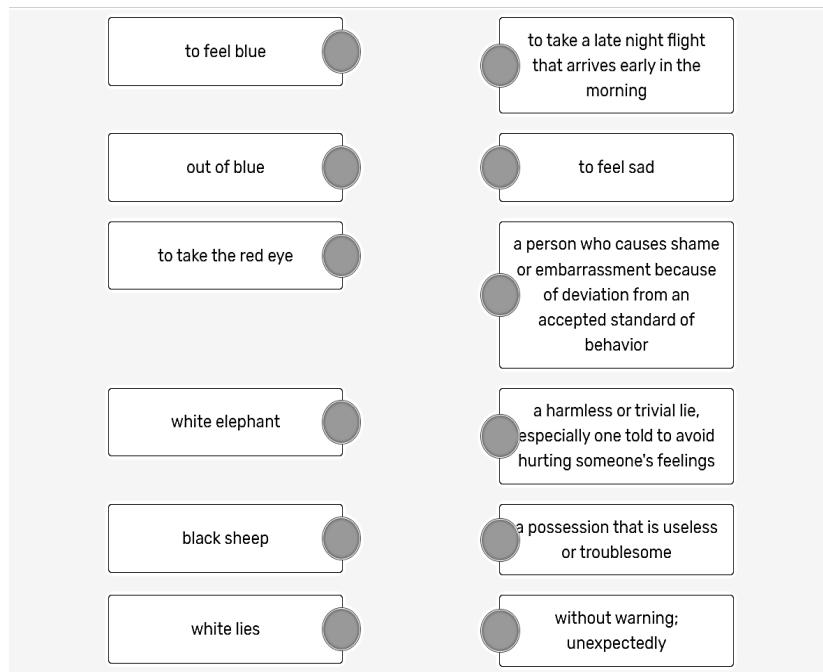


Fig. 3. Beautiful People Beautiful Problems matching task

• Another task that can be suggested for the pre-listening stage is filling in the gaps. Students have to predict and complete the blanks with missing words on their worksheets. This type of task can be used at the next stage, i.e. while listening to a song. Part of the song by Kygo *Stole the Show* demonstrates the feel-in-the-gaps worksheet for this song (Fig. 4).

Darling, darling, you know that we are _____
 This is fading, but the band plays on now
 We're crying, crying, so let the velvet roll down, down
 No heroes, _____, one to blame
 While wilted roses fill the _____
 And the thrill, the thrill is gone
 Our _____ was a masterpiece
 Our lines we read so perfectly
 But the show, it can't _____

Fig. 4. Filling in the gaps in *Stole The Show*

2. The next stage of a listening lesson is the while-listening stage. It consists of activities and tasks to be done while learners listen to a song. If feel-in-the-gaps task was used in the pre-listening stage, students can be asked to check whether the predicted variants are correct. Otherwise, this task can be offered to students during the while-listening stage. Students have to listen carefully and fill in the blanks with the missing words. It might be necessary for students to listen to the song more than once. The part of the song *Shape of My Heart* by Sting was chosen to demonstrate the example of this task during the while-listening stage (Fig. 5).

He may play the jack of _____
 He may lay the _____ of spades
 He may conceal a _____ in his hand
 While the memory of it fades
 I know that the _____ are the swords of a soldier
 I know that the _____ are weapons of war
 I know that _____ mean money for this art
 But that's not the shape of my _____
 That's not the shape
 The shape of my heart

Fig. 5. Filling in the gaps in *Shape of My Heart*

Another task is that of unjumbling, in which students try to work out the original order of the lyric's lines while listening to the song either on their own or in pairs. Afterwards, they compare their guesses and if needed listen to the song one more time:

I know that diamonds mean money for this art

I know that the clubs are weapons of war

I know that the spades are the swords of a soldier

But that's not the shape of my heart

3. The after-listening stage is the last stage of a listening class. It implies taking students beyond listening making them practice their speaking skills. Students can be asked to express their opinion concerning the artist and the song and discuss its message. Difficulties students faced while listening to the song can also be discussed at this point.

Conclusion

Music as a big part of our society has found its place in English classrooms. The reason for that is clear: using songs in the English classroom is useful as they serve not only as a motivator but also as a significant tool for acquiring vocabulary. Songs change the atmosphere in the classroom drastically by making it less stressful and more energizing. Doing tasks based on song lyrics allows students almost subconsciously learn vocabulary as they become interested in what the song is about and start trying to understand the meaning of the lyrics and the song itself. Furthermore, repetitive lyrics and catchy tunes help ensure that vocabulary goes straight to students' long-term memory. Teaching becomes less monotonous with songs as they give students a break from their usual learning routine. Songs provide enjoyable vocabulary and language practice in general. On top of that, songs are an authentic language material and have significant methodological potential since they demonstrate language in real communication situations [9]. That is why songs are a vital tool when it comes to learning how to use certain words and phrases in a native-speaker way.

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Первый этап семантической разметки в научно-технических текстах

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Рассмотрен процесс обозначения семантических ролей в научных текстах по аэрокосмической тематике. Следует обратить внимание на отношения между компонентами предложения с учетом их семантической функции и закономерностей их сочетаемости. Результаты, полученные в результате анализа аутентичных предложений из научной литературы, демонстрируют закономерность постановки семантических ролей, основанную на синтаксических связях между словами.

Ключевые слова: глагол, валентность, семантическая разметка, семантические падежи, семантическая валентность, актанты

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The Initiation of Semantic Role Labelling in Scientific Texts

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The paper discusses the process of semantic role labelling in scientific texts on aerospace. It focuses on the relations between the constituents of the sentence with the regard to their semantic function and patterns of their combinability. The results obtained by the analysis of the authentic sentences from scientific literature demonstrate the regularity of semantic roles depending on the basic syntactical connections between the words.

Keywords: verb, semantic cases, semantic valency, verb arguments, semantic role labeling

Introduction

This article deals with the semantic role labeling in scientific texts. That process is primarily related to the computational linguistics as its prior goal is to simplify the understanding of the natural language for an artificial-intelligence based systems. The idea of semantic role labeling is directly related to the frame semantics which is a linguistic theory originally introduced by an American linguist Charles J. Fillmore [1–6]. The frame semantics presupposes the analysis of the constituents of the sentence due to its extralinguistic features such as their ontological function in the world. Due to these meta-linguistic roles, we may help the system to conclude the relations between the constituents of the sentence making the language procession more conceivable. Thus, semantic role labeling remains a significant task for linguists.

This theory has been thoroughly examined abroad and it resulted in a number of special applications and websites which may label semantic roles automatically in English texts. Among them there is a website “frame.net” which is widely used to obtain information about the semantics of the constituents of the sentence [2]. However, the issue of automatic role labelling still remains slightly investigated for the Russian language and stimulates linguists to continue the research. In this paper we offer an approach to initiate the development of a source in charge of automatic semantic role labeling in aerospace research. This paper discusses more precisely the first step in the procedure of automatic role labelling which is the preparation of hand-annotated examples. It also describes the way of sentence analysis, focusing at the bounds between words in order to determine frequential models of the interdependence between the lexical and syntactic combinatory abilities and combinatory tendencies.

Theoretical frame

1. Semantic Role Labeling (SRL): is the process that assigns labels to words or phrases in a sentence that indicates their semantic role in the sentence, such as that of an agent, goal, or result.

2. Frame Semantics: is a research program in empirical semantics that analyses words' meanings “emphasizing the continuities, rather than the discontinuities, between language and experience”.

3. Semantic cases : Agent: The volitional cause of an event;

Experiencer: The experiencer of an event;

Force: The non-volitional cause of the event;

Theme: The participant most directly affected by an event;

Result: The end product of an event;

Content: The proposition or content of a propositional event;

Instrument: An instrument used in an event;

Beneficiary: The beneficiary of an event;

Source: The origin of the object of a transfer event;

Goal: The destination of an object of a transfer event.

4. Valency: is the number and type of arguments controlled by a predicate.

5. Argument: is an expression that helps complete the meaning of a predicate, the latter referring in this context to a main verb and its auxiliaries.

6. Adjunct: is an optional, or structurally dispensable, part of a sentence, clause, or phrase that, if removed or discarded, will not structurally affect the remainder of the sentence.

Methodology

The data for analysis consists of separate sentences collected from the 18 research papers on aerospace published from 2019 to 2020 years. The sentences have been selected according to the following criteria:

1. It is a complete sentence.
2. It is a declarative or imperative sentence (according to the communicative type).
3. It is an expanded sentence.
4. The sentence has to include a *specific verb*.

The verbs for the examination have been chosen according to the frequency of their use in scientific texts.

When the sentences are selected, they are examined in terms of the bounds within its constituents, these bounds are represented via the connections between the verb and its arguments as a reflection of a verb valency.

When the relations between a verb and its arguments are identified, the arguments are semantically labelled according to their ontological function.

E.g.: This regulation structure **provides** best accuracy characteristics with the least CPU time.

(Данная структура регулирования **обеспечивает** наилучшие точностные характеристики при наименьших затратах процессорного времени.)

The verb “provide” has two valencies, thus, two arguments: “structure”, “characteristics”. The word “structure” performs the function of the subject and its semantic role is “the doer” or “agent”. “Structure” is the object and its semantic roles is “themes”.

It is significant to highlight that in order to perceive the connection between the constituents of the sentence clearly, we should extract only the nuclear word from the multicomponent term, which will be the argument connected with the verb. E.g., in the phrase “high trajectory *accuracy*”, the nuclear word is *accuracy*.

Results

The analysis results are presented in Table. According to the analysis of the bounds between the verb and its arguments we may conclude that in scientific texts the verb “provide” primarily has one argument, it is either agent or theme. The agent, what is rather unconventional, is expressed by an inanimate noun. Arguments with a semantic role of theme are more frequent which can be explained with the impersonality which is embedded in academic writing tradition.

Discussion

This paper is the first step in the development of the algorithm of semantic role labelling of the constituents of the sentences. The outfit of the completed investigation of this issue can be applied in the spheres of automatic processing natural language texts, more precisely it may improve the process of checking the text for anti-plagiarism, designing machine translation systems, voice control systems, question-and-answer systems and others linguistic applications. This encourages us to research further the bounds between words in the natural language and subsequent labeling of their semantic roles.

Among the most significant findings up to this stage is the presence of an inanimate noun as the agent. Typically, agents in semantic role labeling are associated with volitional causes of an event. However, in scientific texts, it seems that certain inanimate entities,

such as structures or systems, take on the role of the agent. This can be attributed to the fact that scientific writing often involves discussing the functionalities or capabilities of objects and mechanisms rather than human or animate agents.

**The correlation of the arguments of the verb “provide” (обеспечивать)
with their semantic roles**

provide	argument 1 English/Russian	SR	argument 2	SR
1	Structure (структура)	agent (inanim.)	characteristics (характеристики)	theme
2	structure (структура)	agent (inanim.)	accuracy (точность)	theme
3	ice (лёд)	agent (inanim.)	system (систему)	theme
4	convergance (сходимость)	theme		
5	parameters (значения)	agent (inanim.)	performances (характеристики)	theme
6	satisfaction (выполнение)	theme		
7	reducing (сведение)	theme		
8	prediction (прогноз)	agent (inanim.)	flexibility (гибкость)	theme
9	accuracy (точность)	theme	load factor (перегрузку)	theme
10	redundancy (сведение к нулю)	theme		

The utilization of frame semantics in the analysis also provides a solid theoretical foundation for understanding the relationship between language and experience. By considering the extralinguistic features and ontological functions of sentence constituents, frame semantics enables a deeper understanding of the underlying meaning and connections within a text.

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Использование англоязычных песен при обучении грамматике

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Рассмотрены способы преподавания английского языка основанные на включении в занятие британских и американских песен. Отдельное внимание уделяется преподаванию грамматики английского языка. Очевидно, что музыка не только влияет на самочувствие, но и повышает активность человеческого мозга. Тексты песен — это единственный в своем роде способ лучше понять британские и американские культурные реалии. Проанализированы некоторые из самых популярных текстов песен и показано, как использовать их на уроках английского языка.

Ключевые слова: преподавание иностранного языка, английская грамматика, использование песен в методических целях, тексты песен, преподавание английского языка, лексика, грамматика, грамматика английского языка

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Using Song Lyrics to Teach and Learn English Grammar

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The paper looks at ways of teaching/learning English through listening to British and American songs, with a special emphasis on teaching English Grammar. It is obvious that music does not only affect our mood but also boosts human brain activity. Moreover, song lyrics is a one-of-a-kind way to get a better insight into British and American realia. The authors analyse some of the most popular song lyrics and show how to use it in the English classroom.

Keywords: song lyrics, teaching and learning English, grammar, lexis, teaching a foreign language, English grammar

Introduction

We apply to songs as an extensive resource of interaction with students with a purpose. Using songs in the classroom definitely affects students in a positive way. As Tim Murphrey states it might happen because music creates a state of relaxed receptivity, or because its rhythms correspond in some way with basic body rhythms, or because its messages touch deep-seated emotional or aesthetic chords, or because its repetitive patterning reinforces learning without loss of motivation – whatever the reason, songs and music ‘stick’ in the head [1].

The issue of the influence of music on a human brain is being investigated by psychologists, teachers and musicians. Since 2006, two professors of University of Central Florida — neuroscientist Kiminobu Sugaya and violinist Ayako Yonetani — have been teaching the popular course “Music and the Brain”. This course explores how music affects brain function and behaviour, by reducing stress, pain and symptoms of depression, as well as improving cognition, motor skills, and spatial-temporal learning [2]. Gilbert Galindo, a composer, elaborates on the idea that by stimulating the mind music has immense worth in all levels of education [3]. Prominent Russian scientist in the sphere of neurolinguistics Tatyana Chernigovskaya in one of the lectures about the influence of music on the human brain emphasized that the process of listening to music adjusts the brain for further cognitive functioning, as it is accompanied with a subtle and refined setting of neurons [4].

Taking into account all the benefits that music can give to the teaching process, the authors of this paper will concentrate on a narrower sphere of English language teaching focusing on the grammatical aspect, and analyze how songs can help further master English grammar.

Object of research and methods

The reasons for using song lyrics in the English classroom are manifold. Listening to English songs, especially those you like, would not only give you a powerful impetus to

carry on and keep up your good humour and cheerfulness but would also be an unprecedented tool of mastering pronunciation as singers you listen to are native speakers and as such form a good role model for learners. Song lyrics would come in handy when it comes to building up (expanding) one's word power [5, 6]. Consider the following examples of multiword expressions in lyrics: *do one's time, lose your grip on smth, rise up to the challenge, stalk one's prey, hang tough, take to the street* (Survivor – *Eye Of The Tiger*, 1982); *take tea, legal alien, walking cane, combat gear* (Sting – *Englishman In New York*, 1987); *leave no stone unturned, against the grain, free ride, make one's mark, swear up and down* (Nickelback – *If Today Was Your Last Day*, 2008). Lyrics are also an inexhaustible source of phrasal verbs: *come over, start up, come on, go out, fill up* (Ed Sheeran – *Shape Of You*, 2017).

The material for research is English songs by American and British singers chosen according to their popularity with students with consideration for music charts. We also relied on the results of the opinion survey among students and teachers of Bauman University. Used in the examples above are some of these songs.

Since the object of research is lyrics grammatical peculiarities, we examine the texts paying attention to recurring grammatical constructions, e.g. passives, continuous aspect, emphasis, conditional sentences, verb patterns, modals of deduction, perfect aspect, participle clauses, inversion, non-finite verb constructions etc. If any of these grammar constructions are found in the lyrics of a song, we consider the song for using in the classroom as a teaching tool and furthermore define the most effective way of its usage with regard to its content.

Listed below are but some examples of grammatical structures from the most popular songs that can be used for the revision of particular grammar structures.

Conditional sentences

Nickelback – *If Today Was Your Last Day* (2008)

- *If today was your last day / And tomorrow was too late
Could you say goodbye to yesterday? / Would you live each moment like your last?*
- *If today was your last day / And tomorrow was too late
Could you say goodbye to yesterday? / Would you live each moment like your last?*

Modals

The Weeknd – *Blinding lights* (2020)

- *You don't even have to do too much / You can turn me on with just a touch...*
- *I can't see clearly when you're gone / I said, ooh, I'm blinded by the lights*

Sia – *Elastic Heart* (2013)

- *And another one bites the dust / Oh, why can I not conquer love?
And I might've thought that we were one / Wanted to fight this war without weapons*

Continuous aspect

Robbie Williams – *Angels* (1997)

- *So when I'm lying in my bed / Thoughts running through my head
And I feel the love is dead / I'm loving angels instead*
- *When I'm feeling weak / And my pain walks down a one way street
I look above / And I know I'll always be blessed with love*

Perfect aspect / Passives

OneRepublic – *Counting Stars* (2013)

- *Lately, I've been, I've been losing sleep / Dreaming about the things that we could be
But baby, I've been, I've been praying hard / Said, «No more counting dollars, we'll be
counting stars»*

- *Oh, take that money, watch it burn / Sink in the river the lessons I've learned*
Robbie Williams – *Feel* (2002)
- *Come on, hold my hand / I wanna contact the living
Not sure I understand / This role I've been given*
Adele – *Rolling in the Deep* (2011)
- *The scars of your love never had met me / Remind me of us (tears are gonna fall)
They keep me thinking rolling in the deep / That we almost had it all (you're gonna wish you)*
- *The scars of your love never had met me / They leave me breathless (tears are gonna fall)/ I can't help feeling (rolling in the deep)*

One of the best songs to illustrate English Grammar structures, that is the use of Present and Past Progressive tenses, is the song *Tom's Diner* written by American songwriter and singer Suzanne Vega in 1982. The main point about the song is that the narrator while looking at people around her in what seems to be a careful way.

- *He is looking out the window at somebody coming in / She is shaking her umbrella*
- *As they are kissing they're hellos / I'm pretending not to see them*
- *And I'm trying not to notice / That she's hitching up her skirt*
- *And while she's straightening her stockings / Her hair is getting wet*

does not actually feel involved, vice versa, she is somehow isolated from anything she is looking at: 'it's not just a song about breakfast, it's a song about being disconnected or feeling alienated and then think this sort of wistful moment back to when you really felt connected to someone when you were in love with them.'

- *Oh this rain it will continue / Through the morning as I'm listening*
- *To the bells of the cathedral / I am thinking of your voice...*
- *And of the midnight picnic / Once upon a time before the rain began.*

The highlighted words are but some examples that illustrate the use of Present Progressive to talk about ongoing actions, or actions that are currently taking place: *is shaking, 'm pretending, are kissing*.

When we combine Past Progressive and Past Simple or Past Perfect, it shows that the past action happened/finished in the middle of the past progressive action, while it was in progress: *Who had died while he was drinking*.

To use this song in English classroom it is recommended to do some pre-listening tasks, e.g. ask your students to do a presentation on Suzanne Vega and the time when the song was written, that is the 80s of the 20th century, and the places described in the song (New York, Tom's Restaurant, the Cathedral). While listening it would be good to offer the students a worksheet to complete the gaps in the lyrics. As the final stage, you might choose to ask your students to share the emotions the song evoked or do an essay on how music affects one's mood.

The song *I was made for loving you baby* by Kiss can be considered as a supporting teaching tool for studying passive voice constructions, which are marked members of opposition of the grammatical category of voice. In this song the passive voice constructions are repeated throughout the lyrics: *I was made for loving you/You were made for loving me*.

The usage of passive constructions reinforces the impression of the inevitability of affection between the protagonist and his beloved implying that their relationship was predetermined by destiny.

The song *Let It Be* by The Beatles could be included in the lesson when studying complex object constructions with dominant causative verbs (*make, let, get, have, help*).

This type of complex object constructions might cause a particular didactic difficulty as students could be puzzled by the usage of bare infinitive. The song can influence the absorption of material in a positive way due to its potential to imprint the pattern of complex object constructions with dominant causative verbs into students' memory unconsciously.

Conclusion

In the songs we have scrutinized particular grammar constructions are constantly repeated throughout the song. This helps students not only to remember it but also consider their application in various other contexts and finally have the construction imprinted in the long-term memory. The examination of the songs proves their value as teaching tools and provokes future research on this topic involving the examination of other song lyrics and their impact on mastering language phenomena.

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Подбор англоязычных песен для занятий по английскому языку

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Цель — подобрать британские и американские песни, рекомендованные для использования при обучении английскому языку продвинутых обучающихся. Данной цели служит опрос и анализ общественного мнения, проведенного среди студентов МГТУ им. Н.Э. Баумана с помощью Google-forms. В список рекомендованных песен не обязательно войдут композиции, занимающие первые места в чартах, так как авторов статьи песни британских и американских авторов и исполнителей интересует не только, и не столько, эмоционально-психологическая составляющая обучения с помощью текстов песен, а особенности английской грамматики, лексики и фонетики.

Ключевые слова: тексты песен, обучение английскому языку, продвинутые обучающиеся, обучение грамматике

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Choosing Songs for Classroom Activities

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The paper looks at the most popular British and American songs of all times from the point of view of their value for an English advanced classroom, i.e. how important the song lyrics is for studying or refreshing students' knowledge of peculiarities of English Grammar, lexis and phonetics. Reported and analysed in the paper are also the results of opinion survey among university students. The above studies aimed at compiling a list of recommended popular songs to be used in the English classroom.

Keywords: song lyrics, teaching English, advanced English classroom, teaching Grammar

Introduction

Throughout the ages, music has been inspiring many people to generate riveting concepts, accomplish various goals and hone their talents. Musical compositions bear a therapeutic effect while influencing positively the human nervous system and enhancing the overall well-being. It is of utmost importance to note that not only is music beneficial for human health but it creates an entertainment and educational effect. In terms of learning a foreign language, songs might be an interesting phenomenon because they contain many useful linguistic collocations, idioms and utterances. Consequently, songs are a great educational tool for learning a foreign language in a productive and enjoyable way.

One of the most fundamental components in the language is mastering vocabulary including correct comprehension of words. Words are the main tool in the language acquisition [1]. Nonetheless, it is not enough to use words correctly. It is necessary to recognize them in both written and spoken language.

The process of acquiring and replenishing your inner language dictionary is very time-consuming. When teaching English, teachers are constantly looking for ways to increase their own and their students' proficiency. There are many methods to motivate people to learn but many of them have a short-term effect. It is pivotal to acknowledge the fact that students' motivation is crucial for language acquisition [2]. Music works as an effective tool that helps to express students' personality in other than traditional methods [3].

Overall, the use of music in the classroom has been scrutinized in the fields of psychology and linguistics. Songs surround us everywhere. Songs constitute an integral part of our lives [4]. Through lyrics we can get to know not only the performer, but also their feelings, thoughts and emotions, understand their way of thinking, customs and values. Music is one of the most effective ways of influencing students' emotions [5].

Murphy describes the phenomenon of a song sticking in one's head. He defines this as the capacity of songs to work at the level of short-term and long-term memory, so that students absorb all the information immediately [6].

Krouse postulates that learners decipher new language structures accidentally and naturally while singing. Afterwards, students are able to transfer this new vocabulary to various conversation situations. Therefore, it can be stated that the utmost purpose of using music in ESL classroom is to transition lyrics from singing to actively using the expressions in significant conversations [7].

Methods of research

Best songs of all times. We have scrutinized various sources of information with ratings of the most celebrated songs and compiled our own list (Table 1). The data was collected and rigorously analysed.

The ranking was compiled based on various lists of the greatest songs of all time published by illustrious music magazines, such as *Billboard*, *Rolling Stone*, *LedgerNote*. Additionally, we researched *Happy*, an Australian youth culture publisher, different music-related websites and YouTube. Moreover, we decided to scrutinize music videos on YouTube and deduce the most viewable ones (remarkably, all the songs listed in the table have over 100 million views) [8–11]. Overall, each playlist was meticulously examined. We then compared all the lists and singled out the recurring songs [12–15].

Table 1
The most widespread and viral songs

American songs	British songs	Canadian songs	Australian songs	Other songs
Metallica – Nothing Else Matters	Ed Sheeran – Shape of you	Céline Dion – My Heart Will Go On	AC/DC – Back In Black	Scorpions – Wind Of Change (German)
Survivor – Eye Of The Tiger	The Beatles – Let it be	Nickelback – If Today Was Your Last Day	Sia – Unstoppable	Avicii – Wake Me Up (Swedish)
Kiss – I Was Made For Lovin' You	Sting – Englishman In New York	The Weeknd – Blinding lights	Sia – Elastic Heart	–

End of Table 1

American songs	British songs	Canadian songs	Australian songs	Other songs
Taylor Swift – I Bet You Think About Me	Robbie Williams – Angels	Shawn Mendes – Treat You Better	Savage garden – To the moon & back	–
Michael Jackson – They Don't Care About Us	Robbie Williams – Feel	Justin Bieber – Love yourself	Savage garden – Truly madly deeply	–
Michael Jackson – Black Or White	Adele – Rolling in the Deep	Bryan Adams – Here I Am	–	–
Eminem – Not Afraid	Adele – Someone Like You	Bryan Adams – Please Forgive Me	–	–
OneRepublic – Counting Stars	Adele – Hello	–	–	–
Taylor Swift – Blank Space	James Blunt – You're Beautiful	–	–	–
Taylor Swift – All Too Well	James Blunt – Goodbye My Lover	–	–	–
–	Coldplay – Viva La Vida	–	–	–
–	Bee Gees – Stayin' alive (British-Australian)	–	–	–
–	The Rolling Stones – Anybody Seen My Baby	–	–	–
–	Sam Smith – I'm Not The Only One	–	–	–
–	Elton John – Can You Feel the Love Tonight	–	–	–

Questionnaire. For the purpose of this research we carried out a survey among University students and teachers with the help of Google-forms, which included the questions below.

You are kindly asked to take part in the following anonymous opinion survey aimed at finding out your music-related preferences in order to compile a list of British and American songs, whose lyrics will be recommended to an English teacher for use in the advanced English classroom.

1. I am 16–20 years old/ 21–25/ 26–35/ 36–50/ over 60
2. I am an engineering student / a humanities student/ a teacher / other / specify _____
3. I am male/ female
4. Mark your preferences by ranking the following British performers using 5 for the most preferred one: *Ed Sheeran/ The Beatles/ Sting/ Robbie Williams/ Adele/ James Blunt/ Coldplay/ The Rolling Stones/ Sam Smith/ Elton John*

5. Mark your preferences by ranking the following American performers using 5 for the most preferred one: *Metallica/ Survivor/ Kiss/ Michael Jackson/ Eminem/ OneRepublic/ Taylor Swift*

6. Mark your preferences by ranking the following Canadian performers using 5 for the most preferred one: *Céline Dion/ Nickelback/ The Weeknd/ Shawn Mendes/ Justin Bieber/ Bryan Adams*

7. Mark the British songs you like the most

8. Mark the American and Canadian songs you like the most

9. Complete the blank spaces with the titles of your favourite songs in order of preference

10. I think listening to songs and studying their lyrics in the classroom is a waste of time/ marginally useful/ very useful

11. Use the blank space provided to specify your opinion

Results and discussion

In total, 155 people participated in the survey. Having analyzed the responses, we came to the following conclusions. The diagram below shows the age of the respondents (Fig. 1). It is apparent that the majority of those who voted are young adults between the age of 16 and 20. They account for 71.4 %.

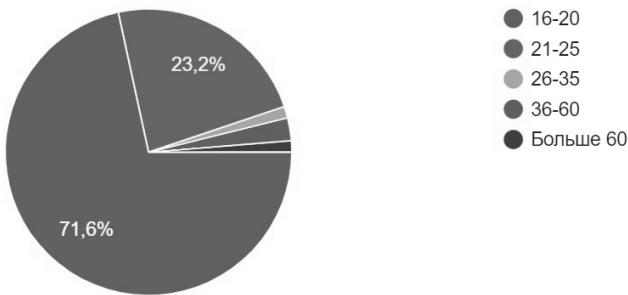


Fig. 1. Respondents' age

Overall, half of the students major in humanities while the rest of the participants in the survey major in engineering. Both engineering and humanities students expressed strong interest in the subject of the survey. It is worth noting that 8 responses were submitted by university teachers.

Collectively, the results reveal that the survey participants enjoy listening to both contemporary artists and musicians of the past. For instance, the respondents were particularly fond of Ed Sheeran, Adele, Eminem, The Weeknd, Coldplay, Sam Smith, and Taylor Swift. However, they also paid homage to The Beatles, The Rolling Stones, Metallica, Elton John and Kiss. The participants' most favourite British songs turned out to be *Shape of you* by Ed Sheeran, *Rolling in the Deep* by Adele, *Let it be* by The Beatles. *I Was Made For Lovin' You* by Kiss, *Not Afraid* by Eminem, *Counting Stars* by OneRepublic and *Nothing Else Matters* by Metallica turned out to be the respondents' favourite American songs. The participants' most favourite Canadian song happened to be *Blinding lights* by The Weeknd (110 votes out of 155).

One of the most crucial aspects of our research was the understanding of the value of music in the English classroom (Fig. 2). As shown in the diagram below, 67.3 % of respondents describe listening to songs and studying their lyrics in the classroom as very useful. The option of “marginally useful” account for 28.8 %, while as few as 3.9 % of the participants chose to label studying song lyrics as “a waste of time”.

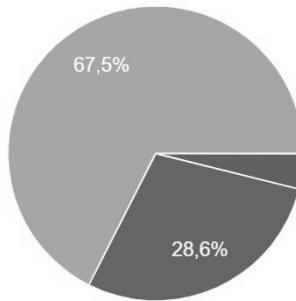


Fig. 2. Opinions about music value

Additionally, everyone specified his or her opinion about the music issue. Summing up, it can be ascertained that listening to songs and looking into lyrics' grammar and lexis peculiarities is extremely rewarding and refreshing for both the teacher and his/her students for many reasons, most importantly because it takes you from the routine of traditional approaches. However, they should be picked adequately to the students' level and range of interests. It is a great idea to analyze lyrics but it is a fun activity to do only if you genuinely like the song.

Thus, using songs in the English classroom is very helpful as it motivates students to learn something new. When you have the opportunity to be close to your favourite singer, to learn a living language, it is always fascinating and engaging.

Table 2 sums up the respondents' most favourite songs highlighting their essential idiosyncrasies that might be helpful to an English teacher.

Table 2
The songs recommended

The song	How can it be useful in a classroom
<i>Shape of you</i> by Ed Sheeran	Ed Sheeran is a marvelous example of a versatile author. He has different nice songs where you can find great collocations, interesting adjectives, idioms, phrasal verbs, cases of personification, linking phrases. Additionally, with the help of Ed Sheeran's songs students can improve their British accent
<i>Rolling in the Deep</i> by Adele	The song is full of great metaphors, epithets, phrasal verbs, idioms. Moreover, Adele is from Great Britain. Hence, an excellent London accent can be traced in the song and can help students with their pronunciation
<i>Let it be</i> by The Beatles	It is an extremely illustrious song, which is truly immortal. It can boost students' mood. There are many fixed expressions that are very popular nowadays. Allusions and metaphors add more charm to the song
<i>I Was Made For Lovin'</i> <i>You</i> by Kiss	The song is very vigorous and energetic. There are lots of abbreviated forms, idioms, collocations and phrasal verbs. Passive constructions are demonstrated very well in the song

End of Table 2

The song	How it can be useful in a classroom
<i>Not Afraid</i> by Eminem	It is a very emotional and motivating song abundant in interesting collocations, contractions, slang terms, allusions, personification and repetitions. This song can be mentally difficult, however, it makes you stronger and motivates you to stop being afraid
<i>Counting Stars</i> by OneRepublic	The lyrics are very well enunciated. We come across very deep meaning of life in the song; there are very useful phrasal verbs, collocations, metaphors, idioms, allusions, present perfect progressive constructions
<i>Nothing Else Matters</i> by Metallica	This song can be helpful when learning grammar constructions and lexis: slang terms, fixed expressions and phrasal verbs. It is also useful in terms of stylistics for studying metaphors, allusion and repetition
<i>Blinding lights</i> by The Weeknd	This song featuring slang terms, negative imperatives, abbreviated forms, phrasal verbs, metaphors, allusions can be useful both from the point of view of vocabulary/ grammar and style
<i>Black Or White</i> by Michael Jackson	Firstly, the focus in the song is on the issue of tolerance. The message of the song is quite clear: it does not matter what your skin colour is. Secondly, this song can be fruitful not only in terms of discussing paramount issues, but also in terms of grammar and lexis (wide range of vocabulary, slang terms, abbreviated forms)

We believe that this list of the chosen songs might be very useful as an additional tool to teach the English language in a creative and innovative way.

Conclusion

The results obtained show how pivotal the usage of music is for students. They enjoy listening to music as a way to relax and to share their tastes and emotions. Students catch a breath of fresh air during such activities, which can be quite time-consuming though energising. In the formal academic environment informal teaching methods, such as using music as a tool to enhance language skills, should be given more attention to as most students are in desperate need of refreshing and inspiring activities in the curriculum. To conclude, we should say that the usage of songs might be one of the most riveting tools for building and replenishing students' vocabulary and increasing their motivation. Furthermore, songs contribute to a positive emotional atmosphere in the classroom.

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Вербализация цветокомпонента «красный» в деловом английском языке

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Рассмотрены экономические терминологические единицы с компонентом красного цвета. Цель исследования — расширить существующую лексическую базу данных терминов с помощью языковых ресурсов деловых СМИ. Материалом исследования послужили термины, содержащие цветокомпонент *red*, из словаря *Longman Business English Dictionary*. Отобранные терминологические единицы проанализированы в их контекстуальном окружении в текстах британских изданий: *The Economist* и *The Financial Times*, представленных на соответствующих интернет-сайтах. Выявлены метафорические значения данных терминов, их коннотации и коллокаты.

Ключевые слова: цветовая метафора, экономическая терминология, деловой английский, цветокомпонент, деловые издания, *ESP*, экономический дискурс

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Verbalization of Color Component “Red” in Business English

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In this paper we discuss economic terminological units with red color component. The aim of the research is to expand the current lexical database of these terms with the help of business media language resources. The research material is the terms containing the red color component from the Longman Business English Dictionary. The selected terminological units are analyzed in their contextual environment in the texts of British publications: The Economist and The Financial Times, presented on the respective websites. The research reveals the metaphorical meanings of these terms, their connotations and collocates.

Keywords: color component, economic terminology, Business English, business publications, color metaphor, ESP, economic discourse

Introduction

Business English terminology consists of a decent amount of terms which have color component. Even though English dictionaries of economics continue to improve day by day, the information they provide on this group of lexical units is not always sufficient for non-native speakers due to the fact that the color component often has a symbolic meaning or represents some type of cultural or historical aspect. To improve the representation of these lexical units through tools of terminography, it is first necessary to expand the lexical database of color component terminological units. Business publications can serve as one of the sources for researching new lexical information on these terms, since the language of the media is often full of figures of speech, especially color metaphors. At the same time business press language can be considered relatively «natural» as many magazines and newspapers of this genre are not only for economic and financial experts, but also for ordinary readers. Therefore, the subject of the research is new lexical-semantic data on terminological units with color components obtained with the help of business publications.

Literature review

A color in the language has been studied for a long time by linguists. The notable advancement in the theory of colors is accomplished by B. Berlin and P. Kay's «Basic Color Terms: Their Universality and Evolution» where they highlight 11 basic color terms and describe the sequence of their appearance in the languages [1]. Subsequently, many authors further classified colors, for instance, A. Wierzbicka in «The meaning of color terms: semantics, culture, and cognition» analyzes the concepts of colors and links them to certain «universal elements of human experience», e. g. day and night, sun, fire, vegetation, sky and earth [2]. Considering that most terms with color component are metaphors, it is important to mention G. Lakoff and M. Johnson's book «Metaphors We Live By» that started Conceptual metaphor theory and influenced research in the semantics and the phraseology [3]. Recently, a decent amount of research has been done regarding phraseological units with color component. In particular, E.V. Shevchenko in her work «Cognitive Aspects of Phraseological Units Containing the “Color” Component in Modern English» deduces the cognitive process behind the formation of such units. Her synopsis of

a thesis presents the symbolism of each color, as well as color cognitive models, such as conceptual metaphors and metonymies [4]. N. A. Zavyalova's scholarly book «Phraseological units with a color component as an element of the discourse of everyday life in Japan, Great Britain and Russia» deals with problems of general theory of color phraseology and examines Japanese, English and Russian lingvo-color image of the world drawing the conclusion of their similarity and the tendency to color unification based on the conducted comparative analysis [5]. The E.V. Kerber and Yu.E. Kosterina's paper «Colour metaphor in the English economic terminology » emphasizes productivity of such type of semantic term-formation and discusses specifically the color symbolism and connotations of color term components in the modern English economic terminology [6].

The Research Objective

The problem of the research is to analyze new lexical-semantic information on economic terms with “red” color component provided by a business media language. Obtained data will expand the current database of a quite large term group.

Methodology

To conduct the research, 7 terms with «red» component are chosen from Longman Business English Dictionary. Subsequently, texts from articles presented on online websites of British business publications, e. g. The Financial Times (FT) and The Economist, containing mentioned above lexical units are selected and analyzed with the purpose to define collocations, connotations and possible derivations. The research is conducted with means of lexico-semantic, component and comparative analysis.

Results

Analyzing The Economist and the Financial Times's articles, we can see that in the minds of native speakers «red ink» more and more corresponds with MONEY IS A LIQUID metaphor [7], the main key feature is that «red ink» is specifically about the loss of money: «flood/oceans/tide/river/flow/sea/spew of red ink», «red ink rising», «left it awash with red ink», «red ink splurge», «sinking in a sea of red ink», etc. We can also see that the vivid imagery of the term influences its contextual environment. «Be in the red» or just «in the red» is a container metaphor in which the concepts of financial debt and money loss are represented as capable of holding something else: «left funds in the red», «put employees in the red», «put ... deeper in the red», «remain in the red» and so on.

The «red tape», according to Longman Business English Dictionary, is official rules that seem complicated and unnecessary and prevent things from being done quickly and easily, and the idiom has its origins in the practice of binding legal documents with red ribbon or tape [8]. Before, the process of cutting through red tape, was a way to get to the first priority documents, when now the verbs «cut» and «cut through» preceding the idiom mean to fight the excessive bureaucracy [9]. We can also observe in the texts the usage of hyperbole when it comes to the synonyms of the verb «cut» such as «slash the Brexit red tape» or «axe EU red tape». The notion that the image of a referent of the expression is still present in the natives' consciousness is supported by headlines like «Red tape and scissors», «Unwinding red tape», «The parting of the red tape», «Stuck to the ground by red tape».

In the Longman dictionary «red chip» signifies «a share in a Chinese company that is listed on the Hong Kong stockmarket», while in the chosen business publications «red chips» are mostly «companies that are registered in Hong Kong but have mainland parents» [8]. It should be noted that the red component here has a relatively neutral connotation, as it represents Communist China. Since the color component in this idiom symbolizes something on its own, journalists can use phrases like «Yet even if red chips falter, Hong Kong's business scene will continue to redder» or «There seems to be a simple rule at work in Hong Kong's stockmarket these days: buyred».

In both publications we are not able to find any articles mentioning «red goods» which may mean the following: native speakers tend to use this term only in very rare specific contexts, or the term is not popular altogether.

British press features a lot of articles dedicated to the «redlining» (the practise of refusing to give mortgage loans or insure properties in certain areas because of the race of the people living here) as it still an occurring practice in the USA and the consequences of its past implementation are still present. The choice of journalists' words such as «crack down on redlining», «bulwark against redlining», «attack “redlining”» can be explained by the usage of a common rhetorical trope of the war metaphor. It is worth mentioning that suggested by Longman Business English Dictionary derivative of the «redlining» — «to redline» is not present in articles texts as «red line» or «redline» is much more prevalent in economic and political discourse as «a boundary or limit which should not be crossed» meaning [8].

Discussion

The main data that we obtained concerns the contextual environment of the color component terms, their collocates, connotations and visual imageries they evoke. However, we have not discovered their possible derivations in the texts. The reason for that seems to be the small number of publications as the source material. To conduct more thorough and fruitful study, we should increase the number of our sources several times. The other limitation that we faced is the one of the search engine on the website of The Economist. While the FT search engine enables users to search for an exact match by putting a phrase in double quotes, or combine searches with operators (AND, OR, NOT), or select the time period for desirable articles, The Economist's options are only to sort the articles by relevance or date.

Another conclusion to be drawn is that we cannot depend on business publications solely as the sources of lexical database of these color terms since there is a clear emphasis on imagery and figurative language in media resources, which is not always present or needed in standard communicative situations in the economic discourse. Nevertheless, the media language is very useful in conveying the perception of color and its symbolic nature in economic sphere.

Conclusion

The results of this work can be used when compiling electronic or traditional dictionaries and other lexicographic tools, as well as in ESP classes with students of economics.

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