Шановні друзі!

Цей номер збірника виходить у знаменну дату – 50-річчя з дня створення кафедри технічної кібернетики КПІ (зараз “КПІ ім. Ігоря Сікорського”). За десятиліття, що минули, кафедра виросла у потужний науковий центр, ставши одним із лідерів по підготовці спеціалістів спочатку у галузі управління, а потім у галузі робототехніки. Крок за кроком зусиллями педагогів, науковців кафедра нарощувала свій науково-освітній потенціал. Створена у 1969 вона вже у продовж 50 років гідно тримає марку однієї з найкращих кафедр університету. Міцна науково-технічна база, високий науковий потенціал, кваліфікований склад викладачів – завжди вирізняли її з-поміж інших кафедр університету.

Сьогодні тисячі висококваліфікованих спеціалістів, які у різний час вийшли зі стін кафедри, успішно працюють у всіх сферах народного господарства, впроваджуючи в життя набуті знання, генеруючи сучасні ідеї, і своєю громадянськістю, моральністю, культурою й сумлінням підтверджуючи високоякісну марку своєї кафедри не тільки на теренах України, а й далеко за її межами. Сукупний внесок усіх, чия доля пов’язана з кафедрою у її становленні й розвитку, важко переоцінити.

Показово, що у складні періоди свого існування колектив кафедри зумів зберегти та примножити свої багаторічні традиції, зміцнити матеріально-технічну базу, не розгубити кадровий потенціал. Усе це тільки вигартувало і зміцнило авторитет кафедри і її загальне визнання.

Dear friends!

This issue of the collection goes out on a significant date - the 50th anniversary of the creation of the Department of Technical Cybernetics of the KPI (now Igor Sikorsky Kyiv Polytechnic Institute). Over the past decade, the department has grown into a powerful research center, becoming one of the leaders in training specialists first in the field of management, and then in the field of robotics. Gradually, the efforts of teachers, scientists, and the department increased its scientific and educational potential. Established in 1969, it has been holding the mark of one of the best departments of the university in the course of 50 years. Strong scientific and technical base, high scientific potential, qualified staff of the teachers – always distinguished it from among other departments of the university.

Today, thousands of highly qualified specialists who at different times left the walls of the department successfully work in all spheres such as the national economy. They are introducing the acquired knowledge into life, are generating modern ideas, and by its citizenship, morality, culture and conscience, are confirming the high-quality brand of its department not only on the ground of Ukraine, but also far beyond its borders. The combined contribution of all whose fate is connected with the department in its formation and development is difficult to overestimate.

It is significant that during the difficult periods of its existence the staff of the department managed to maintain and to multiply its long-standing

Є всі підстави сподіватися, що колектив кафедри і надалі йтиме шляхом креативного розвитку, наполегливо впроваджуючи сучасні наукові здобутки, інноваційні технології та інтелектуальні інформаційно-управляючи системи, і при цьому готуватиме громадян нової формації.

Редколегія нашого збірника, який є науковим виданням кафедри технічної кібернетики, вітає колектив кафедри з цією знаменною датою! Бажаємо кафедрі технічної кібернетики ще багато нових досягнень і перспективне майбутнє, а всім, чиє життя так чи інакше переплелося з кафедрою, добра, любові та достатку.

З повагою, головний редактор,
доктор технічних наук, професор
О. А. Стенін

traditions, to strengthen the material and technical base, not to lose the personnel potential. All this just footed and strengthened the authority of the department and its general recognition.

There is every reason to hope that the staff of the department will continue to pursue creative development by persistently introducing modern scientific achievements, innovative technologies and intelligent information management systems, while preparing citizens for a new formation.

The editorial board of our collection, which is a scientific publication of the Department of Technical Cybernetics, congratulates the staff of the department with this significant date! We wish the Department of Technical Cybernetics a lot of new achievements and a promising future, and to all those whose lives are somehow intertwined with the department, goodness, love and prosperity.

Sincerely,
Chief Editor
Doctor of Technical Sciences, Professor
O. A. Stenin

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J.M. Boiko, I.S. Pyatin, O.I. Eromenko, I.R.Parkhomey

INVESTIGATION OF SIGNALS DISTORTION DURING INTERPOLATION IN SDR TRANSMITTERS WITH QPSK MODULATION

Abstract: Software-defined radio (SDR) allows using software to set or modify working radio frequency parameters: communication standard, frequency range, modulation type, output power, etc. An interpolator is an integral part of the transmitter, which increases the sampling frequency of the modulated signal. Interpolators are built on the basis of integrated cascaded integral-comb (CIC) non-multiplier filters. CIC interpolation filters have uneven amplitude-frequency characteristic (AFC), so the CIC compensator filter is turned on for its alignment. The eye-diagrams of signals with different interpolation coefficients are investigated in the paper. The quality of the signal in the transmitter can be evaluated by the eye-diagram. Interpolation is accompanied by the effect of amplifying the signal, reducing the time of increase in pulse, reducing the signal quality factor. The jitter in the transmitter decreases when the interpolation factor is a multiple of the sampling rate of the information sequence of symbols. If the signal quality factor is $Q>7$, the bit error rate has a $BER<10^{-9}$ value for practice.

Keywords: interpolation, modulation, filter, signal processing, jitter.

Formulation of the problem

SDR is the best technology for modern telecommunication applications. The SDR is suitable for replacement the typical analog equipment such as digital generators, mixers, modulators and demodulators, which allow to be configured and managed with software. This allows communication systems to become more flexible and dynamic in response to changes in the communication channel. In the modern digital communication system the sampling rate plays an important role. High-speed signal processing can be implemented by usage of digital converters with increasing or decreasing sampling rate [1-3].

SDR is a device where signal modulation parameters are specified in software using programmable logic or digital signal processors of general purpose. The signals are digitally generated, then digital signals transform to analog using a bandwidth DAC, and then increasing the frequency from the intermediate to the radio frequency is held. The receiver, similarly, uses a bandwidth analog-to-digital converter (ADC) which captures all the channels of the software radiocommunication node. The receiver selects, converts with lowering the frequency and demodulates the channel signal using the software on the general purpose processor.

The article is devoted to the study of filters used for increasing the sampling rate in the transmitter. The distortion of signals occurring during interpolation using of eye-diagrams is analyzed. The estimate of the jitter and the standard signals deviation is given.

Methods of mathematical modeling, statistical analysis, eye-diagrams are used in this work.

Analysis of recent research and publications

The structural scheme of the transmitter of the digital communication system is presented in Fig.1.

Fig. 1. The transmitter’s block diagram of the digital communication system: DIS – is a digital information source; CCD – channel coding device; M – modulator; I – interpolator; PS – pulse shaper; FC – frequency converter; PA – power amplifier; A – antenna

The channel coder performs interrupt-encoding. Modulator performs the low frequency modulation consisting of the common-mode and quadrature signal components formation. Then an interpolation operation is held so, the sampling rate increases. The pulse generator limits the spectrum of the signal and minimizes inter-symbol interference [4-6].

Quadrature phase manipulation or QPSK is a common method of modulation in satellite communications systems [4].

QPSK has a doubling rate compared to BPSK. In comparison with quadrature amplitude modulation of higher order (QAM), QPSK has a lower data rate, less error rate and a non-complex design of the receiver.

The bit stream of data is multiplexed into *I* and *Q* channels, bits are transmitted to the non-return code to zero. Then the signal is interpolated at *N* times. To increase the sampling frequency, *N*-1 zeros are inserted between each count. The reason for the increase in the sampling rate is about to avoid the problems of overlaying the spectra. The signal then is filtered by any filter that satisfies due to the Nyquist theorem to eliminate intersymbol interference. A filter of square-root-raised-cosine filter (SRRC) is often used.

The SRRC filter is half of the shape of the elevated cosine filter. At the receiver there is a corresponding SRRC filter which together with SRRC transmitter filter generates the same pulse shape as the elevated cosine filter [5-7].

Block diagram of a transmitter that generates in-phase and quadrature components of the modulated signal is shown in Fig. 2 [1, 8].

An important part of the digital interface used for radio frequency communication systems is the frequency converter (FC). The FC main function is to convert one or more data channels from the main band format into a radio signal consisting of modulated carriers belonging to a set of one or more mentioned radio frequencies. This is achieved in two stages: increasing the sampling rate by interpolation, providing spectrum generation and suppressing interpolation images by filtration and shifting the spectrum of the signal to the desired carrier frequencies using a multiplier and a heterodyne [9, 10,11].

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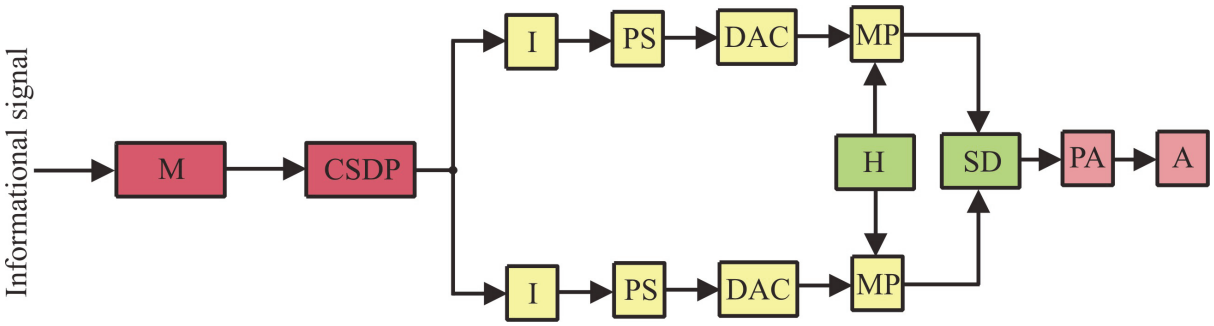

Fig. 2. The block diagram of the transmitter in a quadrature circuit:
M – modulator; CSDP – converter of serial data in parallel; I – interpolator;
PS – pulse shaper; DAC – digital-to-analog converter; MP – multiplier;
H – heterodyne; SD – summing device; PA – power amplifier; A – antenna

CIC interpolation filters

The interpolation unit CIC performs an increase in the sampling rate (interpolation) for the input signal using an integer coefficient. Cascaded filters of (CIC) integrator-comb are a class of linear FIR-filters that consist of a comb part and an integrator [6].

The digital filter with an ultimate impulse response is described by the expression:

$$y(n)=\sum_{i=0}^{N} b_i x(n-i), \tag{1}$$

where $y(n)$ - is the signal at the input of the filter; $x(n)$ - is the signal at the output of the filter; b_i - are the coefficients of the filter; N - is the order of the filter.

To synthesize the FIR-filter it is necessary to determine the coefficients b_i. The block diagram of the third-order interpolator CIC filter is shown in Fig. 3.

Fig. 3. Structural diagram of the CIC interpolator: CF – is a comb filter;
↑R- is the interpolator with interpolation coefficient R; I - integrator

Comb filter has a transmission coefficient:

$$H_C(z)=1-z^{-M}. \tag{2}$$

The integrator has a transfer function:

$$H_I(z)=\frac{1}{1-z^{-1}}. \tag{3}$$

The transmitter function of the CIC interpolator has the form:

$$H(\mathrm{z})=H_I^N(z)H_C^N(z)=\frac{\left(1-z^{-RM}\right)^N}{\left(1-z^{-1}\right)^N}=\left[\sum_{k=0}^{RM-1} z^{-k}\right]^N, \tag{4}$$

where – $H_I(z)$ is a transfer function of the CIC filter integrator;

$H_C(z)$ - is a transfer function of the comb filter;
N - is the number of sections in the comb or in CIC filter integrator;
R - is a coefficient of interpolation; M - is a differential delay.

Simulink-model of interpolation of harmonic signal with frequency of 1 Hz and sampling rate of 6 Hz is shown in Fig. 4. The CIC interpolation filter has an interpolation factor R1=2. The CIC compensation interpolator filter has an interpolation coefficient R2=2.

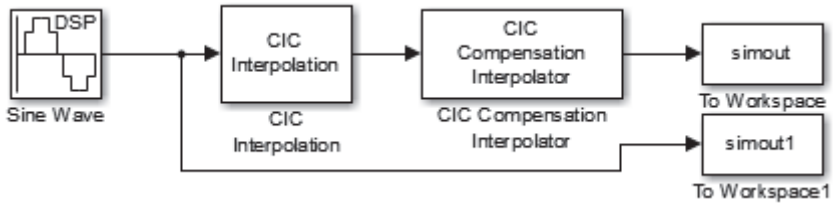

Fig. 4. Simulink- model of interpolation of harmonic signal

The input signal has an oscillogram is shown in fig.5

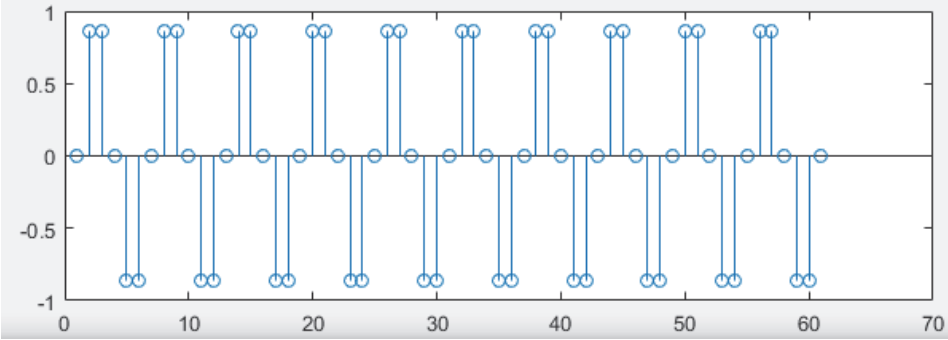

Fig. 5. Oscillogram of input signal readings

During the simulation 10 sec. have 61 countdown. Signal in output of the interpolators filters is shown in fig.6

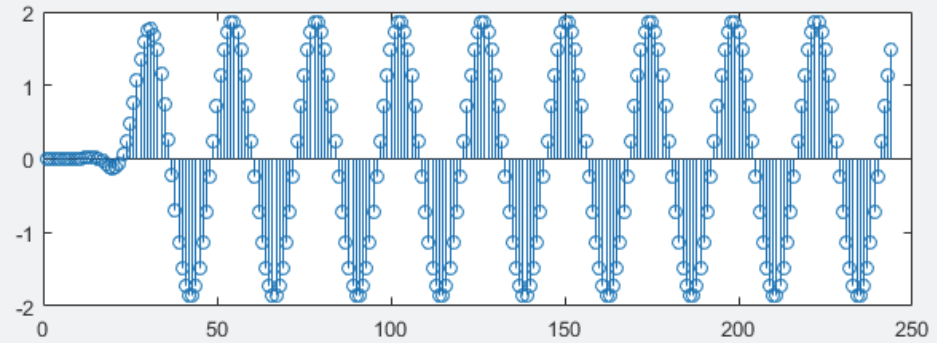

Fig. 6. Oscillogram of output signal readings

During the simulation 10 sec. have 244 counts and the signal amplitude is doubled. Gain factor is $K = (R \cdot M)^N = 2$.

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AFC of CIC compensation interpolator filter is shown in fig.7 [10].

The CIC compensation interpolator block uses the multiphase FIR interpolator as a compensator filter. CIC compensatory interpolators are multi-core FIR filters that can be enabled sequentially with CIC interpolator filters to reduce the disadvantages of CIC filters.

- CIC filters-interpolators are used in areas that require high interpolation factors. These filters are popular in ASIC and FPGA because they do not have multipliers. CIC filters have two disadvantages:

$$H_{CI}(\omega) = abs\left(\frac{\sin\left(M\frac{\omega}{2}\right)}{\sin\left(\frac{\omega}{2}\right)}\right)^{n} \tag{5}$$

where: n - is the number of filter sections; M - is a differential delay; ω - is the normalized angular frequency.

- CIC filters have a wide transition area.

Compensatory interpolation filters have a reverse sinusoid bandwidth for correction of the CIC fall and a narrow transition width.

CIC filters have an amplitude characteristic that causes a recession in the area of radio frequency.

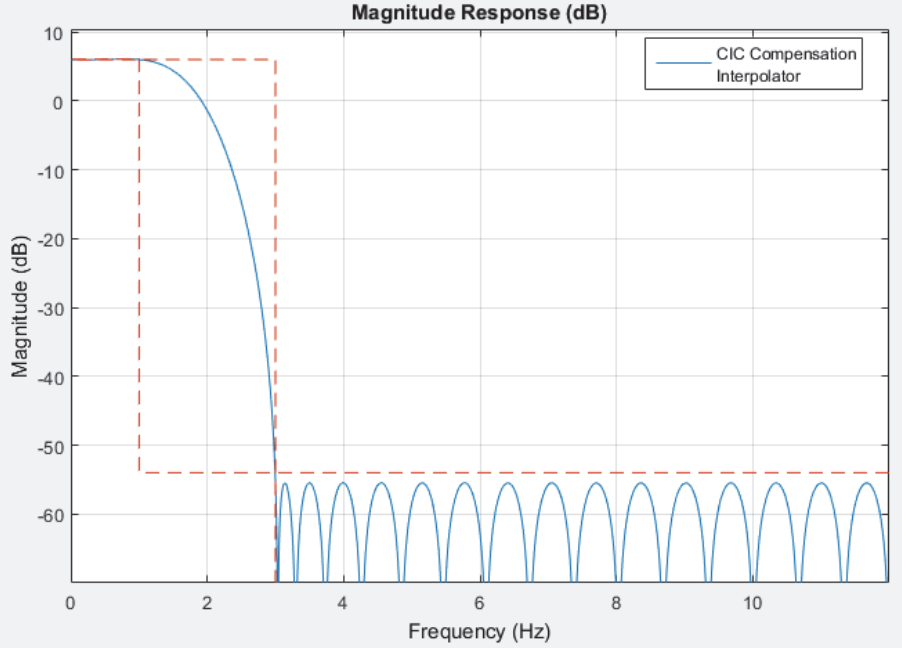

Fig. 7. AFC of CIC compensation interpolator filter

Pulse formation in electronics and telecommunications is a process of changing the shape of transmitted pulses. Its purpose is to make the transmitted signal better to use in the communication channel usually by limiting the signal bandwidth. The intersymbol interferences created by the channel can be controlled with filtering of transmitted pulses.

When processing a signal, a riser cosine filter (RRC) is often used as a transmit and receive filter in a digital communication system to perform an agreed filtering. This helps to minimize intersymbol interference. The combined response of such two filters is a filter with a raised cosine. It is called so because its frequency response H_{rrc} (f) is the square root of the frequency response of an exponential cosine filter H_{rc} (f):

$$H_{rc}(f) = H_{rrc}(f) \cdot H_{rrc}(f), \text{ or: } \left|H_{rrc}(f)\right| = \sqrt{\left|H_{rc}(f)\right|},$$

In order to have minimal ISI (inter-symbolic interference), the overall response of the transmission filter, the channel response and the acceptance filter must fit Nyquist's criterion. A high-rise cosine filter is the most popular filter response that satisfies this criterion. Half of this filtration is performed on the transfer side and other half is on the reception side. The channel response on the receiving side may also be taken into account if it can be accurately estimated so, the overall response is a riser cosine filter.

Nyquist showed that the pulse characteristic will have zeros with evenly distributed intervals if the frequency characteristic has odd symmetry at the cutoff frequency. It's much easier to achieve. The impact of jitter can be minimized.

The filter with the raised cosine characteristic has a frequency transfer coefficient:

$$X_{rc}(f) = \begin{cases} T & \left(0 \le |f| \le \dfrac{1-\beta}{2T}\right) \\ \dfrac{T}{2}\left\{1 + \cos\left[\dfrac{\pi T}{\beta}\left(|f| - \dfrac{1-\beta}{2T}\right)\right]\right\} & \left(\dfrac{1-\beta}{2T} \le |f| \le \dfrac{1+\beta}{2T}\right) \\ 0 & \left(|f| > \dfrac{1+\beta}{2T}\right) \end{cases}. \quad (6)$$

Is the decreasing factor ($0 \le \beta \le 1$) of the filter frequency response, it is a measure of redundancy bandwidth filter that strips exceeding Nyquist bandwidth. The AFC of the Nyquist filter is shown in Fig. 8.

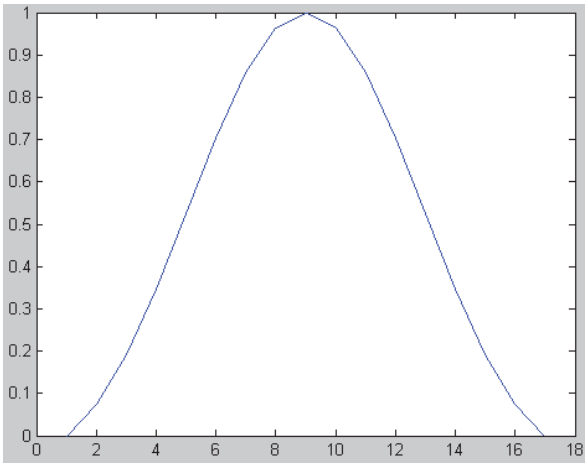

Fig. 8. AFC of the Nyquist filter

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Results of Experimental Studies

In fig.9 is shown the studying of Simulink-model transmitter:

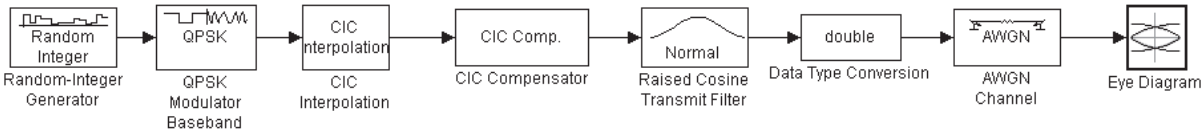

Fig.9. Simulink-model transmitter

Random Integer Generator using as an input signal source and a QPSK Modulator - is as a modulator. To increase the sampling rate with a large interpolation factor, the CIC Interpolation unit is connected. To align the frequency response of the CIC filter, a CIC compensator unit is connected. Filter and the transmit channel with additive white Gaussian noise are included to form the pulse of Raised Cosine Transmit Filter.

The Random Integer Generator output signal is shown in Figure 10.

AFC of CIC Interpolation filter is shown in fig.11.

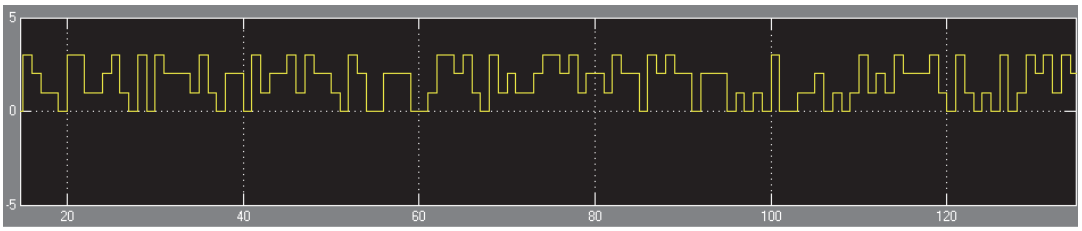

Fig.10. The Random Integer Generator output signal

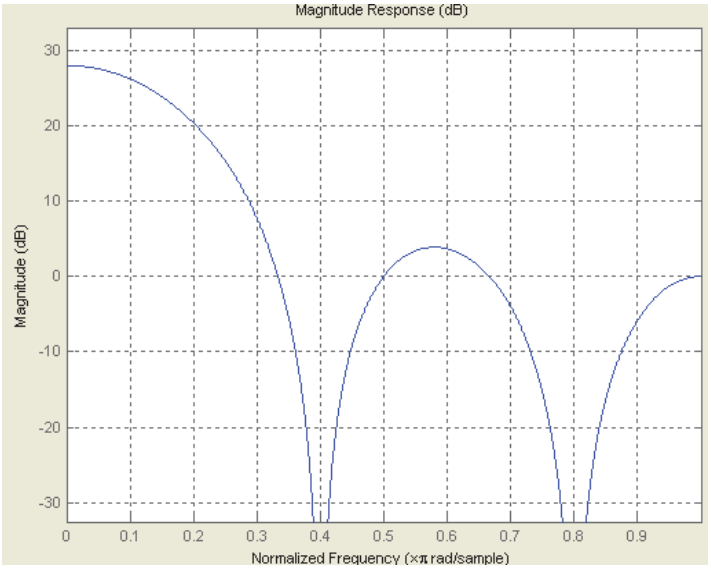

Fig.11. AFC of CIC Interpolation filter

Signal sampling frequency is 1 Hz. The QPSK signal diagram without interpolation filters is depicted in Fig. 12. Eye-diagram of transmitter signal for filter

interpolation coefficient is: CIC Interpolation is R_1=5; CIC Compensator is R_2=2 is shown in Fig. 13.

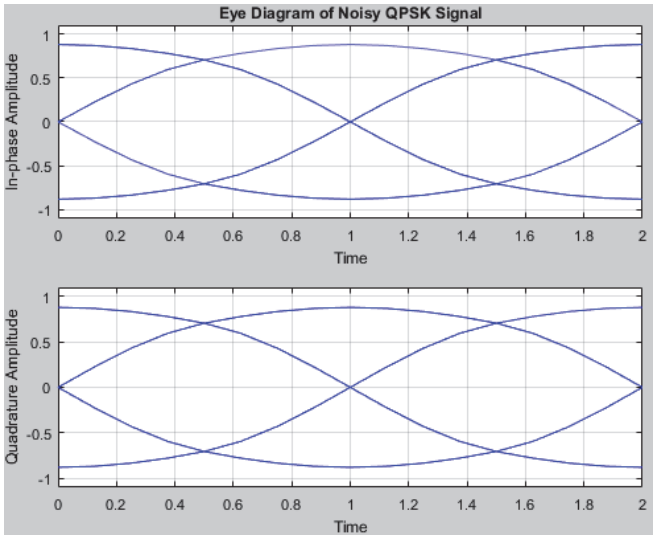

Fig.12. QPSK eye-diagram without interpolation filters

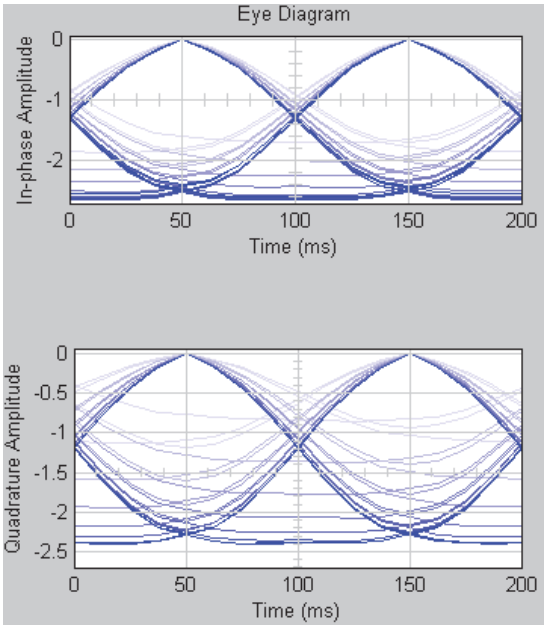

Fig.13. Eye-diagram of transmitter signal for filter interpolation

The total interpolation coefficient is 10. According to the eye-diagram it can be concluded that the period of bits receipt is 100 msec or 0.1 sec, which corresponds to the interpolation coefficient 10. The signal amplitude is about 2.5 V. The signal rise time is 80 msec.

In case of interpolation coefficient of filters the eye diagram is: CIC Interpolation is R_1=50; CIC Compensator is R_2=2 is shown in Fig. 14. The total interpolation coefficient in the transmitter model is 100 and the gain is K=18. Time of signal rise is 8 msec.

Eye diagram in case of interpolation coefficient of filters is: CIC Interpolation is R_1=60; CIC Compensator is R_2=2 is shown in Fig. 15. That is, the total interpolation coefficient in the transmitter model is 120. A sufficiently strong jitter is observed with defined interpolation factor.

The eye diagram is an oscillogram and the digital signal is periodically discretized and fed to the vertical scan of the oscilloscope to create it a well as the data rate is used to trigger the horizontal scan of the oscilloscope. It is a tool for evaluating the combined effect of channel noise and intersymbol noise on the performance of the pulse transmission system in the main band of frequencies. This is a synchronized superposition of all possible realizations of the signal which is considered in a specific transmission interval. Several performance indicators of system can be got by analyzing the mapping. The open-eye pattern corresponds to the minimum distortion of the signal. Distortion of the signal shape through intersymbolic noise and noise is manifested as the closure of the eye structure.

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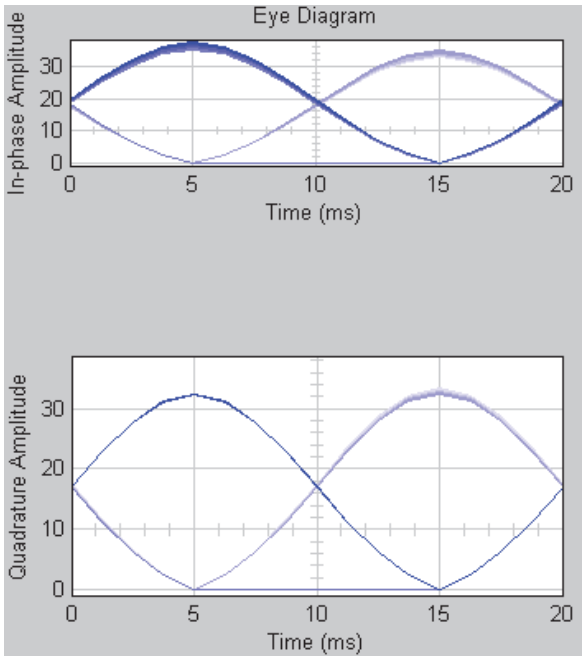

Fig.14. Eye diagram in case of interpolation coefficient of filters is: R_1=50; R_2=2

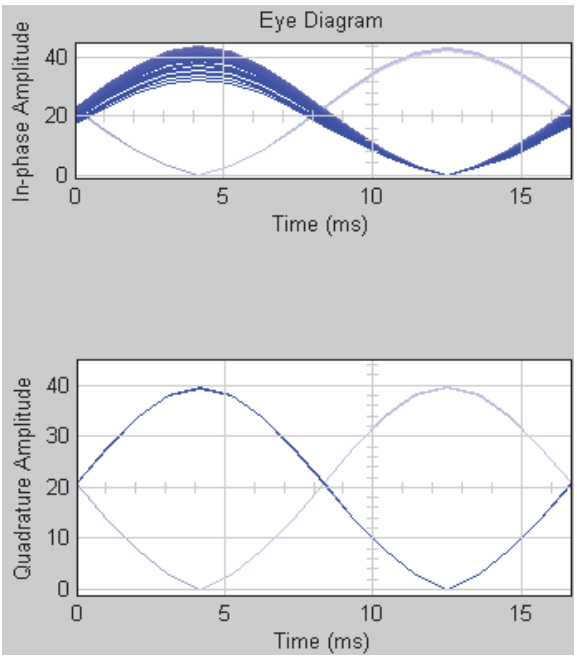

Fig.15. Eye diagram in case of interpolation coefficient of filters is: R_1=60; R_2=2

An important characteristic of communication signals, especially in high-speed systems, is the trembling of synchronization (jitter). Trembling of synchronization is defined as the deviation of the clock signal from the ideal clock signal. Jitter in the time field is deterministic and random. Examples of deterministic jitter are periodic jitter and intersymbol interference. The periodic jitter can be modeled as the sinusoid sum and intersymbol interference can be modeled as a sequence of Dirac's functions. Random jitter is modeled as a Gaussian function. The jitter that occurs in the communication system may have any combination of these components.

Quality factor (Q-factor) is an indicator of high-quality signal in the communication system. The coefficient Q is defined as the difference between the mean values of the two levels of the signal (the level for the bit "1" and the level for the "0" bit) is divided by the sum of the mean square deviations of noise at two levels of the signal. A higher number in the result means that the pulse is relatively free of noise.

$$Q = \frac{I_1 - I_0}{\sigma_1 + \sigma_0}, \tag{7}$$

where σ_1 and σ_0 - is the mean square deviation of the logical zero and the logical unit; I_1 and I_0 - the level of the logical zero and the logical unit.

For the interpolation coefficient 10 (Fig. 13), the signal-to-noise ratio is 30 dB. In the eye-diagram it can be determined: I_1=2,5 and I_0=0 σ_1=0,05 and σ_0=0,1, Q=16,7.

If the interpolation factor is 100 (Fig. 14), the signal-to-noise ratio is 30 dB. In the eye-diagram it can be determined: I_1=36 and I_0=0, σ_1=3 and σ_0=0,1, Q=11,6.

If the interpolation factor is 120 (Fig. 15), the signal-to-noise ratio is 30 dB. In the eye-diagram it can be determined Q=3.

The intensity of bit errors in the eye-diagram can be determined from the expression:

$$BER = \frac{1}{Q\sqrt{2\pi}} e^{-\frac{Q^2}{2}}. \quad (8)$$

The intensity dependence of bit errors on the signal quality factor is shown in fig.16.

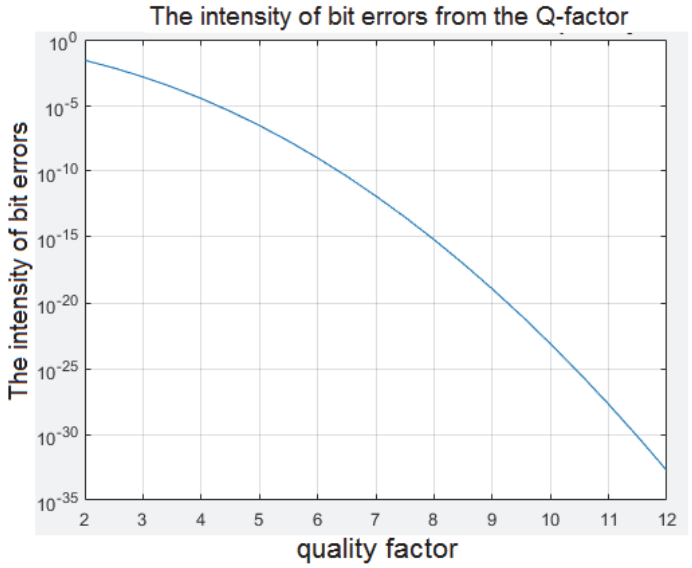

Fig.16. Dependence of the intensity of bit errors on the signal quality factor

From the received schedule it is possible to draw a conclusion that the intensity of bit errors becomes unacceptably high at low signal quality.

Conclusion

Analyzing the obtained eye-diagrams it can be concluded that the interpolation is accompanied by the effect of signal amplifying, reducing of the pulse rise time, reducing of the signal quality factor. The jitter in the transmitter decreases if the interpolation factor is a multiple of the sampling rate of the information sequence of symbols. If the signal quality factor is $Q>7$, then the bit error rate has a $BER<10^{-9}$ value for practice.

References

1. Скляр Б. Цифровая связь. Теоретические основы и практическое применение. Изд. 2-е, испр.: Пер. с англ. – Москва : Издательский дом «Вильямс», 2003. – 1104 с.

2. Витязев В. В. Анализ шумов квантования многоскоростных структур узкополосных КИХ-фильтров / В. В. Витязев, Р. С. Горюшкин // Цифровая обработка сигналов. - №4. - 2015. С. 36-39.

3. Ugwuanui S. Radio frequency and channel investigation using software defined radio in Matlab end Simulink environment / S. Ugwuanui // Nigerian Journal of Technology (NIJOTECH). – 2018. - Vol. 37, No. 4. - pp. 1049 – 1057.

4. Бойко Ю. М. Синтез і аналіз інформаційно-управляючих систем синхронізації засобів телекомунікацій / Ю. М. Бойко // Адаптивні системи автоматичного управління : міжвідом. науч.-техн. зб. / Нац. техн. ун-т України "Київ. політехн. ін-т ім. Ігоря Сікорського". – Київ, 2017. – Вип. 1’(30). – С. 8-28. DOI: https://doi.org/10.20535/1560-8956.30.2017.117700.

5. Ting-An C., Kuan-Ting L., Guan-Cheng C., Shu-Hui C., Jar-Ferr Y. Super resolution using trilateral filter regression interpolation / C. Ting-An, L. Kuan-Ting, C. Guan-Cheng, C. Shu-Hui, Y. Jar-Ferr // Proceedings 2017 IEEE 2nd International Conference on Signal and Image Processing (ICSIP). – (Singapore,4-6 Aug. 2017). – 2017. – P. 86-89.

6. Wangqian C., Mo H., Xin L. Sparse FIR Filter Design Based on Interpolation Technique / C. Wangqian, H. Mo, L. Xin // Proceedings 2018 IEEE 23rdInternational Conference on Digital Signal Processing (DSP). – (Shanghai, China, 19-21 Nov. 2018). – 2018. – P. 1-5.

7. Бойко Ю. М. Підвищення завадостійкості блоків оброблення сигналів засобів телекомунікацій на основі модифікованих схем синхронізації / Ю. М. Бойко // Вісник Національного технічного університету України "Київський політехнічний інститут". Серія : Радіотехніка. Радіоапаратобудування. - 2015. - Вип. 61. - С. 91-107. http://nbuv.gov.ua/UJRN/VKPI_rr_2015_61_11.

8. Бойко Ю. М. Теоретичні аспекти підвищення завадостійкості й ефективності обробки сигналів в радіотехнічних пристроях та засобах телекомунікаційних систем за наявності завад : монографія / Ю. М. Бойко, В. А. Дружинін, С. В. Толюпа. – Київ : Логос, 2018. – 227 с. http://elar.khnu.km.ua/ /jspui/handle/ /123456789/6291.

9. Avi G., Meenakshi A.,Tarun Kumar R., Kunwar S. FPGA implementation of reconfigurable architecture for half-band FIR filters / G. Avi, A. Meenakshi, R. Tarun Kumar, S. Kunwar // Proceedings 2017 4th International Conference on Signal Processing, Computing and Control (ISPCC). – (Solan, India, 21-23 Sept. 2017). – P. 592-596.

10. Бойко Ю. М. Особливості квазікогерентної обробки сигналів у засобах телекомунікацій з частотною маніпуляцією / Ю. М. Бойко, І. С. Пятін // Телекомунікаційні та інформаційні технології : наук. журн. / Держ. ун-т телекомунікацій. – Київ, 2018. – № 1 (58). – С. 27-39. http://elar.khnu.km.ua/ /jspui/handle/ /123456789/6594.

11. Parkhomei I. Features of digital signal processing in the information control systems of multipositional radar/ Parkhomei I., Bojko J. // Journal of achievements in materials.: - volume 77, issue 2, august 2016. - C.75-84.

UDC 004-042

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APPLICATION OF EVENT SOURCING AND CQRS PATTERNS IN DISTRIBUTED SYSTEMS

Annotation: The purpose of this report is finding suitable approaches for dealing with the issue, particularly ability to recreate system state in modern high load distributed systems. In order to achieve the goal, the report will overview existing problems, compare conventional design to proposed architecture solutions. A combination of command query responsibility segregation (CQRS) and event sourcing is suggested to solve performance and design issues that often arise in conventional information systems development.

Keywords: CRUD, CQRS, event sourcing, software architecture, design patterns, data modeling.

Problem Statement

The common template for any data-oriented application is multi-level architecture [1]. The main idea is to use the division of responsibility to keep the presentation, data storage and business logic separated from each other. The persistence layer should not know about the mechanisms used to store and retrieve data, it's only responsible for data operation with storage. A data layer has to deal with different relations between entities and often works as a bridge from application domain model to its normalized view in data storage. Data changes are generally expressed as C, U, and D of CRUD (create, update and delete).

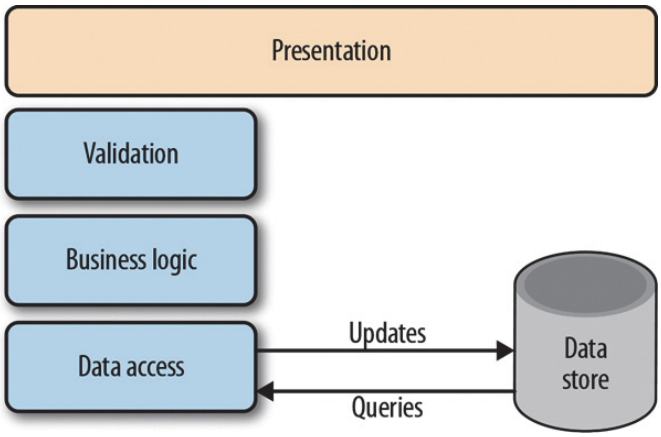

Fig. 1 - A traditional CRUD architecture

So, what's wrong with this approach? This model is so popular that most people are not even thinking about an alternative, and for simple applications it may not cause any problems. However, there are a few shortcomings in this conventional architecture.

The common problem of CRUD applications is that they are receive all data

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models and views from its primary data storage on which they depend. It enforces two different requirement of data structure: fast writes and fast reads. These parameters are hard to balance using only one solution and in most cases this problem is lessen by adding caches. However, with caches comes additional complexity which requires tremendous knowledge to handle properly.

Another issue with CRUD-like systems is violation of single responsibility principle, since update operation may not only do the update but also read newly changed data. The User object may have an id or update datetime, or other generated data that is present while reading the object, however the persistence layer will forbid you from updating them yourself. Therefore, code becomes more unmaintainable as the scope of application grows.

In fact, writing and reading can be differentiated by its priorities:

Table 1

Comparison of areas of concern of two operations

Writing	Reading
Assuring data integrity	Perform efficient queries and lookups
Enabling atomic updates and transactions	Calculate derived and aggregated values (sum, average, etc.)
Optimistic concurrency or locking	Provide a number of data views
Enforcing write permissions	Enforce row and column level permissions

An overview of existing solutions

There are a lot of way to deal with some of the issue above. Most application use caches [8] as fast and denormalized way to access heavily requested data. However introducing them adds new layer of complexity since caches need to be synchronized for all instances of application, its size and objects it contains is a very debatable subject considering different applications may use it for various amount of reasons. But the most difficult task regarding caches is keeping them up-to-date. Caches aren’t the persistent data storage meaning they have to be rebuilt on each application launch from some source. This creates a gap between this data storage - source of truth - and caches.

Transactions [9] are mostly considered as silver bullet of CRUD applications. While they are effective at keeping data integrity is SQL databases it causes a lot of overhead and business logic put on the data storage further violating single responsibility pattern. Transactions that are held open for quite a long time make the data storage track changed rows of frequently-modified tables that could be cleared. Moreover, it is really costly to roll back transactions. For some databases to roll back transactions takes more time than committing it.

Another way to increase application performance is vertical scaling [10]. It’s a concept of adding more resource to single instance allowing for faster computation

of larger amount of data. In most scenarios the servers are already at full capacity physically. To see an actual impact of scaling typically would involve purchasing an entire new server to replace the old one. This is still vertical scaling from the database/application point of view. Having one high performance server is generally more expensive than buying a few less powerful.

Proposed solution

Main idea of CQRS (Command Query Responsibility Segregation) is separation of models for updating and reading information. Collaboration and staleness are two driving forces of CQRS. Collaboration means set of rules on how many participants will use / change the same shared data. Often there are rules that indicate which actor can execute which modifications and modifications that can be accepted in one case may be forbidden in another. Actors can be people like ordinary users or automated as software.

Staleness is demonstrated by the fact that in shared use, when data is shown to one actor, it may be changed by another one. Almost any system that uses caches serves stale data - often due to performance reasons. This means that we can not take into account the decisions of their actors, because they can be made on the out-of-date data. Standard layered architectures do not address any of these issues. Although all in one database could be a single step in the direction of collaboration, the staleness is usually more unpleasant in these architectures because of the caches usage as a performance improvement after data modeling is already done.

These issues are addressed in CQRS via read and write models segregation, where queries are for reading while commands deal with data updates.

- Commands have to tell what needs to be done rather that tell how it should be done. ("Switch the lights on, "not" set LightStatus to ON."). In most scenarios they are put in some queue for later asynchronous processing.
- Queries aren’t allowed to change anything in data storage. They should return DTO which is a container for data. You may think of it as a struct.

Comparing data flow of CRUD-based applications to CQRS ones, implementation and development process is far simpler with separation of responsibility. Both models can be designed via one data storage or be completely separated having different structure. Distributed systems greatly benefit from having numerous read optimized model closely located to request them applications. The separation of reading and writing storages also allows each to scale according to the corresponding load. For instance, reading stores are generally faced with a much greater load than store recordings.

Denormalization of data allows creation of read optimized views which may make enormous impact on a performance by reducing number of data transformations necessary to form the result.

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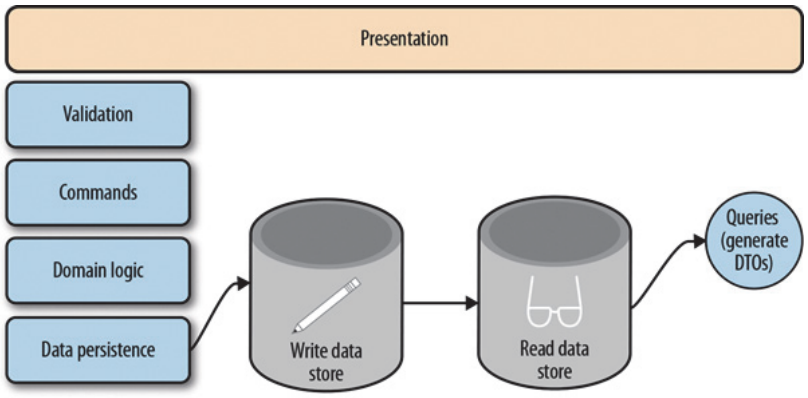

Fig. 2. - A CQRS architecture with different read and write stores

Let’s analyze benefits and drawbacks of this approach before taking it to another level by adding event sourcing on top.

Advantages

- **Optimized data schemas**. Data models can be designed for read intensive purposes while write model should assure fast write operations.
- **Independent scaling**. Segregation of models allows independent scaling of different services based on their load.
- **Simpler queries**. Read optimized views make this operation that much faster and easier.
- **Security**. Permission enforcement is handled better for actors to perform write operations.
- **Concerns separation**. Maintainability and flexibility are gained as a result of the data models segregation. Writing model should be responsible for complex business logic, while reading model is kept relatively simple.

Things to consider

- **Complexity**. While core of CQRS is fairly straightforward an actual implementation may lead to some complexity.
- **Messaging**. In most cases messaging goes hand in hand with CQRS, though it’s not a requirement. This enforces asynchronicity in application design.
- **Eventual consistency**. Separating read and write models may result in read data being stale. However, data loss or inconsistency are impossible by design.

Event sourcing

Event sourcing neatly supplements CQRS further enhancing availability and eventual consistency of application. Main idea of event sourcing lies in having ordered set of changes rather than aggregated state. This means each event doesn’t replace shared data but rather works as delta. Generally, it is presented as append-only log where actor can send commands and when we need to recreate entity state we can replay each command.

Dealing with events implies introducing asynchronicity to application. There-

fore, this model is eventually consistent – every event will be processed at some point in future. Using log as a transport and storage of events prevents any concurrent issues since every command for one entity is processed one by one. Event sourcing and log model are heavily used in databases as a tool to synchronize different nodes. Every write to database is stored in its log and when replication happens new node just needs to replay all commands from the log. There’s a lexical difference between command and event. Event is a fact, it happened at some time in the past, while command is more of an intent to do something, an application which may be satisfied or rejected.

Multiple data services may consume events and update its model accordingly without any repercussions for not thinking about permissions or data integrity. It allows to store data in whichever model suits the cause, duplicating and precomputing any required data. Usually application that use event sourcing also have denormalized data. Having one log of all commands allows easy synchronization of multiple data storages which can be tuned to be either read intensive or write intensive. This is very different from normalization standards of typical CRUD application. Having different read optimized data representations will increase performance tremendously and data integrity issue is dealt via each data service separately updating its model.

There are quite a few benefits of event sourcing:

- Asynchronicity.
- Source of truth.
- Concurrency.
- Tracing.
- Scalability.
- Reusability.

Event replay

Let’s take a closer look at example of accounting system with event sourcing. Here is a log of events concerning bank account:

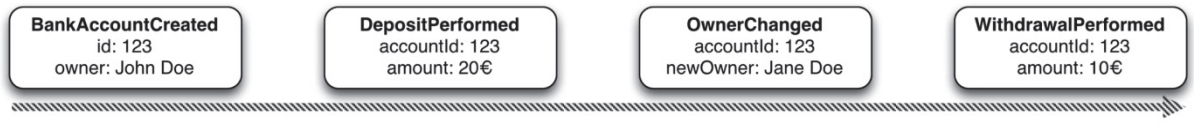

Fig. 3. - Append-only log of accounting events

Each of these events are persisted and are processed one by one. It allows to recreate account’s state at any given time by replaying all previous events. This process creates an aggregate - data model which represents state of account at a moment. This aggregate is similar to domain object in CRUD-based application. In the example below each event is applied to previous aggregate having empty BankAccount as the initial state.

In order to query this, aggregate we can either build it from scratch on each request or have pre build version stored and continuously update it. The second approach is more preferred considering performance implications on aggregating history of events every time. It also allows to tune this presentation for read intensive purposes since it can be requested often. It showcases distinct segregation of commands and queries.

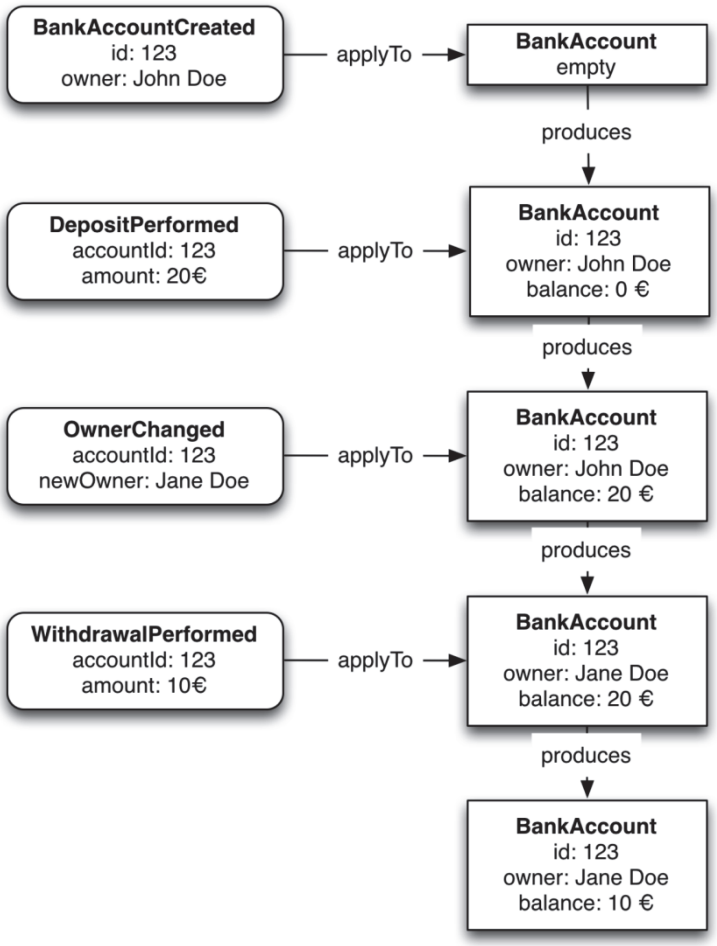

Fig. 4. - Creation of a BankAccount aggregate

One of the biggest pitfalls of CRUD architecture is inability to proper trace changes to domain entity. The only approach used for that is logging, however most of the times it’s not enough for debugging purposes and it doesn’t allow to properly recreate state of the system. This is solved in event sourcing architecture by enforcing the log onto commands which leads to ordered sequence of events - traces of each actor’s actions. This approach allows to work with domain objects (aggregates) as well as keep the changelog.

Conclusion

Event sourcing enables straightforward and reliable way to log state changes via zero loss protocol. With ordered log or a journal as a backbone such systems

can easily and efficiently recover. CQRS goes a step further, making queryable view of raw events which can be used by other data services.

Moreover loosely-coupled design is a result of building stateful applications in this way. Simple troubleshooting and upgrading, resilience and scalability are the most glaring benefits.

Having different read optimized data representations will increase performance tremendously and data integrity issue is dealt via each data service separately updating its model.

REFERENCES

1. Fowler M. Patterns of Enterprise Application Architecture / M. Fowler. — Boston: Addison-Wesley Longman Publishing Co., Inc., 2002. — 576 с.

2. Udi D. Clarified CQRS [Електронний ресурс] // http://udidahan.com. 2005. URL: http://udidahan.com/2009/12/09/clarified-cqrs/.

3. Fowler M. CQRS [Електронний ресурс] // https://martinfowler.com. 2008. URL: https://martinfowler.com/bliki/CQRS.html.

4. Richards M. Software Architecture Patterns / M. Richards. — Sebastopol: O'Reilly Media, 2015. — 47 с.

5. Korkmaz N. Practitioners’ view on command query responsibility segregation / N. Korkmaz, M. Nilsson // School of Economics and Management Department of Informatics Lund University. — 2014. — С.33-37.

6. Barnkob M. Event Sourcing and Command Query Responsibility Segregation Reliability Properties / M. Barnkob, J. Krukow // Computer Science University of Aarhus. — 2018. — С.21-39.

7. Kleppmann M. Making Sense of Stream Processing / M. Kleppmann. — Sebastopol: O'Reilly Media, Inc., 2016. — 172 с.

8. Handy J. Cache Memory Book, The (The Morgan Kaufmann Series in Computer Architecture and Design) 2nd Edition / J. Handy. — Burlington: Morgan Kaufmann, 1998. — 229 с.

9. Bernstein P. Principles of Transaction Processing (The Morgan Kaufmann Series in Data Management Systems) / P. Bernstein, E. Newcomer. — Burlington: Morgan Kaufmann, 2009. — 400 с.

10. Atchison L. Architecting for Scale / L. Atchison. — Sebastopol: O'Reilly Media, 2016. — 154 с.

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PROTECTION OF AN ELECTRONIC DOCUMENT USING A CONSOLIDATED APPROACH TO THE APPLICATION OF ELECTRONIC DIGITAL SIGNATURE

Abstract: The article deals with the use of electronic digital signature based on software models of cryptographic methods for protecting the document integrity. The most appropriate in terms of protection software tools for working with electronic digital signature were analyzed. There was defined advantages and disadvantages of the algorithms. An algorithm for initiating and authenticating a user that uses an electronic digital signature was proposed.

Keywords: network infrastructure, document, electronic document, electronic digital signature, authentication, verification, EdDSA, SHA-512, Argon2.

Introduction

The Internet is an integral part of our everyday life, and therefore a guarantee of a high level of security is one of the priorities in the development of information technology. Currently, users and the Internet infrastructure, such as routers, servers and services, are targets of various kinds of malicious attacks, such as denial of service attacks, hacks, phishing attacks and unwanted e-mail (spam) - especially dangerous - and ensuring sufficient protection indicator involves the effective use of the Internet.

The reason of the vulnerability of the Internet to various attacks lies in its initial creation goals, in which it was assumed that the network would be used in a completely different way than today. Initially, the Internet was developed to be used by relatively few friendly parties. At present, the situation is quite different: a large number of different users are using the Internet, and almost all attacks against it occur from within the network. Protecting the Internet from attacks is quite a difficult task, since there is no effective security measure that can cover all types of attacks. You can protect yourself as much as possible against direct attacks from the network using HTTPS (TLS1.2 + trusted certificate), but you should be afraid of various attacks based on social engineering. Unfortunately, only awareness and attentiveness of users can save him from this type of attack.

Problem statement and current developments

Traffic verification and integrity check can be provided for comprehensive security solutions. One of the main problems is the low efficiency: if the network infrastructure compromised and cannot deliver packets. This requires a clear need for new solutions. If traffic can be verified in the network infrastructure, control measures can be taken on the network. This will allow you quickly and effectively stop the attack and keep your data safe.

Document management systems typically provide security and control access to documents in a controlled environment. However, when a document leaves a secure environment, it is easy to modify it. Unprotected documents do not allow

to determine whether the document is authentic, who was the originator and the approver or has it been modified since its creation.

The problem of keeping electronic documents from being copied, modified, and forgery requires specific approaches and methods of protection for its solution. One of the most common method of such protection in the world is an electronic digital signature (EDS), which confirms the authenticity, integrity its details and the fact of signing by a specific person of the document with the help of special software.

Dependence on digital signatures alone is a matter of concern, since a pair of keys can be obtained by another person or organization using one method or another. This can be resolved by verifying by certification center. The certification center is a trusted third party (for example, a bank) that will ascertain the identity of the person or company. For example, it can be done by checking passports or driver's license details, as well as corporate documents. Then certificate center will issue a digital certificate signed with its own digital signature, which will be attach to user’s digital signature as an identity card.

Certification center is a trusted third party that provides information about the identity of the key holder in the form of an authenticated key certificate [2]. All electronic certificates are digitally signed by a certification authority with a private key. If the certification authority supports strong private key protection, it is almost impossible to forge an electronic certificate. The certificate can be distributed in several ways. The certificate can be “handed over” to the owner of the signature. Then the owner can distribute the certificate anywhere he decides. This approach is preferable to publishing a certificate on a website.

Modern information systems allow organizations to improve their efficiency, significantly reduce their costs and meet regulatory requirements. A good document management system is often regarded as all that is required, but additional protection measures are also needed to ensure that data is protected from unauthorized access and forgery.

The purpose of this article is to modify the algorithms of cryptographic methods of protecting the integrity of a document using an electronic digital signature.

Use of electronic signatures creates significant problems in relation to the individual. The use of paper tools for creating and maintaining records often includes handwritten signatures, and verification tools such as seal are the predominant approach of performing official actions. Typical examples of paper rules are formal legal requirements in favor of paper documents and handwritten signatures or archiving rules that require storing valuable information on paper. These rules can be found in various national, international and supranational legal frameworks.

Traditionally, a handwritten signature is a sufficient means of authentication. By signing a paper document, the manufacturer “identifies” itself as the author of the document and confirms the “integrity” of the document. The signing procedure serves as a warning, and also confirms the fact that the information has been finalized and was

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not changes since signing. Distinguishing marks can be encoded in the information itself to identify the source and authenticate the content. Many forms of digital authentication are currently used, such as using a password, such as a PIN code, using encryption methods such as digital signatures, and using biometric identification, such as finger-prints, face, retina and voice recognition. Basically, these authentication methods are combined to provide a high level of authentication security.

The issue of identification is a concern due to insufficient data protection. However, the European Directive requires general compliance of the Data Protection Directive (95/46/EC) [13]. The Electronic Signature Directive also requires Member States [13] to ensure that service providers issuing certificates to the public do not collect personal data, except directly from the data subject, or without the explicit consent of the data subject. There is another requirement that only required data in case of necessity can be collected for the certificate maintenance and issuance.

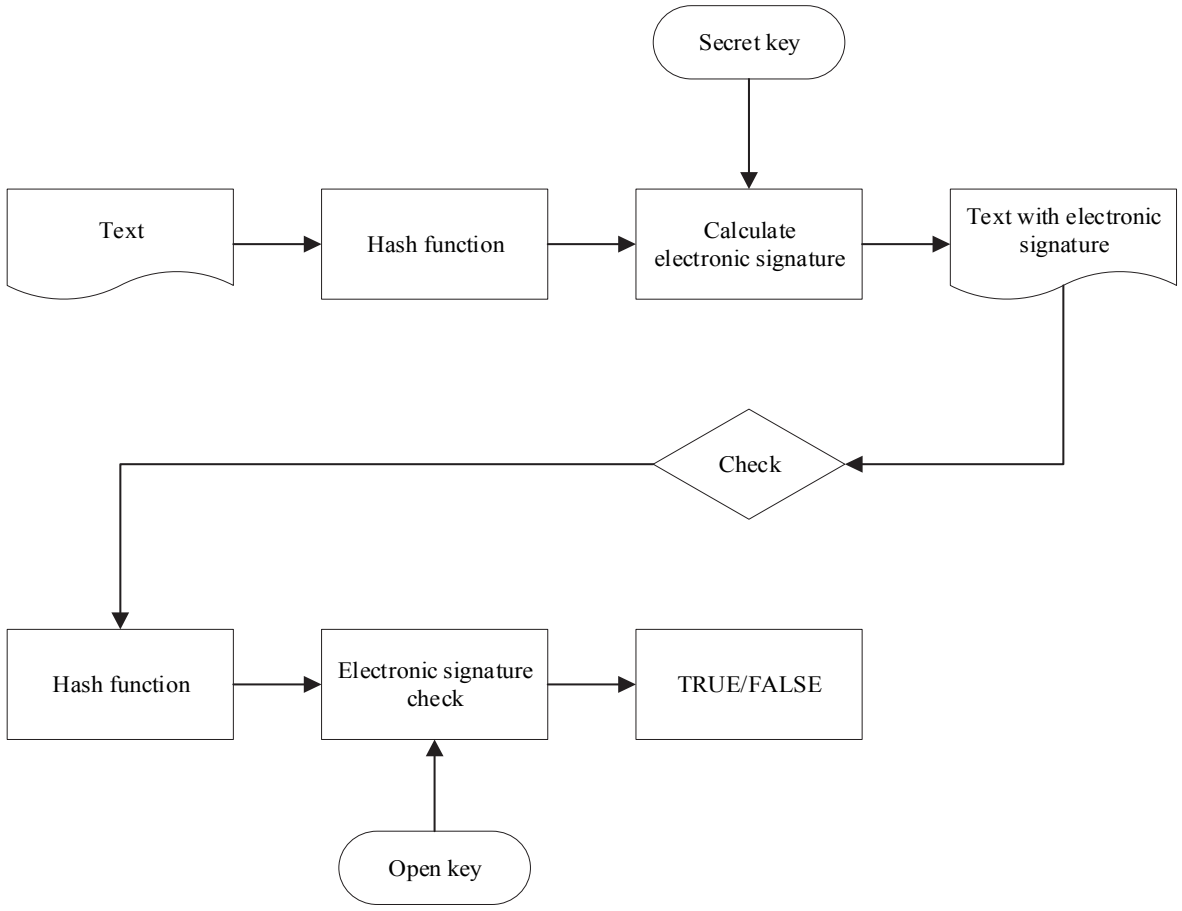

Fig. 1. Typical Electronic signature algorithm

There are several schemes of constructing a digital signature [1]:

- Based on symmetric encryption algorithms. This scheme provides for the presence in the system of a third party enjoying the confidence of both parties. The authorization of the document is the fact of encrypting it with a secret key and transferring it to the authorized person;

- Based on asymmetric encryption algorithms. Currently such schemes are most common and are widely used;

Combined.

Symmetric encryption. Encryption, in which the same cryptographic key is used for encryption and decryption. A huge advantage of this approach is the encryption speed, but both parties, between which information is sent, must know the key. There are two types of this encryption type: stream ciphers, where each character of the message is encrypted one by one with the corresponding digit of the key stream (RC4, SCALA20, Achterbahn); block ciphers that devides the message into blocks of fixed length and operates with the received blocks (DES, AES, Blowfish).

Asymmetric encryption. Encryption, in which there are two types of keys, public and private key. The public key is transmitted over the open channel and is used to check the electronic digital signature and to encrypt the message. The private key is used to generate the EDS and to decrypt the message. Types of asymmetric ciphers: RSA, DSA, ElGamal, Rabin.

Combined encryption. With the help of symmetric encryption, the necessary data is encrypted quickly, the key is attached to the message or the EDS, and the key of the symmetric cipher is encrypted with an asymmetric public key.

For generation EDS, a hash function is needed, which will reduce a message of any size to a certain number of bytes. The resulting hash is encrypted and added to the original document for verification [2]. According to the obtained composition, it is possible to prove that the document has not been changed since the moment of signing.

Common encryption methods are based on factorization of large numbers (RSA, DSA, ElGamal) and discrete logarithmization (ECDSA, EdDSA, GOST R 34.10–2012).

Ed25519 is a type of signature algorithm based on the elliptic curve Curve25519, belonging to the EdDSA family. It was firstly introduced in 2007 as scientific research and from that time it have been spreading among many spheres and companies. These days it is being used by OpenSSH, Apple, Sony, I2p, Tor, Tox, etc. The curve looks like this [11]

$$y^2 = x^3 + 48666 * x^2 + x \quad (1)$$

This is the Montgomery curve over the prime field modulo a prime number $2^{555} - 19$ (which gave the name to the scheme) and with a base point $x = 9$. The scheme uses points in compressed form (only X coordinates), thus allowing the use of the “Montgomery Staircase”, which multiplies the points in a fixed time, saving us from time attacks. Ed25519 consists of three modules [11]:

- Digital signature algorithm;
- Hashing function SHA-512;
- Random number generator for generating key pairs.

ECDSA and EdDSA require the generation of a random value (scalar pair of ephemeral keys) during the signature generation process and the secrecy of this random value is critical for security [12]: knowing one such random value or partial knowledge of several of them allows the signer's private key to be recovered [8].

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ECDSA does not describes how to generate this random value and, therefore, implementations critically rely on the quality of the random number. EdDSA removes this dependency by deterministically extracting the secret from the message and the long-term auxiliary key using the SHA-512 cryptographic hash function.

EdDSA is considered to be more resistant to side-channels attack. The authors rely on the idea of “generating random signatures secretly in a deterministic way”, so that “different messages lead to different, difficult-to-predicted ephemeral key values. A few bits can usually be obtained from side-channel attacks or from uneven distribution from which r is taken, so EdDSA authors rightly point out the fact that the “deterministic feature” does not lead to obvious leaks when attacking side-channels attack.

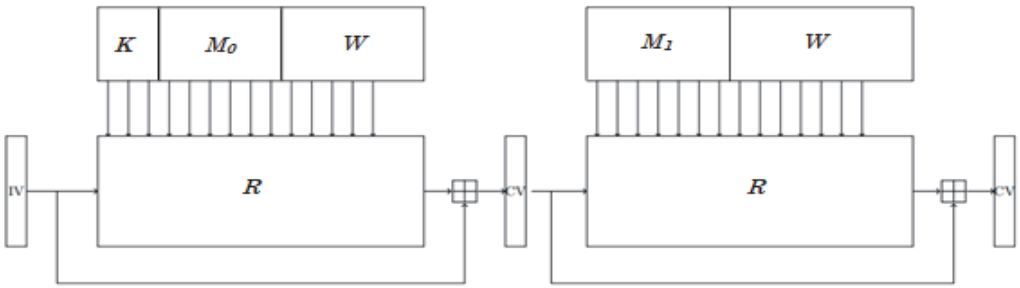

Fig. 2. Generation of the ephemeral key

SHA-512 belongs to the family of SHA-2, developed by the NSA and it has Merkl-Damgard structure [4]. The structure assumes an iterative update of the CV value; this value is initialized with a fixed initial value IV. The message is supplemented (if necessary) and divided into blocks. At each iteration, a message block is processed. The figure shows the generation of an ephemeral scalar, where the auxiliary key and the message are hashed [12]. The letter K denotes the auxiliary key b, M_i - is the input message, W is the queue of the remaining messages, and R is the compression function. M_0 - is a message fragment that is in the same block as the key. Unfortunately, this structure is also vulnerable to side-channel attacks.

It will be enough just a few hundred EDS to find out the auxiliary key, and with it, you can already extract the private key. Although it is possible to protect against such attacks by setting up a random number generator to provide same number sometimes, that you can use same number to sign several messages, this contradicts the security requirements of EdDSA.

If you use electronic digital signature to protect company data, you can modify Ed25519 with another hash function that will vulnerable to the same attacks as SHA-512.

At present, one of the most reliable and flexible functions is Argon2. It was designed for efficient hashing, especially password hashing. It was developed for high speed memory filling (high bandwidth) and efficient use of several computational units (CPU cores), and at the same time providing protection against many types of attacks. Argon2 has three types: Argon2i, Argon2d and Argon2id. Argon2i uses data-independent memory access, which is preferred for hashing, but it is slower as it takes more memory passes for protection against compromise attacks [11].

Argon2d works faster and uses data dependent memory access, which makes it resistant to attacks using the GPU (brute force) and is suitable for applications that do not have to face side-channel attacks [11]. Argon2i reliably fills memory, using 2 CPU cycles per byte, and Argon2d is three times faster [9]. Argon2id is a hybrid of Argon2i and Argon2d, it uses combination of data-dependent and data-independent memory access [11], which gives Argon2i’s some resistance from side-channel attacks and most of Argon2d's resistance from GPU relying attacks.

Despite its high performance, Argon2 provides a reasonable level of reliability and protection. With the default number of passes over memory memory (1 for Argon2d, 3 for Argon2i), an attacker, equipped with an ASIC, cannot reduce the execution time (time-area product) if the memory is 4 or less times less than required [9]. The more memory passes, the more severe penalties will be imposed.

Table 1

Penalties for reading while reducing the required amount of memory

Memory fraction	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$
1 pass	1.7	3	6.3	16.6	55
2 passes	15	410	19300	2^{20}	2^{25}
3 passes	3423	2^{20}	2^{20}	–	–

Table 2

Penalties for time while reducing the required amount of memory

Memory fraction	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$
1 pass	2.7	3.5	4.8	6.7	9.2
2 passes	6.7	13.3	27.8	48	74
3 passes	21.7	57	104	–	–

Argon2 scales both in time and in memory. Both parameters can be changed independently, but you should remember that it always takes a certain amount of time to fill the memory.

Argon2 can use up to 2^{24} threads in parallel, but 8 threads use maximum available bandwidth and computing power of an average PC.

Table 3

Characteristics of the average PC

OS Version	Windows 10 x64
System RAM	8 GB
The number of physical cores	4
Clock frequency	3.3 Ghz

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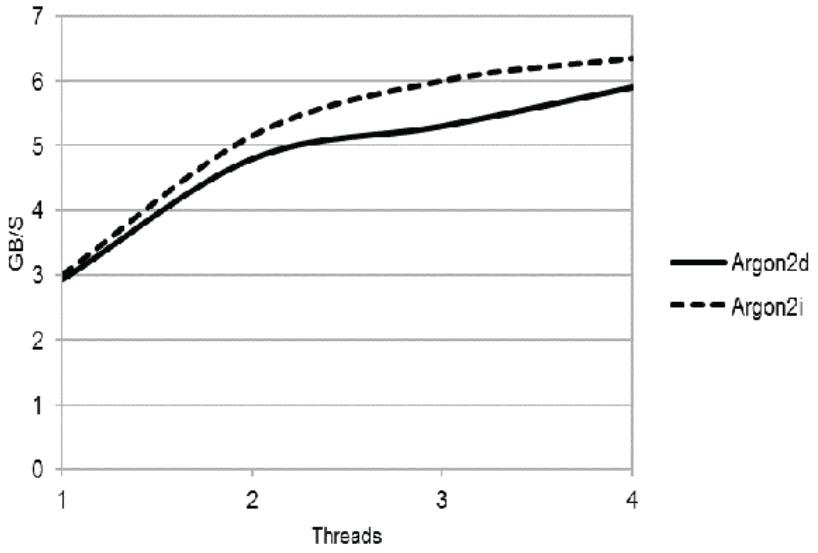

Fig. 3. Memory bandwidth depending on thread

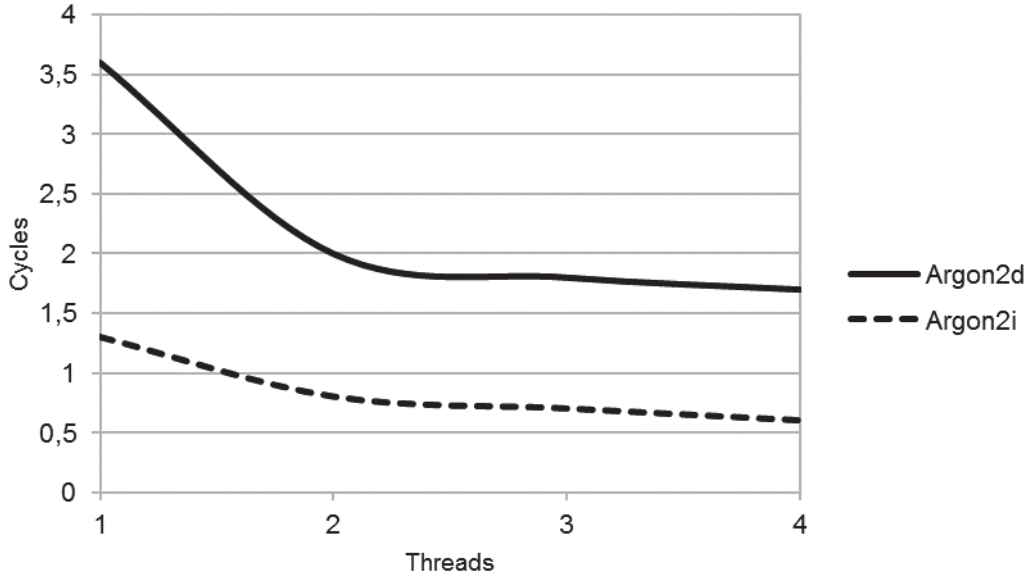

Fig. 4. Performance in cycles per byte depending on thread

Argon2 is optimized for x86 architecture, so its adoption to special equipment will not be either cheap or fast. Even specialized ASICs will require significant space and will not allow decreasing use of time (product of time).

Also Argon2 supports additional input data that is separated from the message and nonce, such as the private key, environment settings, user data, etc.

First, Argon2 hashes the message using the Blake2b hash function. The hash result is written to memory blocks, which are converted using the G compression function (it takes two 8192-bit blocks as input, and outputs a 1024-bit block), and the key is generated as a result.

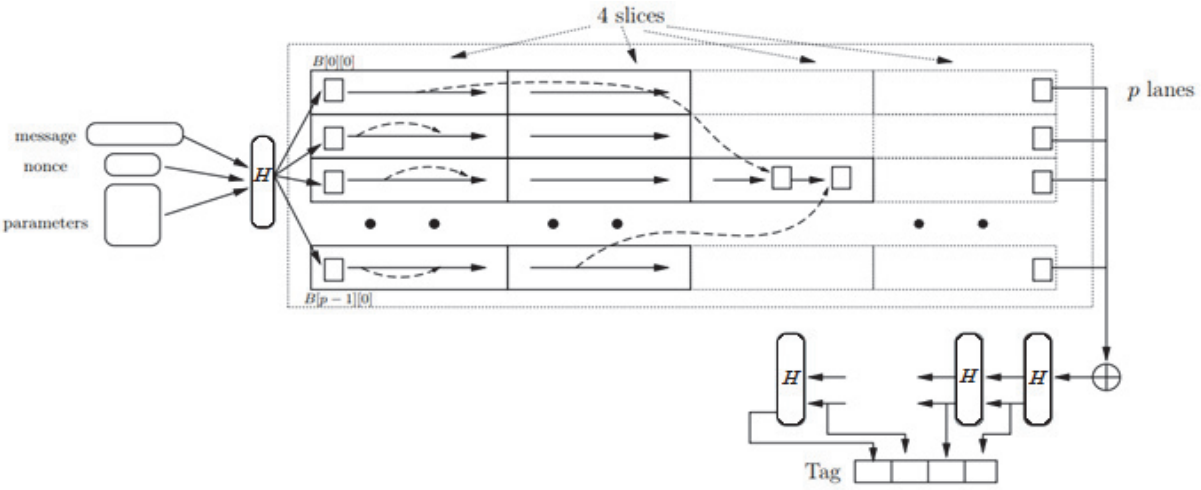

Fig. 5. Argon2 1 memory pass

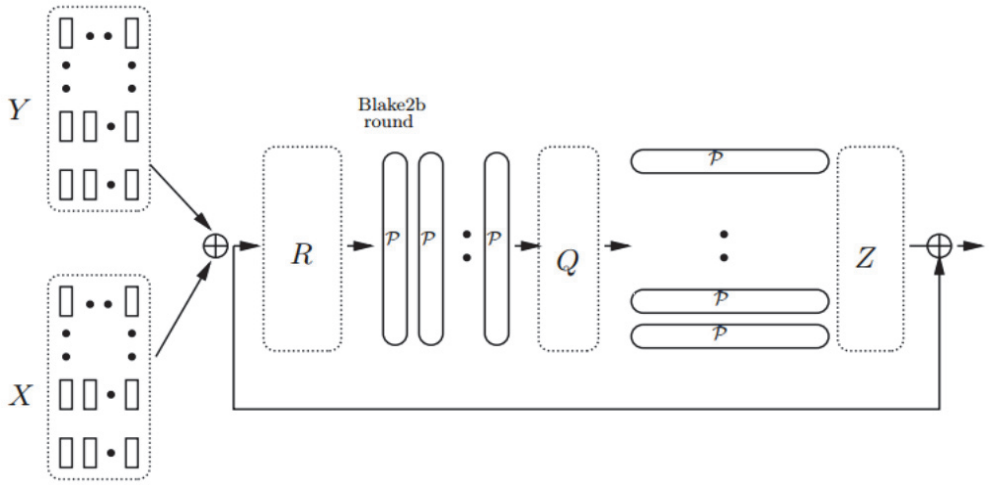

Fig. 6. Compression function

As Ed25519 consists of three of three weakly connected blocks, we can easily swap SHA-512 to Argon2. Thanks to Argon2, you can secure the private key and whole EDS without increasing required computing power, and thanks to Curve25519 the signature size will be only 512 bits.

Conclusion

As a result, it is worth noting that electronic digital signatures have created a completely new level of convenience and secureness for companies all over the world that have dealt with legally binding contracts. What previously was estimated as week for delivery of the contract to the recipient, and then provided the same amount of time to return it signed, now happens instantly. Digital signatures are also much more efficient than sending documents by fax and sending them by courier with a signature, sending documents by e-mail, printing them and scanning signed documents back to a computer.

An electronic digital signature associates a digital sequence with an electronic document as a handwritten signature on a printed paper document. This digital signature should be considered as a handwritten signature. At the core, electronic digital signature is based on using of two different digital keys, known as a pair of keys and two different cryptographic actions. Each pair of keys consists of a private key and a public key. They are interdependent, but can be used separately. Usually, each pair of keys may belong to a specific key holder. The algorithm works in such a way that it is impossible for third parties to calculate the private key, even if they own the public key.

While technology and globalization are growing, electronic digital signatures have become an important requirement for all kind of businesses. In connection with the growing usage of the Internet as an acceptable and truly standard means, there is an urgent need to confirm the growing need for electronic signatures, and therefore research in this area continues, and it is assumed that it should be focused on the need to improve security measures.

REFERENCES

1. EDS — electronic digital sinature. Available at: https://cryptoworld.su/ /ecp-elektronnaya-cifrovaya-podpis-polnyj-manual/ (accessed 23 December 2016);

2. Public-key signatures. Available at: https://libsodium.gitbook.io/doc//public-key_cryptography/ public-key_signatures (accessed September 2018);

3. Algorithm Identifiers. Available at: https://tools.ietf.org/id/draft-ietf-curdle-pkix-06.html (accessed 12 September 2017);

4. Descriptions of SHA-256, SHA-384, and SHA-512. Available at: http://www.iwar.org.uk/comsec/resources/cipher/sha256-384-512.pdf ;

5. Joseph Migga Kizza, Computer Network Security [Department of Computer Science]. Chattanooga, TN, U.S.A., 2005, 534p.;

6. ECM-literacy class, part 1: electronic workflow and archive. Available at: https://habr.com/ru/company/alee/blog/137407/ (accessed 1 February 2012);

7. Aggregate signature implementation based on GOST 34.310-95 and DSTU 4145-2002. Available at: http://pnzzi.kpi.ua/15/15_p82.pdf (accessed 1 November 2007);

8. Breaking Ed25519 in WolfSSL. Available at: https://eprint.iacr.org/ /2017/985.pdf ;

9. Fast and Tradeoff-Resilient Memory-Hard Functions for Cryptocurrencies and Password Hashing. Available at: https://eprint.iacr.org/2015/430.pdf ;

10. The Password Hashing Competition and Argon2. Available at: https://eprint.iacr.org/ 2016/104.pdf ;

11. Argon2: the memory-hard function for password hashing and other applications. Available at: https://github.com/P-H-C/phc-winner-argon2/blob/master/ /argon2-specs.pdf ;

12. High-speed high-security signatures. Available at: https://ed25519.cr.yp.to/ ed25519- 20110705.pdf ;

13. ICT and communication Directive 95/46/EC. Available at: https://ec.europa.eu/eip/ ageing/standards/ict-and-communication/data/directive-9546ec_en(accessed 23 November 1995).

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Evaluating the effectiveness of measures to reduce the level of occupational injuries and occupational disease in the enterprise

Annotation: The article proposes a methodical approach to assessing the effectiveness of measures to reduce the level of industrial injuries and occupational morbidity in the enterprise, taking into account the causal relationships betweenthe implementation of measures and the economic indicators of the enterprise.A mathematical model for the prediction of indicators of industrial injuries and occupational morbidity has been adopted.

Key words: occupational injuries, occupational diseases, occupational health, harmful and dangerous working conditions, predictive model

Problem statement

The most important principle consolidated in the EU legal framework for occupational safety and health is its aim of encouraging improvements in the field of safety and health at work (EU Directive 89/391/EEC). That is, the main focus is not only the protection of workers and the prevention of accidents and occupational diseases, but also improving the state of safety and health. Accordingly, an assessment of the effectiveness of measures to reduce the level of occupational injuries and occupational disease at the enterprise is an important part of the modern system of management of occupational safety.

Analysis of recent research

Unfortunately, in Ukraine, the principle of the protection of workers who work at work with harmful and dangerous working conditions and at work with unfavorable weather conditions prevails. Moreover, in such cases, the main measures are the payment of compensations, allowances for work in hazardous and harmful working conditions, protection by time (reduction of working time), early retirement, free food, etc.

In this approach, workers who are not engaged in hazardous and hazardous working conditions are not entitled to the compensation given, although the risksof occupational disease or injury to the work are high enough or not appreciatedat all.

The existing legal framework is not focused on the implementation of the principle of prevention and improvement of working conditions. Analysis of the risk of occupational diseases and accidents, their impact on the economy of the enterprise is still not widely conducted. The main reasons are the lack of appropriate methodology for assessing the risk and the professional and psychological unpreparedness of specialists in this area.

Analysis of statistical data in recent years suggests that the main causes of occupational injury are:

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- Organizational: insufficiency or lack of training on occupational safety issues; failure to comply with labor safety instructions; violation of technology; poor organization of work;

- technical: malfunction of production equipment; imperfection of technological processes; constructive disadvantages of workplaces;

- psychophysiological: false actions due to fatigue; monotony of labor; morbid condition of the worker; negligence; mismatch of psycho-physiological data of the worker to the work performed.

The main causes of occupational diseases: elevated levels of harmful substances in the air; insufficient or irrational lighting; increased levels of noise, vibration, infra and ultrasound radiation; unsatisfactory microclimate conditions and more.

It should be noted that today in Ukraine a significant number of injuries and occupational diseases are concealed, which has a significant impact on statistical reporting.

Formulation of the problem

On the basis of the foregoing, there is a need for such systems of labor protection management, which would be closely linked with the economic activity of the enterprise and allowed to form economically grounded measures to increase the safety of production.

The main criterion for assessing the effectiveness of safety management in such a system should be the actual magnitude of the risk exposed to workers in their workplaces, which should be constantly compared with the standard permissible level of risk.

The planning of events should be closely linked with the forecasting of the state of the labour protection at the enterprise, which allows: to assess the changes in the state of safety of production in the future; to identify the indicators and factors that have the most significant impact on the level of risk of production processes, to quantify the extent of this impact; to identify possible changes in its structure in the future and to predict the main directions of activity to improve the safety of production; to identify alternative actions to achieve the goal, as well as to formulate the goal itself; to substantiate managerial decisions on optimal distribution of available financial and material resources; to determine the priority of investing in preventive measures.

Presenting main material

The study of the dynamics of quantitative indicators of injury and occupational morbidity makes it possible to determine the patterns of their changes and, with this in view, predict the probable values of the level of indicators within the forecast error. Modeling methods are based on the construction of mathematical and statistical models that reflect the cause-effect mechanism of the process.

The initial data in the calculations are the performance indicators of the enterprise, on the basis of which the mathematical-statistical model for the previous pe-

riod is developed. Economic information on damage from injury and occupational disease should include cost data for the following articles:

- compensation for work in harmful working conditions;
- compensation for the consequences of injuries and occupational diseases;
- coverage of losses due to work in harmful working conditions;
- one-time and operational costs for improving the safety of production.

The methodical approach to assessing the effectiveness of measures to reduce the level of occupational injuries and occupational disease is as follows. The effectiveness of measures to reduce the level of occupational disease in an enterprise is determined by the sum of partial economic effects:

$$C = \sum_{i=1}^{l} c_i, \tag{1}$$

where c_i - economic evaluation i-th indicator of improvement of working conditions at work, l – number of indicators.

The economic effect caused by the reduction of losses due to occupational injuries and morbidity due to harmful working conditions is determined by the formula:

$$c_1 = \sum_{m=1}^{n_1} \Delta D_m \cdot N_m, \tag{2}$$

where ΔD_m - revenue from volume increase m-th type of products in the workplace by improving working conditions; Nm – number of workplaces m-th type, where measures to improve working conditions are implemented.

$$\Delta D_m = (D_1 - D_2) \cdot V_p, \tag{3}$$

where D_1, D_2 - total number of days lost due to illness associated with harmful working conditions before and after events conducted; V_p - average output per worker in the workplace m-th type.

Revenues at the expense of saving on training and retraining in connection with the replacement of workers who fell ill or left due to staff turnover due to hazardous and harmful working conditions, is calculated by the expression:

$$c_2 = \sum_{m=1}^{n_2} N_{m1} Q_m, \tag{4}$$

where N_{m1} - number of workers in the workplace m-th type, requiring retraining due to the replacement of workers who have become ill or have left due to staff turnover caused by dangerous and harmful working conditions; Q_m - the average industry expenditure on re-training one worker in the workplace m-th type.

The income caused by the decrease in the amount of compensation for work in harmful working conditions due to the improvement of its conditions, is determined by the formula:

$$c_3 = \sum_{m=1}^{n3} \Delta T_m Q_m, \tag{5}$$

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where ΔT_m - Reducing the number of workers in the workplace *m*-th type that work in harmful working conditions; Q_m - the amount of compensation for work in harmful working conditions in the workplace *m*-th type.

Income due to a decrease in the value of compensation for the consequences of injuries and occupational diseases, is determined by the formula:

$$c_4 = \Delta Y_1 \cdot K_1 + \Delta Y_2 \cdot K_2 \quad (6)$$

where ΔY_1 – the predicted value of reducing the number injured due to the introduction of measures to improve the safety of production, K_1 – the average size of the compensation of the consequences of trauma; ΔY_2 – the predicted value of reducing the number of occupational diseases by introducing measures to improve the safety of production, K_2 – the average size of the reimbursement of the consequences of occupational diseases by industries.

Expenditures on the implementation of measures to improve the safety of production are determined by the formula:

$$c_5 = -\sum_{m=1}^{m_1} W_m \cdot N_m, \quad (7)$$

where W_m - average costs for implementation of safety improvement measures at the workplace *m*-th type; N_m – amount of workplaces *m*-th type, on which measures to improve the safety of production are implemented.

To predict the level of occupational morbidity and injury, data is collected on the number of victims per n previous years. Mathematical model for determining the increment of the number of the indicator y_j can be represented as a system of differential equations:

$$\begin{aligned} \frac{dy_j}{dt_1} &= \sum_{i=1}^{6} a_{1i} \cdot y_i + F_{1j}(t_1) + F_{2j}(t_2) \\ \frac{dy_j}{dt_2} &= \sum_{i=1}^{6} b_{1i} \cdot y_i + R_{1j}(t_1) + R_{2j}(t_2), \end{aligned} \quad (8)$$

where Y_j – modeling index; $F_{1j}(t_1)$, $R_{1j}(t_1)$ - the function of taking into account the monthly trendy; $F_{2j}(t_2)$, $R_{2j}(t_2)$ - the function of taking into account the annual trend, t_1 – serial number of the month and t_2 - ordinal number of the year in the model.

Having constructed differential equations for the indices, we obtain a system of linear homogeneous equations of the first order, which can be solved by numerical methods. The predicted value of the simulated indicator will look like:

$$y_{j\text{прогн}} = y_j + \frac{dy_j}{dt_1} \cdot \Delta t_1 + \frac{dy_j}{dt_2} \cdot \Delta t_2. \quad (9)$$

To construct the mathematical model of the indices, the conditions must be fulfilled - the quantity Y is normalized and its dispersion is constant. The normality of the distribution of indicators is provided by an unlimited set of factors through the use of the central boundary theorem.

When constructing a forecast model, the region of factors changes is determined which, in the general case, should correspond to the scale of those indicators, whose values are calculated as output data for predictive models. These requirements do not apply to the non-stationary part of the model, since in this case we are dealing with extrapolation over time (that is, we investigate the effect of the nonlinear time trend).

Conclusions

The proposed methodology allows to assess the effectiveness of the plan of measures to increase the safety of production, taking into account the causal relationships between the implementation of measures and economic indicators of the enterprise.

Estimates obtained using methods of forecasting and economic analysis of measures to reduce the level of injury and occupational disease, are only a basis for the adoption of a final decision on the management of occupational safety and health of the enterprise. In addition, additional criteria, including informal, may be taken into account. The proposed approach allows to proceed to the next stage - creation of an automated control system of labour protection in the enterprise, based on scientifically grounded methods for assessing the effectiveness of measures to reduce the level of occupational injuries and occupational disease.

REFERENCES

1. Національний профіль з безпеки та гігієни праці. Україна 2018. Міжнародна організація праці. URL : http//www.ilo.org/UkraineEUProject.

2. Кружилко О.Є., Майстренко В.В., Полукаров О.І., Демчук Г.В. Оцінка ефективності управлінських рішень у сфері охорони праці. *Проблеми охорони праці в Україні.* 2015. Вип. 29. С. 3–9.

3. Кружилко О.Є., Сторож Я.Б., Ткалич І.М., Полукаров О.І. Підвищення ефективності управління охороною праці на основі виявлення небезпек та оцінки ризиків виробничого травматизму. *Адаптивні системи автоматичного управління*. 2017. Вип. 2 (31). С. 38–45.

4. Оценка рисков на рабочем месте : практическое пособие : [перевод с финского] Мерви Муртонен; [науч. ред. : Г. З. Файнбург]; VTT-техн. исслед. центр Финляндии, М–во социал. обеспечения и здравоохранения Финляндии, Отд. охраны труда. – М.: Международная организация труда, 2011. 63 с.

5. МОТ. Окружающие факторы на рабочем месте. Инструкция МОТ. Женева, Бюро Международной Организации Труда, 2001 (ISBN 92-2-111628-X).

6. Парменова Д.Г. Систематизация факторов опасности для построения профиля риска судових работ. *Науковий вісник Херсонської державної морської академії.* 2014. № 1. С. 30–35.

7. Кружилко О.Є., Богданова О.В. Алгоритм вибору методів та визначення результативності оцінки ризику. *Вісник Кременчуцького національного університету імені Михайла Остроградського. Екологічна безпека.* 2016. Вип. 2 (97). С. 76–81.

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O. Kruzhylko, I. Tkalych, A. Polukarov

IMPROVEMENT OF OPERATIONAL MANAGEMENT OF HYGIENE AND LABOR SAFETY ON THE BASIS OF ASSESSMENT OF OCCUPATIONAL HAZARD

Abstract: The purpose of the work is to provide grounds for the approach to the occupational hazard assessment. To complete the purpose, it is proposed to analyze the existing methods and approaches to the occupational hazard assessment and an approach to the occupational hazard assessment is proposed, which is based on the use of statistics on occupational injuries rates. The necessity of application of information systems for occupational hazard assessment is emphasized.

Keywords: hygiene and labor safety, occupational hazard, operative management, planning, information system.

Articulation of issue

The process of adaptation of the Ukrainian legislation on labor protection to European and international legislation is underway, and the use of world scientific and practical experience and deepening of international cooperation in the field of labor protection is intensifying. In order to create a national system for preventing occupational hazard, the “Concept for Reforming the System of Labor Protection Management in Ukraine” [1] has been developed to ensure the effective implementation of workers' rights to safe and healthy labor conditions. Implementation of the Concept will ensure the formation of a new national system for prevention of industrial risks by introducing a risk-oriented approach in the field of occupational safety and health at the legislative level.

Analysis of recent research and publications

As evidenced by the analysis of scientific works, operative management of labor protection during the development of measures to reduce occupational injuries is performed on the basis of an analysis of the causes and types of events that led to accidents, considering the data on the circumstances of accidents and data on the victims [2, 3, 4]. Standards of the OHSAS series are designed to provide elements of an effective system for managing occupational hazard. These elements can be integrated with other management requirements. They can assist organizations in achieving hygiene and safety objectives and can also be used to determine economic outcomes.

Purpose of work

To conduct research on the main methods of assessment of occupational hazard and to develop and substantiate the approach to the risk assessment of an occupational accident for the practical use.

Presentation of the main material and research results

The State Standard of Ukraine DSTU OHSAS 18002:2015, adopted in Ukraine, sets requirements for a safety and health management system (SHMS) to enable the organization to control the hazard connected with occupational safety and health [4]. Organizations and enterprises of various types of economic activity are increasingly interested in achieving good results in the field of hygiene and safety, through the active use of methods for managing occupational hazard. At the same time, even modern methods of occupational hazard management cannot be sufficient and effective if they are not integrated into the overall system of enterprise (organization) management.

Implementation of SHMS at enterprises, developed with consideration of the requirements of the State Standard of Ukraine DSTU OHSAS 18002:2015, ensures the following: implementation of national laws and regulations; proper organization of all types of work on occupational safety; risk reduction for occupational accidents and diseases; reduction of expenses related to labor protection (including – punitive sanctions). In accordance with this standard, the basis of the SHMS should become the identification and assessment of the risk of occupational accidents and diseases. Evaluation of the results of activities with consideration of the occupational hazard assessment can become an effective motivating factor in stimulating the owners of enterprises in performing activities aimed at creating safe and harmless labor conditions.

The transition to a SHMS, based on the occupational hazard assessment, necessitates appropriate scientific developments. Despite a sufficiently large number of hazard assessment methods, they cannot be considered acceptable for the enterprise of any particular type of economic activity. At the same time, the analysis of existing methods and approaches to the estimation of occupational hazard allows us to conclude that it is necessary to adapt them to the characteristics of enterprises considering their branch affiliation (type of economic activity) and further substantiation of management decisions on hazard level reduction.

The assessment of the risk of injury is proposed to be conducted with consideration of the probability of an accident occurrence and assessment of its consequences. Such an approach to the occupational injury assessment is calculated as the product of the probability of occurrence of the occupational injury event and the extent of the expenditures inflicted (in value terms). The peculiarity of this approach is that it proposes the possibility of comparing the indicators of the frequency of fatal and non-lethal injuries.

The occupational injury risk assessment is based on the identification of the main factors that affect the safety of the production most. According to research results, algorithms designed to analyze the safety of production based on procedures for calculating occupational hazard levels can be developed. Practical implementation of such algorithms is possible with the use of specialized computer programs that allow automating the calculations of the probability of emergencies, hazardous situations, occupational accidents, to determine the risk of these events for staff.

In modern conditions, operational hygiene and safety management approaches are more effective, based on the use of data not only of a particular enterprise, but also of other enterprises belonging to the same type of economic activity. The calculations are performed on the basis of factors determined by a priori analysis. In the future, there is a possibility of transition to the development of corresponding mathematical models that will allow modeling the dynamics of occupational hazard indicators, and modeling results will provide grounds for the plan of operational measures regarding labor safety. When planning preventive measures on the basis of the calculated risk indicator, first of all, such measures shall be chosen that must provide the greatest socio-economic effect at the lowest cost.

It is proposed to calculate the risk that one employee (of specific profession) of the company (of specific type of economic activity) will suffer an accident R_H with temporary disability by the formula:

$$R_H = P_H \cdot K, \tag{1}$$

where P_H – the probability that with one employee of a given profession in this type of economic activity in a year, one accident may occur with different material losses for a certain period;

K – coefficient of disability, with consideration of the number of lost working days in the total amount of working days worked in this profession of this type of economic activity for the same period.

The introduction of the coefficient K for the further calculation of the overall risk of an accident with various material losses – from an accident without loss of working days (transfer to light labor) to a complicated one makes it possible to objectively account for these differences.

The probability that one worker per year may experience one accident with different consequences is calculated by the formula:

$$P_H = 1 - e^{-\lambda_H}, \tag{2}$$

where λ_H – the frequency of an accident with a disability for a given profession in this type of economic activity during the year.

The coefficient of loss of labor ability, with consideration of the number of lost working days in connection with accidents in the total amount of working days worked for the same period, is calculated by the formula:

$$K = \frac{Д_{CP}}{Ч_{CP}}, \tag{3}$$

where $Ч_{CP}$ – the average annual number of employees in this type of economic activity;

$Д_{CP}$ – the average number of lost working days as a result of temporary disability of employees of the profession in this type of economic activity.

In practice, after receiving all the necessary data, the calculation of an accident risk is performed. In the event that it is higher than the average in the main type of economic activity, it indicates the need for preventive measures.

However, the practical implementation of the proposed approach requires the availability of specialized information systems and up-to-date databases on occupational injuries. As an example of the occupational hazard assessment, consider using the information system [5]. Initial data entry is entered, with further occupational hazard calculation for each event and the subsequent ranking of events by reducing the amount of hazard is automatically performed (Figure 1).

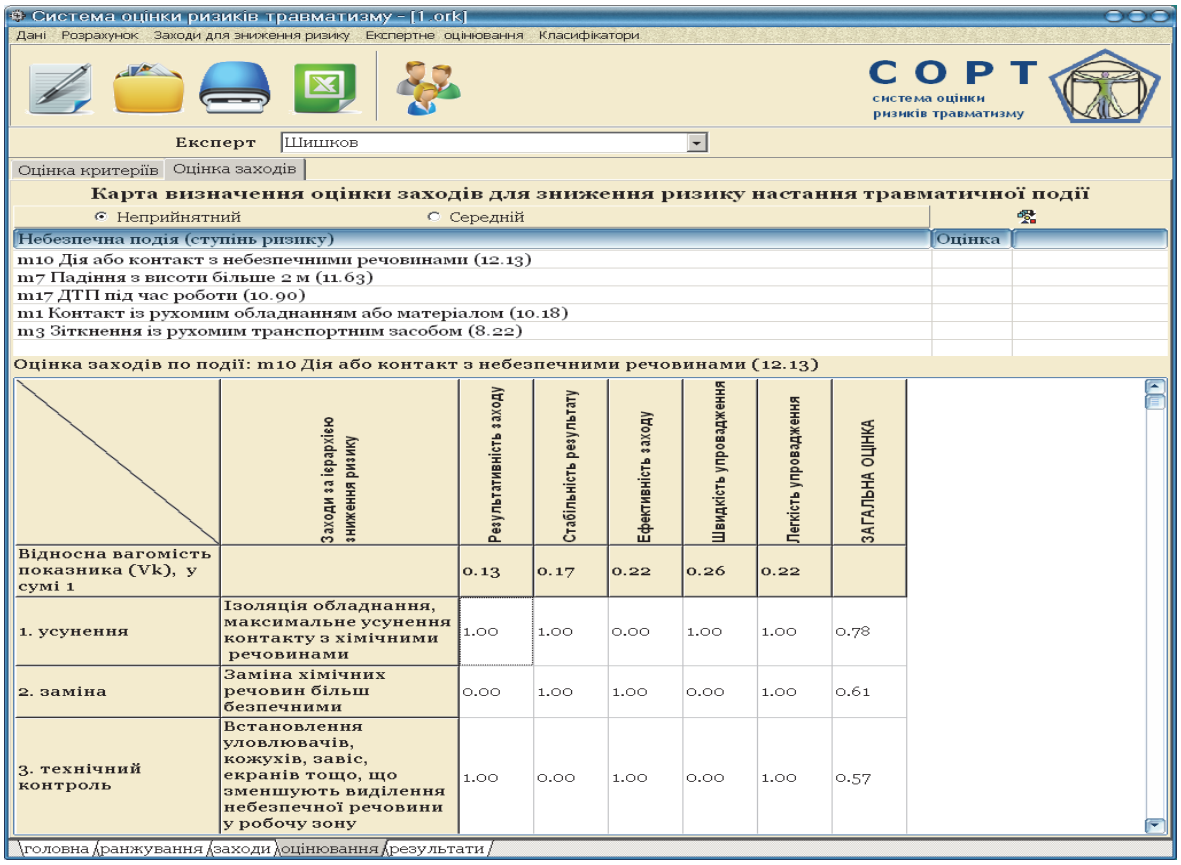

Fig. 1 – Information system of occupational hazard assessment

Upon forming arrays of activities, their grouping by the level of risk is performed. Formation of a set of measures for risk level reduction is performed separately for each group. The measures are entered manually or by copying from the corresponding electronic documents. Subsequently, their expert evaluation is performed.

Conclusions

The basis of reasonable planning and implementation of effective preventive measures is the identification of dangers existing at work and an adequate occupational hazard assessment. However, the hazard assessment process, as the basis for the hygiene and safety management system, requires a complex of scientific research. Hazard assessment should be based on the sectoral affiliation of enterprises (type of economic activity). An approach to the estimation of occupational hazard

is proposed, which is based on the use of statistics on indicators of occupational injuries. The necessity of application of information systems for occupational hazard assessment is emphasized.

The result of the implementation of a risk-oriented approach in the field of occupational safety and health should be the increase of the labor safety level, prevention of emergencies and accidents, the reinforcement of the occupational injuries and occupational disease prevention.

REFERENCES

1. Про схвалення Концепції реформування системи управління охороною праці в Україні та затвердження плану заходів щодо її реалізації : Розпорядження Кабінету Міністрів України від 12.12.2018 р. № 989-р. URL: https://zakon.rada.gov.ua/laws/show/989-2018-%D1%80?lang=ru (дата звернення 20.03.2019).

2. Бочковський А.П. Теоретичні аспекти універсалізації оцінки професійного ризику в системах управління охороною праці. Вісник Львівського державного університету безпеки життєдіяльності. 2016. № 14. С. 134–151.

3. Кружилко О.Є., Богданова О.В. Алгоритм підготовки управлінських рішень на основі комбінованого методу оцінки ризику виробничого травматизму. Наукові праці Національного університету харчових технологій. 2016. № 3 (том 22). С.140–149.

4. Безручко О.О. Особливості управління економічним потенціалом підприємства в умовах мінливого зовнішнього середовища. Вісник Кременчуцького національного університету імені Михайла Остроградського. Економічні науки. 2014. Вип. 1/2014 (3). С. 96–107.

5. ДСТУ OHSAS 18002:2015. Системи управління гігієною та безпекою праці. Основні принципи виконання вимог OHSAS 18001:2007 (OHSAS 18002:2008, IDT). [Чинний від 01.04.2016]. Вид. офіц. Київ: ДП «УкрНДНЦ», 2016. 60 с.

6. Кружилко О.Є., Богданова О.В. Наукові та практичні аспекти застосування інформаційної системи оцінювання виробничого ризику. Теорія і практика будівництва. 2015. № 16. С. 38–42.

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HYBRID APPROACH TO THE FORECASTING OF ELECTRIC CONSUMPTION TIME SERIES FOR ORGANIZATIONAL MANAGEMENT IN THE WHOLESALE MARKET

Abstract: The improvement results of the hybrid approach to design of time series forecasting models with an uneven distribution of values of the electric consumption indicator in solving organizational management problems in the wholesale electricity market are presented.

Keywords: hybrid approach, time series forecasting, electric consumption processes, organizational management, wholesale electricity market.

Introduction

The problem of a significant increase in the energy efficiency of using electric energy - electric consumption is one of the main problems at the current stage of development of the electric power industry. The possibility of its effective implementation is directly related to the solution of the complex of tasks of managing electric consumption planning by electricity supplier companies - subjects of the organizational management system of the wholesale electricity market (WEM) [1].

These tasks also include the preparation of a daily schedule of electric consumption by wholesale suppliers, which they must submit to the WEM in the form of an hourly request for the amount of electric consumption in accordance with the regulations of its Rules. This schedule is used as input data for the sequential solution of subsequent tasks of the organizational and operational dispatch management aimed at ensuring reliable and cost-effective coverage of the declared volume of capacity by generating companies - electric power producers.

The technological process of electric consumption planning includes two levels. At the first level, planning is carried out directly by enterprises - end users. At the second level, planning is carried out by electric suppliers based on the use of data on the forecast of electric consumption received from enterprises of the first level. The plan of electricity consumption drawn up by them is drawn up in the form of an application and is submitted to the WEM at the time of day determined by the regulations.

The problem of planning electric consumption has been studied for many years in relation to enterprises in various industries. And in recent years, quite a lot of works has been devoted to solving this problem, as applied to the peculiarities of their functioning in market conditions [2-5]. The proposed methods of planning electric consumption are currently used in many industrial enterprises. Usually they are focused on a certain period of time during which no significant changes in production volumes occur in accordance with the prevailing conjuncture in the industry markets.

However, the peculiarity of market relations is that these changes may occur at different times in different industries. Therefore, to solve the problem of plan-

ning electric consumption, it is necessary to apply methods that use mathematical and information technological tools for the current assessment of electric consumption, taking into account the influence of market conditions on the functioning of enterprises [6]. The issues of systematization, analysis of existing methods of electric consumption planning at enterprises of various sectors of the economy and the creation of sound calculation methods that meet modern requirements for the accuracy of electric consumption planning is the subject of an self study. And in this paper they will not be considered.

The forecast data of electric consumption of a separate regional supplier constitutes the basic source information for carrying out all subsequent calculations in forecasting and planning deliveries by electricity producers to the WEM with the aim of forming trading and dispatching active load schedules for the «day-ahead» market [7].

1. Problem analysis and formulation of research objectives

In condition of operation of the electricity market, which received the meaningful name of the bilateral contracts market and the balancing market, mechanisms are provided to compensate for additional expenses in the power system by those suppliers whose declared volumes exceed the absolute value of the tolerances from actually volumes of consumed electricity. This circumstance should encourage electricity suppliers to use modern tools for modeling and forecasting electric consumption, used in the preparation of hourly planned electric consumption schedules for the next day to improve the quality of the forecast. Such hourly electricity planning based on the use of modern forecasting tools by suppliers is of interest not only for them, but also for large enterprises - qualified end-users of electricity.

When solving the problem of daily electric consumption planning at the level of electricity suppliers, certainly, a more detailed structure of electric consumption in the region of a particular supplier should be taken into account. According to various studies, it is the daily irregularity of electric consumption, along with seasonal irregularity, that largely determines the forecasting accuracy of electric consumption schedules [8].

The structure of the regional industries for a separate supplier is usually known. Planning of electric consumption by suppliers, taking into account the peculiarities of electric consumption in the production process by enterprises of these industries, is a rather difficult task [9]. Quite a large number of papers, the analysis of which is given in [10], are devoted to research related to electric consumption planning at the supplier level. Basically, they are designed to solve very important and complex tasks of medium-term and long-term forecasting of electric consumption. However, not always the data of such a forecast can be used to plan electric consumption for the coming day.

Determination, further study and consideration of the multifaceted influence of deterministic, quasi-deterministic and random factors on the results of electric consumption forecasting, in order to improve their quality, necessitates the devel-

opment of new tools for mathematical and computer modeling based on the integration of statistical analysis methods, expert and artificial intelligence methods.

Therefore, the main objective of this paper is the development of mathematical modeling tools for dynamic, operational hourly forecasting for the coming day and planning electric consumption by electricity suppliers a day ahead in the wholesale market.

Currently, in many power systems of the world, when creating forecasting models, statistical methods are used to analyze dynamic time series, reflecting an ordered sequence of observations of a time-varying process [11]. Their practical implementation to reduce the error of calculations requires the collection, storage and further use of significant amounts of the original historical data of hourly actual electricity production. And to identify and correct errors, maintain a certain level of correctness, the implementation will require taking into account other factors that affect the forecast result, and as a result, the use of additional data.

An analysis of a number of studies carried out in [12] allows us to conclude that there is no universal method that could solve the problem of forecasting the characteristics of random processes of various natures. However, approaches have been developed, the use of which in solving specific applied problems makes it possible to build a prognostic model that provides reasonable reliability and accuracy for practice [13].

One of these is an approach based on the use of hybrid methods for constructing the forecasting models. To determine the numerical values of the predicted values at given points, an unformalized mathematical model of the required dependency is used, the constructing possibility of which is provided by applying a hybrid computational algorithm based on the joint use of the artificial neural network apparatus (ANN) and the genetic algorithm (GA). The experience of developing and applying such a technique for building the forecasting models is described in [14]. However, the quality of ANN application essentially depends on the completeness and reliability of the training sample, which is formed from the prepared initial retrospective data. Therefore, retrospective data must be first processed, i.e. filtering and normalization to ensure the specified conditions of use.

The aim of this paper is to improve the hybrid approach to the development of non-formalized mathematical models of electric consumption forecasting of a large regional supplier based on the combined use of modern information technologies deals with the ANN apparatus, GA and Kalman filters, which provide the required quality level of the forecasting process.

The need to improve the quality of forecasting the production and consumption of electricity is due not only to technological, but also economic reasons that are no less important in the conditions of market competition.

2. Time series formalization of electric consumption processes

As it is known, many authors [15] use the so-called additive form of the model to solve the forecasting problems of electric consumption and active load:

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$$P(t) = U(t) + V(t) + C(t) + E(t),$$

where $P(t) = (P^{act}(t_i^j) \mid i = \overline{1,N}, j = \overline{1,24})$ is a generalized time series of the actual hourly values of electric consumption (for *j*-th hour of the *i*-th day) of a regional company that supplies electricity for *N* days; $U(t)$ is a trend component; $V(t)$ is a seasonal component; $C(t)$ is a cyclic component; $E(t)$ is a random component of the time series.

The selection of interrelated trend, seasonal and cyclical components of the time series is a separate and very difficult task. The assumption of their additivity in the distribution, and further use of these components for solving problems of electric consumption forecasting, may introduce an additional error, which is difficult to take into account. Therefore, in this paper, in order to solve the problem of forecasting electric consumption, studies have been conducted of the possibility of using the time series model in the form:

$$P(t) = F(U(t), V(t), C(t)) + E(t),$$

where $F(U(t), V(t), C(t))$ is a unknown function of the three components.

To determine the numerical values of the predicted values at given hour points *j*, we will use a non-formalized mathematical model of the unknown function *F*, the possibility of constructing which is provided by applying a hybrid computational algorithm based on the sharing of the ANN apparatus, GA and Kalman filter.

Obviously, the members of the time series formed from the actual electric consumption data, in addition to the trend, seasonal, cyclical components, also contain a random component, which reflects the influence of hard-to-count factors on the electric consumption process. Its presence in the training sample data when building an ANN can significantly affect the result of network training, and, therefore, the quality of the forecast. Therefore, before using the actual data for the training process of a neural network, it is necessary to carry out their preliminary preparation as filtering, in order to eliminate the influence of random parts of the time series members on the training process.

It is known that the use of statistical methods for these purposes provides only the alignment of the time series components. At the same time, their random components are definitely distributed, but not separated from the main component. Therefore, at this stage of the study, a simplified version of the Kalman filter [16] was used to filter the time series members in order to precisely separate the random component of the time series components.

An example of the manifestation of a random component can be the case when an unknown value of the control action of the dispatch control of electric consumption leads to a deviation of the actual dispatching schedule of electric consumption from the planned one. We will carry out the further reasoning for a one-dimensional time series constructed for the *j*-th hour for *i* days of observations.

Let $X_j = (P^{act}(t_i^j) \mid i \in I)$ is the actual electric consumption data of the *j*-th hour for *I* days and $Y_j = (P^{pred}(t_i^j) \mid i \in I)$ is the forecast electric consumption data and $Z_j = (P^{plan}(t_i^j) \mid i \in I)$ is the planned schedule of electric consumption.

According to the WEM Rules, the planned schedule of electric consumption is compiled on the following day based on the data of the electric consumption forecast by large regional consumers and suppliers taking into account the meteorological conditions for the next day, current and retrospective weather conditions, actual data of electric consumption in previous periods and other external factors that may affect on electric consumption process. The actual schedule of electric consumption is implemented on the basis of the planned schedule by dispatch center during the implementation of the centralized operational and technological management of the integrated power system. Dispatch center on the basis of the online network status information and producers accident information should change the specified planned schedule. As a result, we present the forecast, planned and actual data of electric consumption in the following form:

$$Y_j = F^Y(U_j, V_j, C_j),\ Z_j = F^X(Y_j) + E_j^X,\ X_j = Z_j + D_j,$$

where F^X, F^Y are the values formed from the main components of the time series of the actual and forecast electric consumption schedules, E_j^X is the random component of external factors affecting the electric consumption process, D_j is the random component of the deviation of actual dispatch schedule from the planned one.

It is necessary to select time series of actual data, the filtered components of which do not contain random components. Denote this data as $X_j^{main} = X_j - E_j^X - D_j$, which will be used for training the neural network.

To form the series X_j^{main}, we will use the simplified Kalman filter of the following form:

$$X_{j+1}^{main} = K * X_{j+1} + (1-K) * X_j^{main} \quad (1)$$

The coefficient K must be determined from the condition $\min | X_{j+1}^{main} - X_{j+1} |$. At the same time, we will take into account the fact that the actual electric consumption data is much more accurate than the forecast one, although they contain a random component. Based on the same considerations, we assume that $X_1^{main} = K * X_1 + (1-K) * X_1 = X_1$. And all the following components of the desired series are determined by the formula (1).

3. Technique for constructing a non-formalized hybrid forecasting model

In general, the electric consumption forecasting model is represented by the following dependency:

$$P^{pred}(t_i^j) = F\left(P_{main}^{act}(t_{i-1}^j), \ldots, P_{main}^{act}(t_{i-n}^j), T_i\right),$$

where $P^{pred}(t_i^j)$ is the forecast value of electric consumption, $P_{main}^{act}(t_{i-1}^j), \ldots, P_{main}^{act}(t_{i-n}^j)$ are the filtered actual values of electric consumption for $n \in N$ previous days of observations, T_i is the set of external factors affecting electric consumption.

The use of external factors in forecasting improves the accuracy of the forecast. In this case, the more factors taken into account, the higher the accuracy of the

forecast. The categories of groups of days of the week, temperature and climatic factors, seasonality, etc. are considered as external factors.

Taking into account the fact that on different days of the week, electric consumption schedules may differ significantly, we select from the series $P(t)$ the following sample of values for groups of days of the week, during which daily consumption schedules can be taken such that they have approximately the same, both quantitative and qualitative changes:

1) $X^M = \left(\left(P_{main}^{act}(t_i^j) \,|\, i \in I^M \right) |\, j = \overline{1,24} \right)$ is an array of 24 time series for mondays and before holiday days I^M;

2) $X^W = \left(\left(P_{main}^{act}(t_i^j) \,|\, i \in I^W \right) |\, j = \overline{1,24} \right)$ is an array of 24 time series for working (regular) days I^W;

3) $X^H = \left(\left(P_{main}^{act}(t_i^j) \,|\, i \in I^H \right) |\, j = \overline{1,24} \right)$ is an array of 24 time series for weekends and holidays I^H.

A distinctive feature of the proposed technique for building a hybrid forecasting model is that for each selected group of days, a separate sample of 24 daily-hour time series is constructed on actual historical data on electrical consumption for a certain number of days, which is determined by the forecast quality requirements. Moreover, a mathematical model of the total daily consumption $\tilde{Y}^r = \left(\sum_{j=1}^{24} P_{main}^{act}(t_i^j) \,|\, i \in I^r \right), r \in \{M, W, H\}$ for each of the days of the selected group's *r* is being built simultaneously.

The idea of building such a horizontal-vertical structure (Fig. 1) of a mathematical model of a time series system was used in [17, 18]. The choice of just such a method of forming a sample of initial data is due both to the technological features of the wholesale electricity market operation in its purchase mode for the day ahead, as well as the methodological features of building a neural network model when choosing an activation function and the need to check the adequacy of network training in the hourly and daily consumption for each selected groups of days.

Thus, for the purpose of forecasting electric consumption of a regional supplier, it is necessary to form three groups of time series X^r - training samples of 24 representative hourly series in each, as well as three series $\tilde{X}^r$ - daily volumes of actual electric consumption for training in the corresponding neural networks.

Next, the GA is used to search for a solution to the optimal ANN topology in order to accelerate the process of its learning. Using the GA, a population of neural networks is distinguished in which each individual represents a separate ANN [19]. During population initialization, one half of the individuals are randomly assigned. The genes of the second half of the population are defined as the inversion of the genes of the first half of the individual (genome). This allows to evenly distributing the bits "1" and "0" in the population to minimize the likelihood of early convergence of the algorithm.

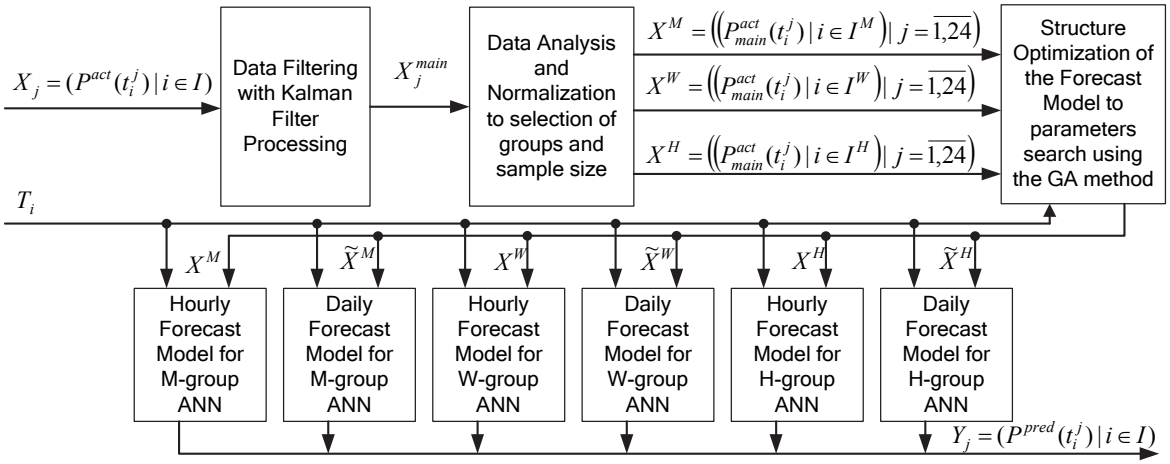

Fig. 1 Hybrid scheme of a complex of mathematical tools for constructing generalized nonlinear multifactor models

After initial initialization, networks without hidden neurons are encoded in the genes of all individuals. Moreover, all input neurons are connected to each output neuron. That is, at first all presented ANNs differ only in weights of interneuron connections. In the evaluation process, based on the genetic information of the individual being considered, a neural network is first constructed, and then its performance is checked, which is determined by the individual's fitness. After evaluation, all individuals are sorted in order of decreasing fitness. A more successful half of the sorted population is allowed to cross. And the best individual immediately goes into the next generation. In the reproduction process, each individual is crossed with a randomly selected individual from among the selected individuals for crossing. Two formed descendants are added to the new generation. After the new generation is formed, the mutation operator starts working. Since the selection made by cutting significantly weakens the diversity within the population [20] and leads to the early convergence of the algorithm, the probability of mutation about 15-25% is quite large. If the best individual in the population does not change for more than 7 generations, the algorithm is restarted. During the restart, the entire population is reinitialized and the process of finding a solution starts from the beginning. Thus, there is a way out of local minima due to the relief of the objective function, as well as a large level of individuals in one generation [21].

A distinctive feature of this algorithm is that the number of hidden neurons is theoretically unlimited, unlike the one proposed in [21, 22]. To regulate the size of the resulting networks, two coefficients are used, which allow, at the mutation stage, to adaptively choose which type of structure transformation is more suitable for this network.

In practice, several methods are used to encode information about the neural network in the individual’s genotype [23]. The presented algorithm uses link coding. In addition, each gene contains information about the indices of the initial and final neuron of the link, as well as the weight of their link (Fig. 2).

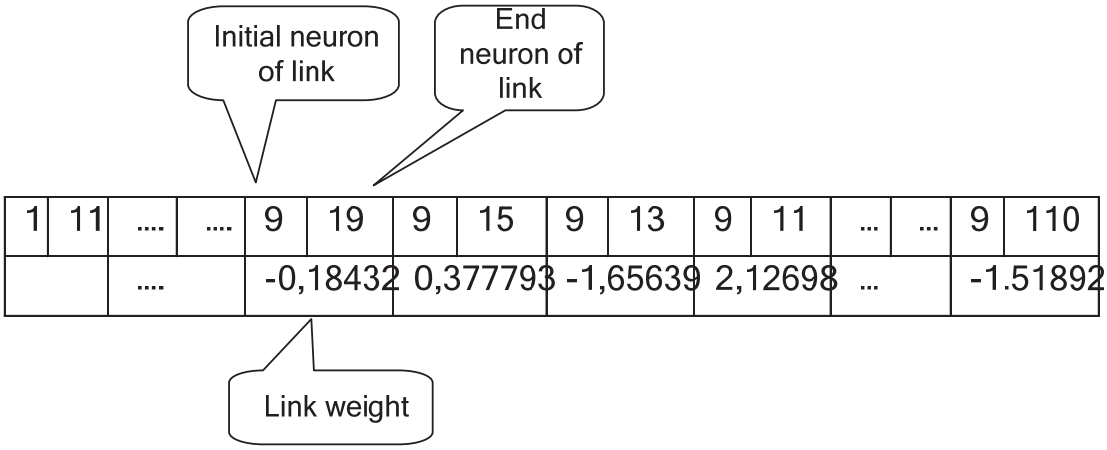

Fig.2 ANN Coding

It is obvious that the chosen coding technique requires special genetic operators that implement crossing and mutation. When performing the crossing, two parents are used, which produce two descendants. Common neurons and links are inherited by both descendants, and the value of links in the network of descendants is formed using a two-point crossover [24]. ANN elements that differ are distributed among descendants. The example of crossing is shown in Fig. 3. The solid lines show the common neurons and links, the dotted ones are those that differ. An important feature is that neurons with the same indices are considered identical, despite the different placement and number of links in the network. It is also important that one of these neurons may have a different index, which will change as a result of the correction of the indices after mutation.

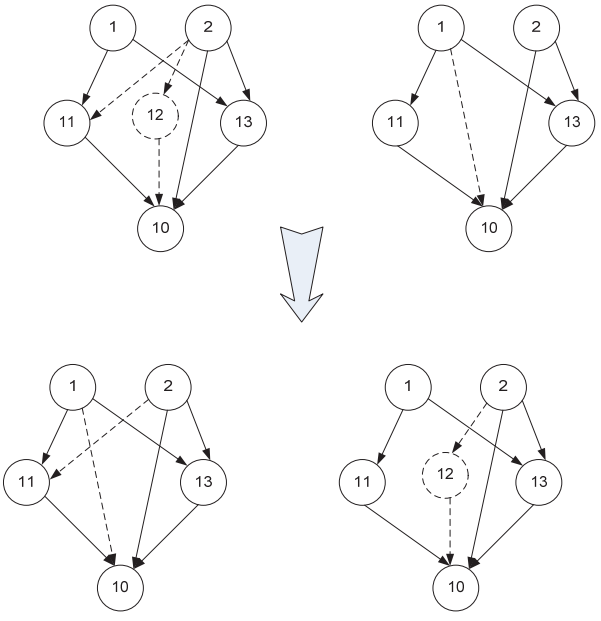

Fig.3 Example of Crossing

Mutation can be of several types:

- adding a hidden neuron with the assignment of the index [*N*-1], where *N* is the number of hidden neurons in the network after the addition;
- deleting a randomly selected hidden neuron along with all input and output links;
- adding a link;
- deleting a randomly selected link;
- changing in the weight of a randomly selected link by a random value from the range [-0.5; 0.5].

Thus, using a mutation, one can change the parameters of the ANN structure point by point. Accidental addition or removal of neurons and links can lead to situations where there will be many neurons and few links in the network. Therefore, it will be more logical to apply different types of mutations depending on the characteristics of the network architecture that an individual represents after a mutation. To do this, you must enter the coefficients that regulate the size and direction of network change.

One of them characterizes the degree of "connectivity" of neurons in the network and is calculated by the formula:

$$f_C = \frac{N_C}{2^{FB-1}\left[N_N(N_N-1) - N_I(N_I-1) - (1-FB)N_O(N_O-1)\right]} \quad (2)$$

where N_C is the number of links in the network; N_I, N_O, N_N are the number of input and output neurons and the total number of neurons in the network, respectively; FB is the flag indicating the presence ($FB = 1$) or absence ($FB = 0$) of feedback.

It is worth noting that links from hidden neurons to output neurons may appear randomly. Thus, the smaller the coefficient f_C, the more likely a new link will be added as a result of the mutation.

The use of the second coefficient is based on the assumption that the more elements as a result in the input and output vectors of the training sample (input and output neurons), the more likely it is that a more complex network will be required to solve the problem. The second coefficient is calculated by the following formula:

$$f_N = \frac{N_I + N_O}{N_N} \quad (3)$$

Thus, the more neurons in the network, the lower the coefficient f_N will be, and, consequently, the less likely the mutation will be chosen, which will add a new hidden neuron.

The algorithm uses a pack of coefficients $f_N * f_C$ in order to take into account the degree of connectivity of already existing neurons.

Deleting links in the ANN generates a side effect: “hanging” neurons may appear that have no input links, as well as “dead-end” neurons that do not have output links. In such cases, when the value of the neuron activation function is not zero for a zero weighted sum of its inputs (for example, logistically and sigmoid function), the

presence of “hanging” neurons provides the ability to adjust the neural displacements. On the other hand, it should be noted that the removal of links can help to remove some non-informative or little informative input attributes (neurons) and thus optimize the structure of the ANN and improve the quality of its learning.

Conclusion

As show analysis of the use of modeling methods in solving the problem of choosing and building a model for forecasting electric consumption confirms the thesis that it is impossible to build a universal prognostic model devoid of the shortcomings of individual modeling methods. As a result, preference is given to the approach to the hybrid use of a complex of mathematical tools based on the apparatus of ANN, GA, Kalman filters for constructing generalized nonlinear multifactor models, which will increase the efficiency of the process of their construction and subsequent use for searching both short-term and long-term forecasts.

References

1. Borukaiev Z.Kh. Approach to Building Computer Models for Operational (daily) Planning of the Supply of Electric Energy in the Wholesale Market. Part 1. Task formulation / Z.Kh. Borukaiev, K.B. Ostapchenko, O.I. Lisovychenko // Pukhov Institute for Modelling in Energy Engineering, Collection of scientific works. – 2012. – No. 63.- PP. 164-186.

2. Alexandrov O.I. Optimal Distribution Method of Active Loads between Power Plants and Electricity Consumers // Izvestiya of Higher Education Institutions, Energetics.- 1999.- No. 2.- PP. 3-15.

3. Abakshin P.S. Program Complex for Daily Regimes Planning of Energy Associations PRES-SUTKI / P.S. Abakshin, T.M. Alyabysheva, R.M. Yaganov // Power stations.- 2004.- No. 8.- PP. 42-46.

4. Makoklyuev B.I. Specialized Software Package for Planning and Analysis of Regime Power Systems and Energy Incorporations / B.I. Makoklyuev, A.V. Antonov // New in the Russian electric power industry, Electronic journal. - 2002. - No. 6.- PP. 41-45.

5. Lezhnyuk P.D. Criteria Formation for Optimal Load Distribution between Electric Stations in Modern Conditions / P.D. Lezhnyuk, V.V. Kulyk, V.V. Teptya // Visnyk VPI, Power engineering and electrical engineering.- 2008.- No. 6.- PP. 59-65.

6. Borukaiev Z.Kh. Planning Trade Dispatch Schedule of Active Load Distribution in the Wholesale Electricity Market / Z.Kh. Borukaiev, K.B. Ostapchenko, O.I. Lisovychenko // Pukhov Institute for Modelling in Energy Engineering, Collection of scientific works. – 2012.- No. 64.- PP. 127-137.

7. Borukaiev Z.Kh. Models for Determining the Forecast Wholesale Price for Buying Electricity / Z.Kh. Borukaiev, K.B. Ostapchenko, O.I. Lisovychenko // Adaptive Systems Automatic Control. – 2015. - Vol. 2(27). - PP. 35-43.

8. Makoklyuev B.I. Relationship of Forecast Accuracy and Irregularity of Energy Consumption Graphs / B.I. Makoklyuev, V.F. Yech // Power Stations. – 2005. – No. 5. - PP. 64-67.

9. Galperova E.V. Features of Power Consumption Forecasting at the Regional Level // Izvestiya RAN, Energetics.- 2004.- No. 4.- PP. 61-65.

10. Makoklyuev B. Formation and Planning of Electric Consumption, Electricity Balance of the Far Eastern Energy Company / B. Makoklyuev, N. Tsuprik, A. Antonov, A. Artemyev, E. Fedorov, D. Vankievich / Energy Market.- 2009.- No. 6.- PP. 1-5.

11. Ivaschenko V.A. Industrial Enterprises Power Consumption Forecasting on the basis of Statistical Methods and Artificial Neural Networks / V.A. Ivaschenko, M.V. Kolokolov, D.A. Vasilyev // Vestnik SGTU.- 2010.- No. 2(45). - PP. 110-115.

12. Ostapchenko K.B. Selection of the Electric Consumption Forecasting Model for solving Operational Daily Planning Problems to Electricity Supply in the Wholesale Market / K.B. Ostapchenko, O.I. Lisovychenko // Adaptive Systems Automatic Control. – 2014. - Vol. 1(24). - PP. 76-86.

13. Schelkalin V.N. Hybrid Models and Time Series Forecasting Methods based on methods «SSA-track» and Box-Jenkins // East European Advanced Technology Journal.- 2014.- No. 5/4 (71).- PP. 43-62.

14. Penko V.G. Time Series Forecasting by Hybrid Artificial Intelligence Methods / V.G. Penko // Informatics and Mathematical Methods in Simulation.- 2012.- Vol. 2, No. 2, PP. 165-172.

15. Bann D.V. Comparative Electric Load Forecast Models / D.V. Bann, E.D. Farmer. - Moscow: Energoatomizdat, 1987. – 200 p.

16. Brammer K. Kalman-Bucy Filter / K. Brammer, G. Ziffling. – Moscow: Nauka, 1982. – 200 p.

17. Vasiliev V.G. Mathematical Model of Short-term Forecasting of Electric Consumption of the Integrated Power Grid using the Automated Workplace “Orakul” / V.G. Vasiliev, S.P. Vasilieva, A.A. Preigel // Problems of Computer Science and Energy, Uzbek Journal. – 2000. – No. 4. - PP. 36-41.

18. Russkov O.V. Planning for Subject Uneven Consumption of the Wholesale Electricity Market based on the Hourly Prices Ratio Forecast / O.V. Russkov, S.E. Sarajishvili // Science and Education. N.E. Bauman MGTU, Electronic Journal. – 2015. – No. 2. – PP. 115–135.

19. Yampolsky L.S. Neurotechnology and Neurocomputer Systems / L.S. Yampolsky, O.I. Lisovychenko, V.V. Oliinyk.- Kiev: Dorado-Druk, 2016.- 576 p.

20. Blickle T. A comparison of Selection Schemes Used in Genetic Algorithms. Technical Report No.11 / T. Blickle, L. Thiele. – Zurich, Switzerland, Swiss Federal Institute of Technology, 1995.- 65 p.

21. Montana D.J. Training Feedforward Neural Networks using Genetic Algorithms/ D.J. Montana, L. Davis // Proceedings of the 11-th International Joint Conference on Artificial Intelligence. – Morgan Kaufmann, San Francisco, California. - 1989. – PP. 762–767.

22. Moriarty D.E. Efficient Reinforcement Learning through Symbiotic Evolution / D. E. Moriarty, R. Miikkulainen // Machine Learning.– 1996.– No. 22.– PP. 11–32.

23. Koehn P. Genetic Encoding Strategies for Neural Networks // University of Tennessee, Universität Erlangen-Nürnberg, Germany. - 1996.- 4 p.

24. Moriarty D.E. Forming Neural Networks through Efficient and Adaptive Coevolution / D. E. Moriarty, R. Miikkulainen // Journal Evolutionary Computation. – 1997. – Vol. 5, No. 4.- PP. 373-399

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INFORMATION PROCESSING WITH AN OPTICAL SENSOR WHEN INCOMPLETE INITIAL INFORMATION

Abstract. The range of tasks, solved by the properties of classification and generalization, is quite broad. However, the quality of solving to the problem, for one reason or another, is not always the same. Some tasks cannot be solved at once, but a detailed study of phenomenon allows us to make the necessary classification. For instance, the task is to divide the objects, with the same geometric dimensions and objects, by visual observation into two classes. Moreover, the part is madeof steel, and another one - of gypsum. In principle, such task cannot be solved.To classify these subjects, a more detailed study of them is required. It is sufficiently to get data on the weight of objects, so that the task of classification has become trivial. The difficulty is to find such a description of phenomenon, in which the image (phenomenon), within each class, would have defined similar properties. Therefore, in order to eliminate the effect of interference on the recognition process, it is proposed to introduce a special decisive rule based on the fact that the decision to attach the image to the image is made on the basis of an analysis of images that have fallen into a definite close space that is classified.

Keywords: autocorrelation function, invariance, coefficient of similarity, recognition, description of images, image border, signal processing

Introduction

At the present time, the complexity of identification is to find such a description, in which the image (information) of each class would have identified similar properties. The task is to make the transformed description includes the whole set of input images, united by the similarity class by the given ratio.

Using the ordinates of an autocorrelation function is an inseparable shift in the center of gravity of an image, which leads to a change of such description. Nicest, the concept of an invariant description of information arises, this is an autocorrelation function, which is invariant to the description of any displacements of the image in the vertical and horizontal directions.

In the works of authors such as Ravazzi C, Coluccia G, Magli E., Wen X, Qiao L, Ma S, Sheugh L, Alizadeh S.H. and other. It is noted that in practice for solving these problems, when the classification process is based on incomplete data, the problem of finding an optimal deciding rule arises, the methods of determination of which are based on the definition of the maximum incomplete coefficient of similarity. However, these methods do not take into account the effect of interference on the recognition process. Because often in the training sequence images are presented that are not subject to interference, and in the process of recognition, analyzed images distorted by noise.

The problem of finding an optimal decision rule arises, which, in a number of cases, can be constructed on the basis of a method, based on the definition of the maximum incomplete coefficient of similarity.

Using this method, the solutions, that are almost unintelligible to the errors that arise due to the effects of interference, are found. Therefore, in increments set of images, this rule passes into the Bayes’ rule.

Subject of Research

Choosing a description of images is one of the important tasks in pattern recognition. It is known, that the most complete description of the input images can be represented as a continuous function of two variables, which describes the distribution of brightness across the receptor field $Z(x, y)$. The completeness of these input images description has a number of significant disadvantages: the description is too cumbersome; it is not invariant with respect to many isomorphic transformations of the images.

The ability of generalizations of the recognition system’s response to similar input images is required, regardless of their location in the retina field, on the internal interactions and interactions of the system. To ensure the ability of generalizations of the reaction, there are usually some impose limitations, which depend on the nature of the similarity ratio. The restrictions, imposed on the logical nature of the similarity ratio, are they should have the property of symmetry and reflectivity, that is, if *A* is like *B*, then *B* is like *A*, and *A* is always like itself.

There are a large number of similarity ratios in nature, which these conditions are inherent in. These include: the solid motion of the image, some types of continuous deformations, topological equivalence of the images. Solid motion refers to the rotation and movement of the image, which is parallel to the horizontal or vertical axis.

Recognition Systems Problems

Recognition systems, possessing the property of generalization by similarity, are characterized by significant structural complications (for example, an increase in the number of layers of *A*-elements in perceptron) compared with conventional systems. Therefore, it is desirable to pre-convert the original description in such a way as to generalize all such objects and to react, in a differentiated way, to objects that are not similar.

The class of similarity in a given ratio stands for the set of input images, similar in this ratio. It is believed, that the similarity ratio is the imposition of an image so that $A \cup B \,/\, R$, which means *A* is similar to *B* in relation R (where is R the relativity of the motion). This means that *A* is a mapping of the displacement *B*, and *B* is a reflection of the motion of *A*. The problem is that the transformed description includes the whole set of input images, united by the similarity class by the given ration.

The autocorrelation function carries sufficiently complete information about the character of the input image [1], [2], [3], [4], [5] in addition, it is invariant towards to the description of moving images in the vertical and horizontal directions.

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To ensure the invariance of the description to the movement of the image, it is enough to use the ordinates of the autocorrelation function as the description elements. However, the shift in the center of gravity of the image leads to a change in such a description. To reduce the effect of the shift of the center of gravity on the description of the input image, which is compiled from the ordinates of such an autocorrelation function, one should exclude from the description ordinates, corresponding to a rotation angle close to 0^0 and 180^0.

It is desirable to obtain such a description that would cover the whole set of input images, united by the similarity class of all displacements of images relative to the receptor field. Such a description is invariant with respect to any displacement of an image. In order to obtain an invariant description, with respect to all the rigid displacements, it is necessary to create a fundamentally new type of scan. If two random functions $x = x(t)$ and $y = y(t)$ are put on the camera’s deflection system, then the beam will move randomly on the screen, and the signal from the camera will be a random function of the time, the statistical characteristics of which depend on both the nature of the input image and on the properties of the functions $x = x(t)$ and $y = y(t)$.

The multivariate distribution of the output signal gives it a complete probabilistic characteristic. It is obvious, that with stable probabilistic characteristics of functions $x = x(t)$ and $y = y(t)$ the probabilistic characteristics of the output signal will depend only on the nature of the input image. This statement is proved in [6], [7].

If the function, $Z = Z(x, y)$ where $x = x(t)$ and $y = y(t)$. Then if $x = x(t)$ and $y = y(t)$ are stationary and stationary-random functions of the time with even distribution and a vector, which consists of x and y, characterized by a uniformly distribution of probability, then the function $Z(t)$ is stationary in the broad and narrow sense; and its probabilistic characteristics do not depend on the inverses transformations and parallel transfer of the function $Z(x, y)$.

It directly follows from this, that the ordinates of the autocorrelation function $A_Z(t, t')$ depend only on $\tau = t - t'$ and the nature of the dependence $Z(x, y)$ and do not depend on the inverse transformations and the parallel transfer of the function.

Thus, the description of the input image, composed of the ordinates of the autocorrelation function of the output signal of the television camera, under certain restrictions imposed on the signal, is invariant with respect to all the rigid movements of the image inside the screen (the image is arbitrarily moved on the screen, without leaving any of its elements beyond its limits).

The Possible Methods for Describing the Image

It would seem, that using a random scan and description of the image by the ordinates of the autocorrelation function, solves a very complicated problem of recognition. However, the practical implementation of such a system has signifi-

cant technical difficulties. First, it is quite difficult to fulfill all the constraints imposed on the signals $x(t)$ and $y(t)$. In addition, the proved theorem relates only to the qualitative aspect of the question and does not relate to the quantitative one. The autocorrelation function $A_{Z\tau}$ does not really depend on the movement of the image on the screen, but, at the same time, its difference from the representation of the images is so small, that it is practically impossible to distinguish autocorrelation functions, even when the images, corresponding to these functions, are quite different from each other.

The autocorrelation function of the stationary signal is uniquely connected by Fourier transform with its spectral density:

$$A_Z(t,t') = A_Z(\tau) = \int_0^\infty f_Z(\omega)\cos\omega\tau d\omega, \quad (1)$$

Where $f_Z(\omega)$ - spectral density of the signal and vice versa

$$f_Z(\omega) = \frac{2}{\pi}\int_0^\infty A_Z(\tau)\cos\omega\tau d\omega. \quad (2)$$

Therefore, statements, concerning the autocorrelation function, are also valid for spectral density.

If the output signal of the camera $Z(t)$ goes to the analyzer, which consists of a finite number of filters with uniform frequency characteristics, the resonance frequencies of which are located one by one on the axis ω. Let’s suppose that the output signals of the filters are reduced to a square, and then they are integrated. Output signals of such analyzer are determined by the distribution of the energy $W_Z(\omega)$ of the signal $Z(t)$ along the frequency axis.

It is known, that the weighted autocorrelation function of a signal $A_Z(\tau)q(\tau)$ is related to the Fourier transform with its energy spectrum $W_Z(\omega)$:

$$g(\tau) = \int_0^\infty K^2(\omega)e^{-j\omega t} \quad (3)$$

where $K(\omega)$ - frequency response of the filter.

Therefore, the description of the input image can be formed using the ordinate of the energy spectrum.

Thus, each of the functions $A_Z(\tau)$, $f_Z(\omega)$ or $W_Z(\omega)$ may be convenient for describing the input images when recognizing images. However, it is much easier to get a characteristic of the spectral density of a signal than its autocorrelation function.

In [8], [9], [10], [11], [12] one of the possible methods for describing the image is considered with the help of the spectral characteristics of the signal obtained in the frame scan of the image. To simplify considerations, images with only two degrees of intensity of information are considered, but all this is true for images with a continuous change in intensity.

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In the general case, the signal, received at the output of the television camera, carries all information about the scanned black and white image. As a rule, this signal can always be represented by an infinite Fourier series:

$$f(x) = \frac{a_0}{2} + a_1 \cos \omega x + b_1 \sin \omega x + a_2 \cos 2\omega x + b_2 \sin 2\omega x + \ldots, \qquad (4)$$

where

$$a_k = \frac{2}{T}\int_0^T f(x)\cos k\omega x dx, \qquad b_k = \frac{2}{T}\int_0^T f(x)\sin k\omega x dx.$$

Since a television signal has a finite spectrum, then an infinite Fourier series can be written as finite sum:

$$f_n(x) = \frac{a_0}{2} + \sum_{k=1}^{n} a_k \cos k\omega x + \sum_{k=1}^{n} b_k \sin k\omega x. \qquad (5)$$

The function $f_n(x)$, and hence the image to which it corresponds, can be given by the coefficients of this series, which is equal to the representation of the image or coefficients of the Fourier series, or ordinates of spectral density.

The television signal that corresponds to two intensity gradations is a sequence of rectangular impulses of the same amplitude, all of which is contained in the duration of impulses and pauses. In addition, the television signal contains more string and frame impulses, their amplitude are 25 % higher amplitude of useful impulses.

The recognition procedure is greatly complicated with linear and frame impulses, firstly, because they clog the useful signal, and secondly, because their presence leads to significant changes in the spectral density of the signal. This is due to the fact that the offsets and turns of the image lead to a change in the duration and recognition of the useful impulses relative to the string impulses (Fig. 1).

In order to eliminate the effect of the image shift, which is parallel to the axis of the receptor field, it is necessary to remove linear and frame impulses from the TV signal. In this case, the image shift affects only the phase of the signal and does not affect its spectrum.

To eliminate the effect of the rotation, you need to rotate the image on the receptive field of the vidicon and, as a feature, take the average ordinate of the spectrum in one rotation. In this way, we get the same results as when randomly scanned.

However, it may be that images, belonging to different classes, differ little from the spectral component. To distinguish such images, it is necessary to choose not the average values of ordinates per rotation, but the functions of their instantaneous values in time, that is, to take into account the redistribution of the spectral density of the signal during one rotation. The problem of recognition, in this case, is greatly complicated by the fact that the description of images throughout the volume increases sharply. At the same time, it cannot be guaranteed that the transformed description will be less than the original, but it acquires useful properties of invariance with respect to offsets and turns.

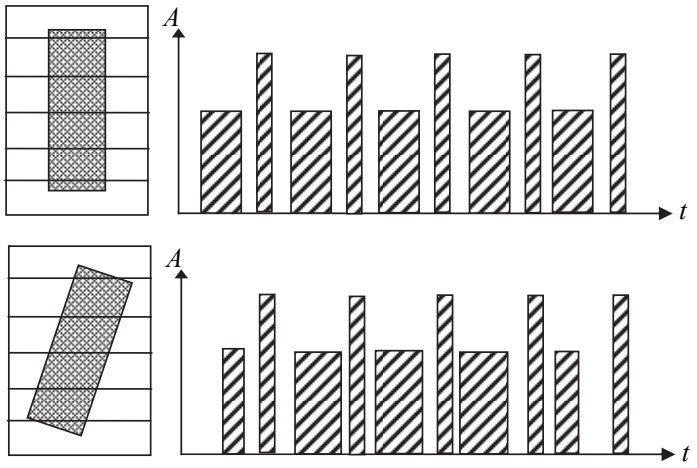

Fig. 1. - Scanning an image

Taking into account the periodic nature of the television signal in frame scan and specific maxima in the frequency area, multiple frame and linear harmonics, containing useful information, band filters should be supplemented by the basic frequencies of these maxima. The harmonics of the frame frequency carry information about the large details of the image and practically, without significant reduction in the recognition quality, the low-frequency part of the spectrum can be combined.

Experimental verification of this statement has shown that when separating from the television signal of the spectrum of low frequencies (50-500 Hz) and at constant time within 0.5 seconds with a period of rotation of the image 2-3 seconds, accurately, simple geometric monochrome shapes such as triangles, squares, rectangles, etc. are described. Functions, received at the filter output, are close to contours. To distinguish the classes of these figures, there are sufficient simple features such as the number of transitions of the redistribution function through zero, the number of positive or negative impulses.

At frequencies, corresponding to the harmonics of linear scan, describing images of moderate complexity it is necessary to take into account the information of a larger volume - practically to the 20th harmonic. Higher frequencies provide information about small details of complex images.

Results

Solving practical problems, there are often cases where the decision to attach an image S to a certain image is based on incomplete data, that is, when not all n elements of the description (attributes) can be measured.

The problem of finding an optimal decisive rule arises, which, in a number of cases, can be constructed on the basis of a method based on the definition of the maximum incomplete coefficient of similarity. In [13], [14], [15] four such methods are given.

1. Let the given image $S = S(x_1, \ldots, x_{n-k})$, where k - the number of missing signs. Then, to determine the belonging of this image to one of two images, use the following rule:

$$S \in V_1 if \frac{P(V_1 / x_1, \ldots, x_{n-k})}{P\left(V_2 / x_1, \ldots, x_{n-k}\right)} > 1. \quad (6)$$

Considering that for each image

$$P(V_1 / x_1, \ldots, x_{n-k}) = P(V_1) \frac{P(x_1, \ldots, x_{n-k} / V_1)}{P(x_1, \ldots, x_{n-k})}, \quad (7)$$

the decision rule can be formulated as follows:

$$S \in V_1 if \frac{P(x_1, \ldots, x_{n-k} / V_1)}{P\left(x_1, \ldots, x_{n-k} / V_2\right)} > \frac{P(V_2)}{P(V_1)}. \quad (8)$$

The decisions, made on the basis of this rule, may vary greatly from the optimal ones.

2. Let’s assume that it is possible to determine the most probable values of missing attributes. Then we can make an expression for conditional density of the probabilities of the following form:

$P(x_1, \ldots, x_{n-k}, x^*_{n-k+1}, \ldots, x^*_n / V_1)$ and $P(x_1, \ldots, x_{n-k}, x^*_{n-k+1}, \ldots, x^*_n / V_2)$,

where x^* - probable values of signs.

The decision rule can be formulated as follows:

$$S \in V_1 if \frac{P(x_1, \ldots, x_{n-k}, x^*_{n-k+1}, x^*_n / V_1)}{P(x_1, \ldots, x_{n-k}, x^*_{n-k+1}, x^*_n / V_2)} > \frac{P(V_2)}{P(V_1)} = \theta. \quad (9)$$

3. There are conditions in which there are no $n-k$ measurements, and the similarity coefficient is a random function of non-measurable coordinates $x_{n-k+1}, \ldots, x_n$. In this case, the similarity coefficient can be determined by the formula:

$$L(x) = \frac{P_{V_1}(x_{n-k+1}, \ldots, x_n / x_1, x_2, \ldots, x_{n-k})}{P_{V_2}(x_{n-k+1}, \ldots, x_n / x_1, x_2, \ldots, x_{n-k})}, \quad (10)$$

where probabilities P_{V_1} and P_{V_2} relate to images V_1 and V_2 accordingly.

With a similarity coefficient $L(x)$ the probability density $P[L(x)]$ is bounded. In this regard, there is such value of $L^*(x)$, that maximizes $P[L(x)]$ value, so $P[L^*(x)] = max\, P[L(x)]$.

Then the decision rule can be written as follows:

$$S \in V_1 if L^*(x) > \theta. \quad (11)$$

4. Considering the similarity coefficient as a random function of the missing measurements, the average value of the decision rule may be used in its construction:

$$\overline{L(x)} = \int_{-\infty}^{\infty} L(x) P[L(x)] dL, \quad (12)$$

In this case the decision rule can be formulated as follows:

$$S \in V_1 if\ \overline{L(x)} > \theta . \tag{13}$$

Comparing different decision rules, it is necessary to determine which rules give the least probability of error. For this purpose, it is necessary to calculate the probability of errors of the first and second series and In the general case, we can write it as follow:

$$\begin{aligned} P_a &= P(V_2)\int_{\Omega_1}\int\dots\int P(x_1,\dots,x_{n-k}/V_2)dx_1,\dots,dx_{n-k}, \\ P_a &= P(V_1)\int_{\Omega_2}\int\dots\int P(x_1,\dots,x_{n-k}/V_1)dx_1,\dots,dx_{n-k}. \end{aligned} \tag{14}$$

The difference between the decision rules is determined only by the choice of the area of integration. We will assume that in the area Ω_1^c, the decision rule will choose an image *V*, and in the area Ω_2^c – an image.

Considering the cost of the error of the first and the second kind, δ_a and δ_b, then, two different decision rules can be compared, taking into account the value of risk for them. So, if $W_c > W_d$, then the decisive rule *c* is better than *d*.

The risk or the average penalty value for this decision rule can be obtained from the formula:

$$W_c = P(V_1)\delta_b\int_{\Omega}\dots\int\left[\begin{matrix}P(V_2)\delta_a P(x_1,\dots,x_{n-k}/V_2)- \\ -P(V_2)\delta_b P(x_1,\dots,x_{n-k}/V_1)\end{matrix}\right]dx_1,\dots,dx_{n-k}. \tag{15}$$

As it was shown earlier, the minimum value W_c is achieved with such a choice of the area Ω^c, in which the subintegral expression would always be negative, that is,

$$\delta_b P(V_1)P(x_1,\dots,x_{n-k}/V_1) > \delta_b P(V_2)P(x_1,\dots,x_{n-k}/V_2). \tag{16}$$

If the cost of the error of the first and the second kind are the same, that is, if $\delta_a = \delta_b$ then area Ω^c, in which $S \in V_1$ should be chosen so that

$$\frac{P(x_1,\dots,x_{n-k}/V_1)}{P(x_1,\dots,x_{n-k}/V_2)} > \frac{P(V_2)}{P(V_1)}. \tag{17}$$

The expression (17) is a rule (8). Therefore, it can be argued that, no introduction of additional probabilistic information about unknown signs, in the case of equality of cost of errors, can give rules better than rule (1).

Before that we proceeded from the assumption, that the statistical properties of collections of educational images and images, which are encountered in recognition, remain constant. Often in the learning sequence images depicting various images that are not subject to interference are presented, and in the process of recognition, images, distorted by noise, are analyzed. In addition, if the training of the information subsystem is conducted considering of the obstacles, then the statistical properties of these obstacles may eventually be unstable. The learning process itself is limited in time. Therefore, recognizable images may differ significantly from those

images that were used in the learning sequence. In this case, the optimal solution, obtained during the learning process, will no longer be optimal for the recognition process, and hence the probability of error increases.

Fig. 2 shows the qualitative dependences of the probability of error from the noise level [16], [17], [18], [19], [20]. In the event that the decision rule will be optimal for each noise level, then the error probability increases with increasing noise and reaches the limit at the value of 0.5 (dotted curve).

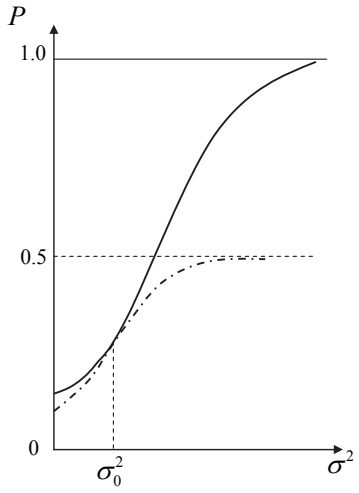

Fig. 2. - The error dependence on noise

If the optimal decision rule is found only for one of any value of the noise level, and in the further process of learning is not repeated, then with the increase of the noise level, the probability of error sharply increases and can reach values close to one (solid curve). At the point corresponding to the noise level, at which the training was conducted, the two curves coincide. The assessment of the noise effect on the recognition process is a very difficult task, which, in the general case, has no analytical solution. The latter can only be obtained when the educational images and audible noises are distributed according to normal law. Almost always, when solving practical problems, it is assumed that at small deviations of the statistical properties of the noise, the deviation of the probability of error from its minimum value is insignificant. In order to eliminate the effects of interference on the process of recognition, special deciding rules are introduced. One of them is based on the fact that the decision on the affiliation of the representation to the image is made on the basis of analysis of representations that have fallen into a certain closest space, which is classified. In this case, the solution takes into account the majority, which is in keeping with the results, obtained by calculating the similarity factor. Let's formulate the decision rule as follows:

$$S \in V_1 if \sum_{q=1}^{M_{V1}} \left[1/1 + \left(\frac{L(S_1 S_q)}{r} \right)^k \right] > \sum_{p=1}^{M_{V2}} \left[1/1 + \left(\frac{L(S_1 S_p)}{r} \right)^k \right]. \qquad (18)$$

In this expression k determines a plurality of images, which quite fully charac-

terizes the whole set of images; r – the radius of the area, which significantly affects the decision. The sphere with the center at the point, corresponding to the image S, formed by the radius r, will be called r - region of the image S (Fig. 3); $L(S, S_q)$ – measure of the similarity of the image S with images belonging to the image V_1, $L(S, S_p)$ – a measure of similarity of the image S with images belonging to the image V_2.

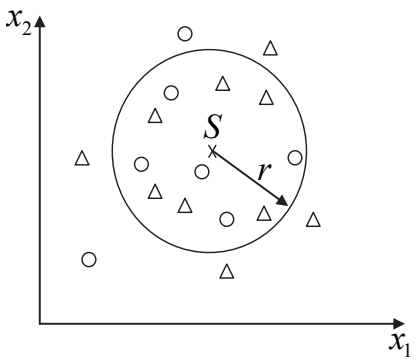

Fig. 3. - The information circle of the image

Thus, for a rather large meaning k, this rule defines the number of the representation of the images V_1 that are contained within a sphere with a radius r centered at the point, corresponding to the image S. This number is compared with the number of representation V_2 of the images in the same sphere. With this method, solutions are found that are almost unintelligible to the errors that arise due to the effects of interference. Obviously, with increasing k this rule goes over to the Bayes’ rule [19].

Conclusion

In this paper, the process of identification is considered in the case of incomplete input information. The complexity of this process is to find such a description in which the image (information) of each class would have defined similar properties. The problem of finding the optimal decisive rule arises, which in some cases can be constructed on the basis of a method based on the definition of the maximum incomplete coefficient of similarity. To eliminate the influence of interference on the recognition process, special decision rules are introduced. One of them is based on the fact that the decision on the belonging of the image to the image is made on the basis of the analysis of the images that fall into a certain close space, is classified. In this case, the decision takes into account the majority, which agrees well with the results obtained by calculating the similarity coefficient. This allows you to find solutions that are almost not sensitive to errors that occur due to interference.

REFERENCES

1. Zhang K, Wang X. Motion fuzzy images reduction of high-voltage line inspection based on spectrum analysis and image autocorrelation. Proceedings of the 2017 IEEE International Conference on Robotics and Biomimetics (ROBIO), China, 2017; 1160 – 1164.

2. Attamimi M, Mardiyanto R, Irfansyah AN. Inclined Image Recognition for Aerial Mapping using Deep Learning and Tree based Models. TELKOMNIKA Telecommunication, Computing, Electronics and Control. 2018; 16(6): 3034-3044.

3. Zhang L, Mahapatra D, Tielbeek Jeroen AW, and other. Image Registration Based on Autocorrelation of Local Structure. IEEE Transactions on Medical Imaging. 2016; 1(35): 63-75.

4. Zhu C, Yu L, Yan Z, Xiang S. Frequency Estimation of the Plenoptic Function Using the Autocorrelation Theorem. IEEE Transactions on Computational Imaging. 2017; 3(4): 966-981.

5. Humennyi D, Parkhomey I, Tkach M. Structural model of robot-manipulator for the capture of non-cooperative client spacecraft. Advances in Intelligent Systems and Computing. 2018; 754: 33-42.

6. Hazra T, CRS K, Nene MJ. Strategies for Searching Targets Using Mobile Sensors in Defense Scenarios. International Journal of Intelligent Systems and Applications. 2017; 9(5): 61-70.

7. Arifin AS, Wahyuni DK, Suryanegara M, Asvial M. Ship Speed Estimation using Wireless Sensor Networks: Three and Five Sensors Formulation. TELKOMNIKA Telecommunication, Computing, Electronics and Control. 2018; 16(4): 1527-1534.

8. Leow CH, Braga M, Stanziola A, and other. Multi-frame rate plane wave contrast-enhance ultrasound imaging for tumour vasculature imaging and perfusion quantification. Proceedings of the 2017 IEEE International Ultrasonics Symposium (IUS), USA, 2017; 1-4.

9. Lu J. Recursive fourier-based high-frame rate imaging. Proceedings ofthe 2014 IEEE International Ultrasonics Symposium, USA, 2014; 121-124.

10. Jaafar H, Ismail NS. Intelligent Person Recognition System Based on ECG Signal. Telecommunication, Electronic and Computer Engineering. 2018: 10(1-13): 83-88.

11. Akshaya R, Hema P Menon. A Review on Registration of Medical Images Using Graph Theoretic Approaches. Idonesian Journal of Electrical Engineering and Computer Science. 2018; 12(3): 974-983.

12. Sun J, Lv Q, Tan Z, Liu Y. An image sharpening strategy based on multiframe super resolution for multispectral data. Proceedings of the 2016 8th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), USA, 2016; 1-5.

13. Ravazzi C, Coluccia G, Magli E. Curl-Constrained Gradient Estimation for Image Recovery From Highly Incomplete Spectral Data. IEEE Transactions on Image Processing. 2017; 26(6): 2656 – 2668.

14. Wen X, Qiao L, Ma S, and other. Sparse Subspace Clustering for Incomplete Images. Proceedings of the 2015 IEEE International Conference on Computer Vision Workshop (ICCVW), Chile, 2015; 859-867.

15. Sheugh L, Alizadeh SH. A note on pearson correlation coefficient as a metric of similarity in recommender system. Proceedings of the 2015 AI & Robotics (IRANOPEN), Iran, 2015; 1-6.

16. Reddy A, Mungara J. Wireless Environment Aware Adaptive Scheduling Technique For Cellular Networks. Idonesian Journal of Electrical Engineering and Computer Science. 2018; 11(1): 318-332.

17. Boiko J, Eromenko O. Signal Processing in Telecommunications with Forward Correction of Errors. Indonesian Journal of Electrical Engineering and Computer Science. 2018; 11(3): 868-877.

18. Parhomey IR, Boiko JM, Eromenko OI. Features of digital signal processing in the information control systems of multipositional radar. Journal of Achievements in Materials and Manufacturing Engineering. 2016; 2(77): 75-84.

19. Dewi YN, Riana D, Mantoro T. Improving Naïve Bayes performance in single image pap smear using weighted principal component analysis (WPCA). Proceedings of the 2017 International Conference on Computing, Engineering, and Design (ICCED), Malaysia, 2017; 1-5.

20. Shynkaruk O, Boiko J, Eromenko O. Measurements of the energy gain in the modified circuit signal processing unit. Proceedings of the 2016 13th International IEEE Conference on Modern Problems of Radio Engineering. Telecommunications and Computer Science (TCSET), Ukraine, 2016; 582-584.

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ALGORITHM FOR DETERMINATION OF ELECTROMAGNETIC COMPATIBILITY FOR SOLUTION OF FREQUENCY PLANNING PROBLEMS

The intensive development of the telecommunications sector is directly connected with the introduction of the latest radio technologies and communication systems, the emergence of new services and communications. In these conditions, the provision of the requirements for the radio frequency resource of all categories of users is carried out at the expense of redistribution of already mastered and further development of new frequency ranges. Redistribution of frequencies, in turn, leads to an increase in supply on already developed ranges, which is due to the growth of the number of existing radio electronic devices, and to the complication of electromagnetic environment. The development of new ranges dictates the need to allocate radio frequency bands for the latest radio technologies, systems and communication standards. In these conditions, the task of controlling the PCR and ensuring the electromagnetic compatibility of radio electronic devices and emitters are of great practical importance.

These tasks can be solved only with the implementation of the appropriate scientific and methodical apparatus of radio monitoring, the application of which would enable the efficient use of radio frequency resource in modern conditions. Therefore, the topic of the thesis is relevant.

The paper presents the reasons for the occurrence of interference in the work of radio electronic devices in a complicated electronic environment, examines the modern scientific and methodical apparatus of radio monitoring with the definition of the electromagnetic environment at this location for the solution of frequency scheduling of RES.

INTRODUCTION

In this paper an analysis of the causes of mutual interference with the work of radio-electronic means in a complicated electronic environment is conducted, the modern scientific-methodical apparatus of radio monitoring with the definition of electromagnetic environment in it for solving the problems of frequency scheduling of the RES of the mobile service is considered.

The object of research – the process of determining the electromagnetic environment for the solution of the problems of frequency planning of radio electronic vehicles of the mobile service.

Subject of research – research and calculation of EMC REF in the planning area.

The purpose of the work is to study the effectiveness of using and defining directions for improving the calculation of EMC REFs in the planning area.

The method involves the analysis of EMC REZ in the planning area, and in the case of using the general site for the disposal of RES-EMC local grouping of RES (object EMC).

In the first case, the following types of interference are taken into account[1]:

– on the main channel;
– on the first adjacent channel;
– intermodulation obstruction of the 3rd order.
– In the second case, in addition to those listed above, the following types of interference are taken into account [2]:
– on adjacent channels;
– intermodulation above 3rd order (up to 13th order inclusive);
– blocking;
– on the mirror channel;
– on the first IF;
– on harmonics.

In carrying out the analysis, the above-mentioned methodology, an indicator of the efficiency of this method was established, with lower costs for measurements of the electromagnetic environment, and recommended for widespread use of this technique, with the control and management of the radio frequency resource and the provision of electromagnetic compatibility of radio-electronic means.

Keywords: source of radio emission, electromagnetic environment, electromagnetic compatibility, point of technical radio control, radio-emitting device, radio regulation, radio technology, radio frequency resource.

MAIN PART

The intensive development of the telecommunications sector is directly linked with the introduction of new radio technologies and communication systems, the emergence of new services and communications. In these conditions, the provision of the requirements for the radio frequency resource of all categories of users is carried out at the expense of redistribution of already mastered and further development of the new frequency range.

Redistribution of frequencies, in turn, leads to an increase transferring to the already developed ranges of radio frequencies, which is due to the increase in the number of existing REFs, and to the complication of electromagnetic environment. The development of new frequency bands dictates the need to allocate radio frequency bands for new radio technologies, systems and communication standards. Under these conditions, the control of PCD and the provision of electromagnetic compatibility (EMC) of REFs and radiating devices (VPs) are of great practical importance.

At the same time, in recent years, developers and manufacturers of telecommunication facilities have paid considerable attention to higher ranges of radio frequencies, which are considered the most promising for practical development. Currently, in Ukraine, the 3.5 GHz radio frequency range is intensively deployed

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by WiMAX radio technologies, 6/4 GHz, 8/7 GHz, 14/11 GHz and 30/20 GHz radio frequencies are saturated with satellite communication systems.

The complexity of solving the problems of radio monitoring in the frequency bands over 3 GHz is due to:

- difficulties in detecting, detecting the location of DRV and measuring the parameters of their radio emission;
- differences in the legislative regulation of the use of HRD in Ukraine from a number of European countries;
- lack of necessary technical equipment and appropriate regulatory and methodological support for radio monitoring.

In spite of the large variety of radio services, radio technologies, systems and communication standards that exist today in the world, in practice, for the purpose of solving radio monitoring problems, a limited number of methods can be used. This is the position of radio technology on the possibility of combining radio technology and communication systems into groups according to certain criteria, which will promote the application of common methods for detecting radiofrequencies, measuring their parameters, positioning and location of DRV, etc. It remains only to determine the criteria for such a classification, to distribute radio communication systems to groups according to these criteria, to note for each of the groups its own methods of radio monitoring and a list of technical parameters that need to be measured and (or) determined during its conduct. In practice, talking about radio monitoring, often mean a few other concepts, in particular, control of parameters of radio signals in high-frequency tracts.

The technical characteristics of RES are [3]:

- transmitter power;
- transmission frequency;
- frequency of reception;
- spectrum (frequency mask) of the transmitter signal;
- radiation class;
- azimuth of maximum antenna radiation;
- Antenna gain, type and polarization of the antenna;
- Antenna direction diagram;
- height of the antenna hinge;
- the value of the required protective ratio;
- reliable communication is required in the absence of interference.

The technical characteristics of the REF, which is planned, can be obtained from the materials of the RF application submitted by the applicant, and the REFs participating in EMC calculations in the planning area from the general database of frequency assignments

The basis of the procedure for selecting the frequency for the RES is the analysis of the EMC RES, which consists in the calculation of EMC in the area of planning and EMC local grouping of RES (object EMC).

The calculation of the EMF REF in the planning area is carried out in the fol-

lowing order:

a) the choice of territorial characteristics of RESs, located in the area of a limited research area;

b) selection of RES that are selected on a territorial basis, on the frequency basis of those REFs that potentially interfere with the new frequency assignment:

– identification of possible sources of noise over the main channel;
– determining the sources of interference on the first adjacent channel;
– identification of possible sources of intermodulation noise in the 3rd order.

c) calculation of the level of noise at the receiver input:

– on the main channel;
– on the first adjacent channel;
– intermodulation of the 3rd order;

d) analysis of the results obtained and decision making based on the results of calculations on the possibility of frequency assignment, taking into account the effect of multiple noise or the need to select a different frequency. In the case of a positive decision on the possibility of frequency assignment based on the results of calculating the EMC, it is necessary to check the presence of other RES on the joint site and, if available such, to calculate EMC local grouping of RES (object EMC).

EMC local grouping of RES is performed in the following order:

a) among RES, selected according to the preceding paragraph are selected RES, which are located within a common area in a circle with a radius of up to 1 km from the BS, under investigation. The radius of 1 km is due to the following assumption: the losses during the propagation of radio waves for this distance are 60 ÷ 100 dB (model of distribution in free space), depending on the frequency range, which minimizes the probability of the receiver effecting other types of disturbances at long distances from the transmitter to a minimum. All stations that fall into a zone limited by this circle are selected for further analysis.

b) RES, which potentially can cause interference with the receiving BS or is subject to its interference, are selected on a frequency basis among the RES, selected on a territorial basis. For each selected transmitter (or group of transmitters), the frequency condition for the possibility of creating an obstacle for the studied receiver is checked, or for each selected receiver in the selected transmitter group, the frequency condition for interference from the researcher transmitter is checked for the following types of interference:

- by adjacent channels;
- on the intermodulation of the 3rd - 13th orders;
- on the mirror channel;
- on the first IF;
- on harmonics;
- by blocking;

c) levels are calculated for each type of interference;

d) an analysis of the results is carried out and, based on the results of calcula-

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tions, a decision is made on the possibility of frequency assignment taking into account the effect of multiple noise or the need to select a different frequency.

General algorithm of frequency assignment for RES is shown on img. 1

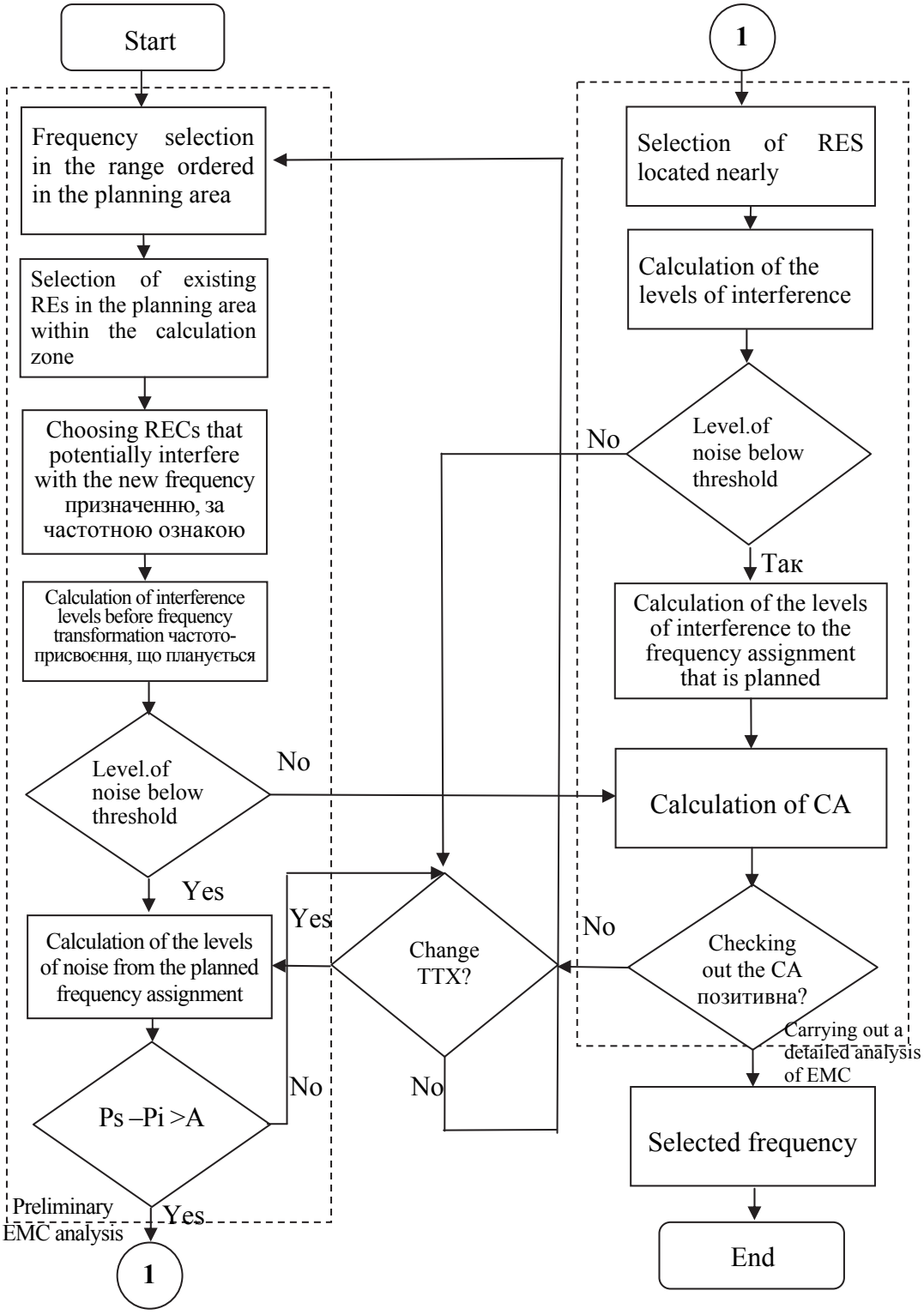

Image. 1 General algorithm of selection of frequencies for RES

To select the stations that characterize the electromagnetic environment at the site of the alleged new frequency assignment, it is necessary to determine the size of the calculated zone. To do this, it is necessary to define a circle with a center at the coordinate of the new frequency assignment (BS) and a radius equal to the double radius of the declared service area (2d) [4] or the corresponding distance according to the standard for this type of communication; and frequency range (img.2)

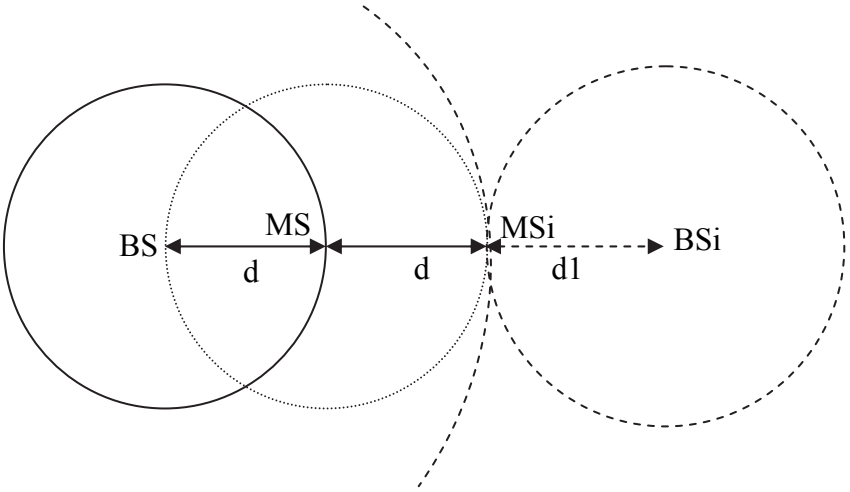

Image.2 Selection of a non-hazardous RES

All stations that fall into space are limited to this circle (moving, together with their base, even if the latter are not in this area), are selected for further analysis to meet the frequency requirements.

Despite the wide variety of factors that influence the quality of signal reception, the classical approach to determining the quality of RES operation is to evaluate the energy ratio of the signal / (noise / noise) with given parameters. Therefore, for the main criterion for evaluating the parameters of the EMC REC, the energy criterion expressed in terms of the signal / noise ratio for the given quality indices is adopted:

$$\frac{P_S}{P_I} \geq A(\Delta f) = A_0 * FDR(\Delta f), \qquad (1)$$

where $A(\Delta f)$ - protective attitude in this frequency decomposition between a useful signal and a barrier;

A_0 - protective relation on the connected channel;

$FDR(\Delta f)$ - a coefficient that characterizes the attenuation of the noise, depending on the frequency deployment between the useful signal and the interference;

P_S - the power of a useful signal at the input of the receiver, subject to interference;

P_I - power interference at the input of the receiver, subject to interference.

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The influence of the medium on the propagation of radio waves, due to the random nature of innumerable causes, is manifested in the change in the amplitude of the wave field, the change in the velocity and direction of propagation of the wave, in the rotation of the plane of polarization of the wave, and other distortions of the signal. Therefore, the fluctuations of the useful signal levels at the input of the receiver are also random variables.

The mobile communication is characterized by large changes in the field strength, as a function of location and time. These changes can be described by the lognormal distribution with a standard deviation of 8 dB in the range of 30-300 MHz and 10 dB in the range of 300-3000 MHz [5].

The specific value of the value of the required protective ratio is the characteristic of the studied system of mobile communication (mobile communication standard) and is given as an initial data in the analysis of the EMC.

CONCLUSION

The reasons of the occurrence of mutual obstacles in the work of radio-electronic means in the complicated electronic environment are described, the modern scientific-methodical apparatus of radio monitoring with the definition of electromagnetic environment in it for solving the problems of frequency scheduling of the RES of the mobile service is considered.

The method involves the analysis of EMC REZ in the planning area, and in the case of using the general site for the disposal of RES-EMC local grouping of RES (object EMC).

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In carrying out the analysis of the aforementioned methodology, an indicator of the efficiency of this method was established, with lower costs for measurements of the electromagnetic environment, and recommended for widespread use of this technique, with the control and management of the radio frequency resource and the provision of electromagnetic compatibility of radio-electronic means.

REFERENCES

1. Recommendation ITU-R P.341-4. / The concept of transmission loss for radio links.

2. Recommendation ITU-R SM.337-4 / Frequency and distance separations.

3. Recommendation ITU-R PN.525-2 / Calculation of free-space attenuation.

4. *Bornemann W.* Aerial Installation on Naval Ship / Summary of the paper presented at Antenna Conference / Karlskrona, 2011

5. *Humennyi D, Parkhomey I., Tkach M.* Structural model of robot-manipulator for the capture of non-cooperative client spacecraft / Volume 754, 2019, Pages 33-421st, International Conference on Computer Science, Engineering and Education Applications, ICCSEEA 2018 – Kiev; Ukraine 18 January 2018

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A. Parkhomenko, R. Segol, O. Lisovychenko

COMPREHENSIVE ANALYSIS OF THE STUDENTS’ MOTIVATION CONNECTION TO THE MASSIVE OPEN ONLINE COURSES COMPLETION RATE

Abstract: The article provides the analysis for the learning outcome at massive open online courses to identify students’ motivational needs. Motivational techniques for improving the learning process quality and increasing the correlation between mastering the theoretical material and passing practical exercises are proposed.

Keywords: correlation, learning outcome, massive open online course, motivational technique, motivational needs.

Introduction

The online learning further development and popularity, the continued blended learning implementation into the educational process in Ukrainian higher education institutions, requires high-quality new online courses in various fields of knowledge [1], adaptations and translations of existing courses from leading professors of the best educational institutions in the world for the further leading teaching methodologies used in the educational process. As noted in earlier studies, the online education development will be the driving force behind changes in the world’s educational trends [2; 3]. Further massive open online courses use with open source software will increase the education’s accessibility for all, provide access for people with disabilities to the desired profession [4; 5; 6].

Problem statement

The proposed article provides the analysis for the learning outcome at massive open online courses "Learning How to Learn" [7] and "Educational Tools for Critical Thinking" [8] to identify students’ motivational needs. "Learning How to Learn" course is adapted in Ukrainian, and the course “Educational Tools for Critical Thinking" are developed by Ukrainian author Serhiy Terno. Courses are distributed on the Prometheus platform during 2018, they are created for different target audiences and include different motivational components for students.

The article aims to solve such problems: analysis and research the testing results at the courses "Learning How to Learn" and "Educational Tools for Critical Thinking" to motivate students [9; 10; 11] and further guidelines for the motivational techniques’ development for online course students.

The "Learning How to Learn: Powerful mental tools to help you master tough subjects" on the Prometheus platform is the Ukrainian adaptation for the course created in 2014 by Barbara Oakley and Terrence Sejnowski. This online course is the most popular in the world and now has over 2.6 million enrolled students. For 4

weeks at 7 hours, the course`s authors help to master the main methods of the educational process in a light and understandable scientific popular form. At the time of the research, the subscription to the Ukrainian version of the course on Prometheus platform was 15053 people. Successfully completed course 1108 people (7.36%), which is an average percentage for MOOC’s successful passing rate [14; 15; 17].

This course is a typical representative of open online learning. It includes short videos collections (maximum 8 minutes, minimum 2 minutes each), notes, additional reading materials, test tasks for self-examination and video interviews with well-known specialists from various fields on the learning process peculiarities [14; 15]. In early September 2018, the Ukrainian platform for massive open online courses Prometheus received permission for translation and the course’s materials free placement for Ukrainian viewers. The Coursera platform feature (the original course is hosted on this online learning platform) text matches and subtitles availability for adapting in different languages, which greatly simplifies the work for the translator and editor.

The online course "Educational Tools for Critical Thinking" was created in 2018 by the doctor of pedagogical sciences, professor of Zaporizhzhya National University Serhiy Terno to improve educators’ qualifications. This online course is the author’s second experience, with this course he proposed a new methodological approach improving the learning outcomes. Under this methodological approach, after each video lecture, the author developed a short test for self-examination. As a result, 45 video lectures (average duration 5-8 minutes) and 45 questions were created, and the final test for the acquired knowledge perception analysis. This methodological approach was used on the platform for the first time, therefore it is interesting for analysis. The course has 6468 enrolled students, 35.2% (2277) have successfully completed their training and received a certificate.

Learning outcomes analysis

The student's motivation for an online course is among the key issues in the online learning successful implementation and its further development.

Among the analyzed courses, only "Educational Tools for Critical Thinking" has a high success rate, which indicates the students’ motivation to complete their studies.

At the same time, the "Learning How to Learn" course is a typical indicator of success for the world’s online learning practice [17]. This indicates a rather low students’ motivation to complete the course, even though they have already registered for the course of their own choice or at the request of the management / teacher, that is, from the beginning, they had a certain intention, desire or purpose to learn. The introductory test took 4082 people, and this is 27,12% of the total number of registered, only 27,14% scored a sufficient points number to obtain a certificate. The introductory test includes 20 different questions, which has 2 answer variants each: right and wrong. The question can be divided into the following groups: on general erudition, on logical thinking, on wit, on attentiveness.

Students responses distribution (right-wrong) to the introductory test questions of the online course "Learning How to Learn" is shown in Fig.1. It shows the most difficult for the listeners are questions 1, 3 and 19. Questions 3 and 19 are issues of attentiveness and question 1 - on the general erudition. This suggests there is a need to further implement techniques to improve the attentiveness, namely: the additional tests of attentiveness creation to affect the certification, the learning elements to improve cognitive skills’ development and implementation, possible to take children's tests for attentiveness.

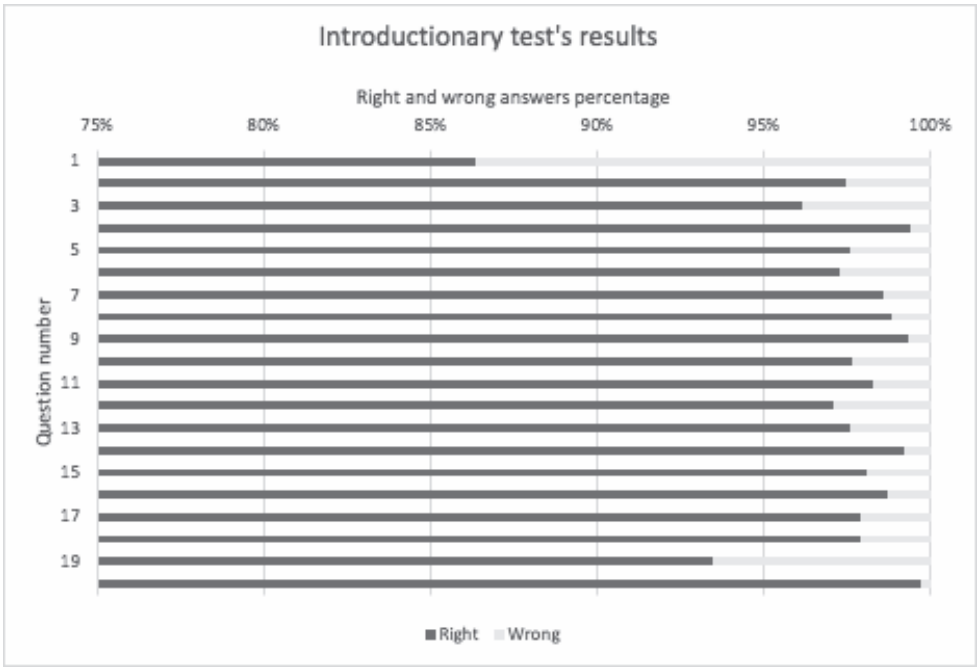

Fig. 1. Students responses distribution (right-wrong) to the introductory test questions of the online course "Learning How to Learn"

During the introductory test’s adaptation, the Prometheus platform technical features were taken into account (lack of opportunity to advance the course without completing the video review, the other classification and division issues availability, the features of the Code of Honor of the platform, etc.), and language units’ perception feature by Ukrainian-speaking listeners. For example, among this course’s features is the presence of a significant number of translations in other languages, which are immediately available on the Coursera platform as subtitles, technically connecting subtitles different for users at Prometheus platform. Similarly, mobile applications and settings for the user are technically different. Part of the course’s terminology is in the neurobiology and information systems of brain activity research fields, which caused problems in translation since the Ukrainian language does not have a well-established terminology base from these fieldsof knowledge. Logical transference, transcription, and transliteration were usedto provide accurate matches that were understood by users without further clarification.

It should be noted that the course "Educational Tools for Critical Thinking" is

aimed at a narrow target audience: secondary schools’ teachers and higher education institutions lecturers, among which a significant number of students who have successfully completed education are women (76.58%), and senior ones over 50 years (20.39%). The main motivation for this category is the certificate availability stating hours number that allows qualifying as an advancement course, which is the main component for contracts renewals for teachers and increase of wages. Thus, a question of classical students’ material motivation with free access to educational materials. The age and sex distribution of certified students of the course "Educational Tools for Critical Thinking" are shown in Fig. 2.

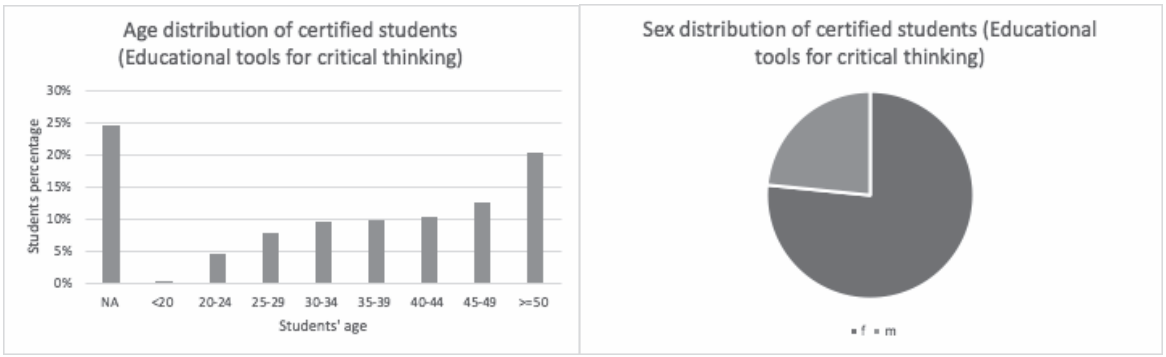

Fig. 2. Age and sex distribution of certified students of the course "Educational Tools for Critical Thinking"

During the data analysis for “Learning How to Learn”, no such sharp differences in gender and age of the students were detected. All students, as they successfully completed the course, were divided according to age, gender, and level of education in proportion to their lack of clearly defined narrow target audience, so is much more difficult to name the components of motivation for this course. The age and sex distribution of the certified students of the course "Learning How to Learn" are shown in Fig. 3.

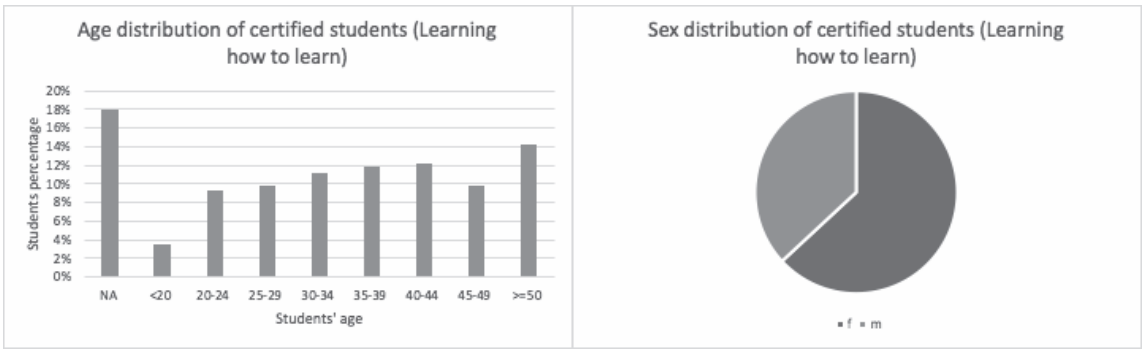

Fig. 3. Age and sex distribution of certified students of the course "Learning How to Learn"

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Students motivation needs

According to the preliminary assumptions [9], motivational factors in the learning process may include a personal feedback from the teacher, constant feedback, increase or decrease the tasks’ complexity under the potential student’s level, etc., and bonus points, the access possibility to new levels of courses professional orientation.

To determine the relationship between the mastering of theoretical material in the video lectures form and the performance with tests to consolidate the acquired theoretical part of knowledge by the same students, statistical analysis was performed on the indicated online courses, and the Pearson criterion r_{xy} by formula (1) was calculated for the correlation between percentage of viewed video materials and percentage of success in related tasks.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_{i=1}^{n}(y_i-\bar{y})^2}}, \quad (1)$$

where x_i is the percentage of user-viewed videos on a specific topic; y_i is a percentage of the user’s success, in the subject corresponding to the test task; $\bar{x}$ is the average value of video views on this topic; $\bar{y}$ is an average success rate of the test on this topic; n is the number of students in the sample group.

The results of the Pearson criteria’s calculation for two online courses, and the average percentage of video material reviewed and the success for the two online courses are presented in Table 1.

Table 1.

Statistics and correlation coefficient between a percentage of viewed videos and success rate in two online courses

Online course (topic)	Average percentage of viewed videos, %	Average test success by topic, %	Correlation coefficient (by Pearson criterion)
Learning How to Learn (introductory test)	54.5393536	97.3388085	0.055236917
Educational Tools for Critical Thinking (video lecture 2.1)	26.2267436	89.7560976	0.058745102

Fig. 4 shows a graph of an online test success for “Learning How to Learn” from video views before the test.

Figure 5 shows the dependence graph of the chapter 2.1 test success of the online course “Educational Tools for Critical Thinking” from the video lectures views of this chapter.

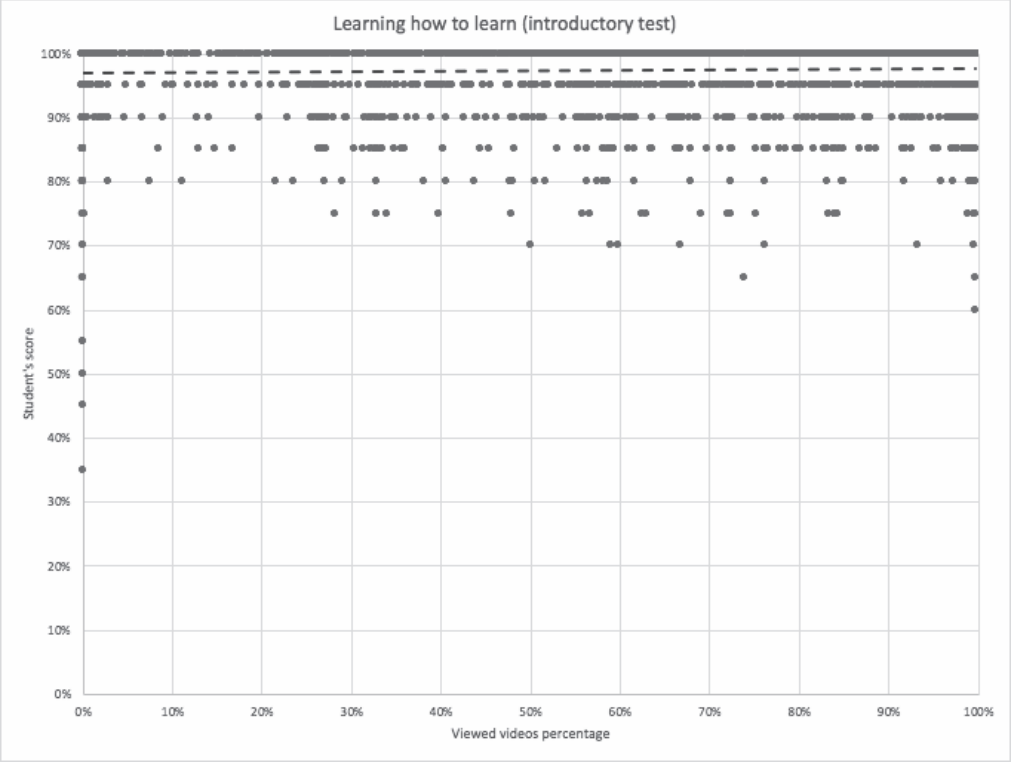

Fig. 4. The success graph of online test for “Learning How to Learn” from video views before the test, the dashed line indicates the regression line

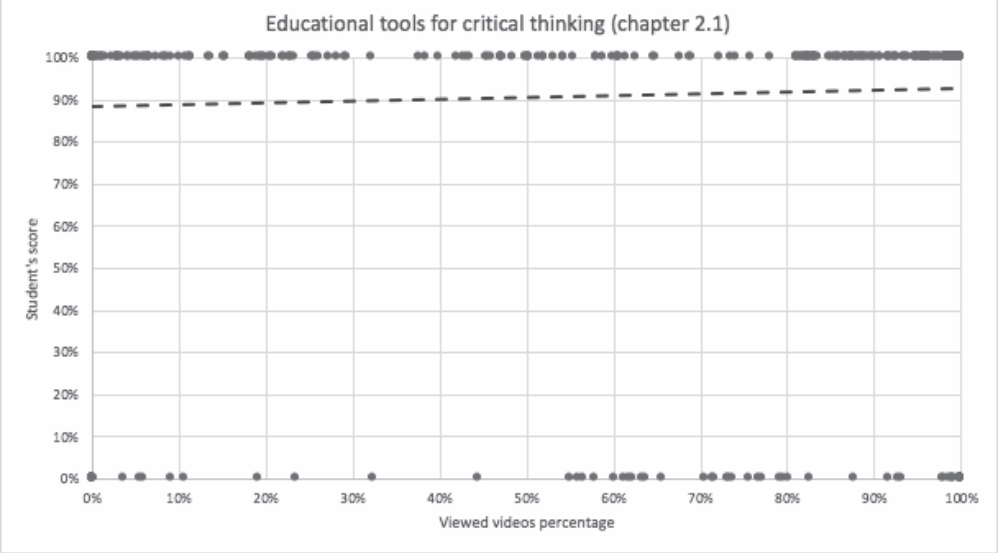

Fig. 5. The test's success graph for the chapter 2.1 of the online course “Educational Tools for Critical Thinking” from the video lectures views of this chapter, the dashed line is indicated by the regression line

Conclusions

The analysis showed a very weak correlation between the video viewed percentage and the assessments of the relevant tests, which indicates that part of the stu-

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dents master the theoretical material only, and the part without the mastery of the theory immediately passes to testing. It should be noted that we considered video lectures views only on the platform, without taking into account possible views directly on the YouTube channel. However, two analyzed courses belongto different areas of knowledge and created for different purposes and for different target audiences and have different performance indicators (from average to very high). In our opinion, we can conclude that such a low correlation will be observed in all other online courses. Therefore, the following motivation techniques are on the development stage to increase the correlation. We propose to use the following motivational techniques for improving the learning process quality and increasing the correlation between mastering the theoretical material and passing practical exercises:

- Encouraging course students through e-mail messages or in their own dashboards (for example, when the user did not complete the course but passed a large part, he or she receives a letter "You have two steps left to the goal, continue your studies today!");
- Motivational elements integrated into the platform (color markers and iconography of theoretical and practical materials passed, the percentage exclusion for mastered material and percent of what is left to learn, progress in learning);
- Comparative motivation against other listeners (the message output about how many listeners with the same results as the given listener completed the course and received a certificate);
- Introduction of different certificates levels for all courses (if a person has gained over 90%, he or she receives a certificate of honors);
- Introducing requirements for the relevant video lectures mandatory viewing prior to the practical tests’ compilation (for example, the ability to go to the next section of the online course after viewing 80% of the video);
- Possibility to share the online course’s successful completion in social media (the opportunity to send a certificate of completion from a personal dashboard or a specially prepared phrase "I have passed such a course on the platform Prometheus");
- Personal cabinet personification (the certain number of graphic elements appearance, symbolizing certain achievements, for example, the receipt of 3 certificates, 5, 10, etc.).

The proposed techniques’ implementation can be the subject of further scientific research using artificial intelligence systems for students’ individual motivation purpose.

REFERENCES

1. Пархоменко А.В. Перспективи розвитку систем дистанційної освітиу вищій школі // IX Міжнародна науково-технічна конференція студентів і аспірантів «Друкарство молоде». Київ, 2009. С.110-112.

2. Пархоменко А.В. Місце дистанційної освіти у вищій школі // VIII Міжнародна науково-технічна конференція студентів і аспірантів «Друкарство молоде». Київ, 2008. С.121-122.

3. Parkhomenko A. The Future of Modern Distance Education Systems // Innovations in Science and Technology. Kyiv, 2009. С.193-194.

4. Parkhomenko A. Free and Open Source Software in Online Education Systems // Innovations in Science and Technology. Kyiv, 2010. С.162-163.

5. Пархоменко А.В. Перспективи використання вільного програмного забезпечення у створенні віртуальних лекційних класів систем дистанційної освіти // Мультимедійні технології в освіті. Київ, 2010. С.79.

6. History and Trends of Learning Management System // Oxigile infographics, 2016. Режим доступу: https://www.oxagile.com/company/blog/history-and-trends-of- learning-management-system-infographics/. Access date: 28.02.2019 р.

7. Онлайн-курс «Навчаймось вчитись: Потужні розумові інструменти для опанування складних предметів» [Електронний ресурс] // Prometheus. 2018. URL: https://courses.prometheus.org.ua/courses/course-v1:Prometheus+ +LHTL101+2018_ T3/about. Access date: 26.02.2019.

8. Онлайн-курс «Освітні інструменти критичного мислення» [Електронний ресурс] // Prometheus. 2018. URL: https://courses.prometheus.org.ua/ /courses/course-v1:Prometheus+CTFT102+2018_T3/about. Access date: 26.02.2019/

9. Пархоменко А.В., Сегол Р.І., Лісовиченко О.І. Вивчення мотивації слухачів онлайн-курсів // Адаптивні системи автоматичного управління. 2018. № 1 (32). С.137-145.

10. Сегол Р.І., Лісовиченко О.І., Пархоменко А.В. Автоматизована система профорієнтаційного тестування // XIII Міжнародна наукова конференція для молодих вчених «Сучасні проблеми математики та її застосування в природничих науках та інформаційних технологіях». Харків, 2018. С.21-23.

11. Gregory R. Psychological Testing: History, Principles, and Applications (Sixth ed.). Boston: Allyn & Bacon, 2011. 672 p.

12. Сегол Р.И., Пархоменко А.В. Использование МООС в учебном процессе // Проблемы современного образования в техническом вузе: материалы V Междунар. науч.-метод. конф. / ГГТУ им. П. О. Сухого. Гомель, 2017. С.143-145.

13. Segol R., Parkhomenko A. Massive open online courses' implementation in blended format as a new approach in Ukrainian higher education // Сучасні проблеми моделювання: зб. наук. праць. 2018. № 11. С.140-146.

14. Segol R., Parkhomenko A. Learning management systems in modern educational process for interdisciplinary students // II Всеукраїнська науково-практична конференція «Теоретико-практичні проблеми використання математичних методів і комп’ютерно-орієнтованих технологій в освіті та науці». Київ, 2018. С.71-75.

15. Parr C. Mooc completion rates ‘below 7%’ // Times Higher Education. Режим доступу : https://www.timeshighereducation.com/news/mooc-completion-rates-below- 7/2003710. article#. – Access date: 07.03.2019.

16. Segol R., Parkhomenko A. The massive open online courses implementation as the main rethinking in Ukrainian educational process (based on massive open online courses platform Prometheus) // Technics. Technology. Education. Safety. '18. Sofia, Bulgaria, 2018. С.287-289.

17. Сегол Р.І., Пархоменко А.В. Змішана форма навчання у вищій освіті в Україні // 20 міжнародна науково-практична конференція «Сучасні проблеми геометричного моделювання». Мелітополь, 2018. С.140-146.

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OPTIMIZATION FOR ONE CLASS OF COMBINATORIAL PROBLEMS UNDER UNCERTAINTY

Abstract: We formalize uncertainty concept, compromise criteria of uncertainty minimization, and efficient formal procedures for a sufficiently common class of combinatorial optimization problems which functional contains numerical parameters. The procedures are based on the well-known idea of linear convolution of criteria. They optimize or implement the compromise criteria or conditions we propose.

Keywords: Combinatorial optimization, uncertainty, probability, efficient algorithm, uncertainty resolution, PSC-algorithm, NP-hard problems.

Introduction

Definitions:

Let σ be a feasible solution;

Ω be a set of feasible solutions of an arbitrary form. One can specify Ω by arbitrary constraints, conditions, enumeration of feasible solutions, etc.

We study the class of combinatorial optimization problems of the following form:

$$\min_{\sigma\in\Omega} \sum_{i=1}^{s} \omega_i k_i(\sigma) \qquad (1)$$

where ω_i are numbers, $k_i(\sigma)$ is i-th arbitrary numerical characteristic of a feasible solution σ.

The model (1) is sufficiently common. It includes, in particular, the following combinatorial optimization problems: transportation problem, flow network problems, NP-hard combinatorial optimization problems (e.g., the total weighted tardiness of tasks minimization on one machine [1], the total weighted completion time of interrelated tasks minimization on one machine [1]) etc.

Remark 1. Efficient PSC-algorithms exist [2] to solve these NP-hard combinatorial problems.

We will consider two formulations of the problem (1) under uncertainty. The first formulation of the problem is partial, the second one is more general. This differentiation is explained by the fact that we were able to obtain some results within the framework of the first formulation of the combinatorial optimization problem under uncertainty that were absent within the framework of the more general second formulation of the problem.

The first formulation of the combinatorial optimization problem under uncertainty

Under the uncertainty of the problem (1) we will understand the uncertainty of the values of coefficients ω_i, $i = \overline{1,s}$, at the time of the problem (1) solving.

$\overline{\omega} = (\omega_1, \ldots, \omega_s)$ can take one of two possible values: $\overline{\omega}_1 = (\omega_{11}, \ldots, \omega_{1s})$ or $\overline{\omega}_2 = (\omega_{21}, \ldots, \omega_{2s})$. Thus, the stage of the problem (1) solving and the stage of its solution implementation may be separated in time. For example, there may be the forward planning stage and the plan execution stage when changes of an external environment may affect the values of the coefficients ω_i, $i = \overline{1, s}$ determined at the stage of the forward planning.

We can specify probabilities $P_1 > 0$, $P_2 = 1 - P_1 > 0$ (the probabilities are absent if the uncertainty is not described by a probabilistic model).

To solve the problem (1) under uncertainty means to find a feasible solution that satisfies one of the following conditions:

1) σ corresponds to $min(\Delta_1 + \Delta_2)$ where

$$\Delta_1 = \sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1, \quad \Delta_2 = \sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2,$$

$$f_{opt}^1 = \min_{\sigma \in \Omega} \sum_{i=1}^{s} \omega_{1i} k_i(\sigma), \quad f_{opt}^2 = \min_{\sigma \in \Omega} \sum_{i=1}^{s} \omega_{2i} k_i(\sigma).$$

2) σ satisfies the condition $\Delta_1 \le l_1$, $\Delta_2 \le l_2$ where $l_1 > 0$, $l_2 > 0$ and are specified by experts.

3) $min\, \Delta_1$, $\Delta_2 \le l_2$ or $min\, \Delta_2$, $\Delta_1 \le l_1$.

4) $min(a_1\Delta_1 + a_2\Delta_2)$ where $a_1 > 0$, $a_2 > 0$ are specified by experts.

5) $\min_{\sigma \in \Omega} \{M\Delta = P_1\Delta_1 + P_2\Delta_2\}$ where M is mathematical expectation operator, if the uncertainty is specified with a probabilistic model.

The criterion to find a compromise solution is specified by experts.

Finding a compromise solution for each of the five criteria (conditions)

We first investigate the theoretical properties of the first model of the combinatorial optimization problem (1) under uncertainty.

Statement 1. It is true that

$$arg \min_{\sigma \in \Omega} \left\{ a_1 \left[\sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1 \right] + a_2 \left[\sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2 \right] \right\} =$$

$$= arg \min_{\sigma \in \Omega} \sum_{i=1}^{s} (a_1\omega_{1i} + a_2\omega_{2i}) k_i(\sigma), \quad a_1 > 0, \; a_2 > 0.$$

Proof. Let us denote

$$\{\sigma_1\} = arg \min_{\sigma \in \Omega} \sum_{i=1}^{s} \omega_{1i} k_i(\sigma); \tag{2}$$

$$\{\sigma_2\} = arg \min_{\sigma \in \Omega} \sum_{i=1}^{s} \omega_{2i} k_i(\sigma); \tag{3}$$

σ_1 is the element of the set $\{\sigma_1\}$ at which we reach $\min_{\sigma \in \{\sigma_1\}} \left[\sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^1 \right]$.

$\sigma_2 \in \{\sigma_2\}$, and we reach $\min_{\sigma \in \{\sigma_2\}} \left[\sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^2 \right]$ at σ_2 (we consider algorithms

of σ_1, σ_2 obtaining in the second framework of uncertainty for the case when Ω is finite);

$$\sigma^1(a_1, a_2) = arg\min_{\sigma\in\Omega}\left\{a_1\left[\sum_{i=1}^{s}\omega_{1i}k_i(\sigma) - f_{opt}^1\right] + a_2\left[\sum_{i=1}^{s}\omega_{2i}k_i(\sigma) - f_{opt}^2\right]\right\}; \quad (4)$$

$$\sigma^2(a_1, a_2) = arg\min_{\sigma\in\Omega}\sum_{i=1}^{s}(a_1\omega_{1i} + a_2\omega_{2i})k_i(\sigma), \quad a_1 > 0, a_2 > 0 \quad (5)$$

where $\sigma^1(a_1, a_2)$ is the set of solutions of (4), and $\sigma^2(a_1, a_2)$ is the set of solutions of (5). We have:

$$\sum_{i=1}^{s}\omega_{1i}k_i(\sigma^1(a_1, a_2)) - f_{opt}^1 \ge 0, \quad \sum_{i=1}^{s}\omega_{2i}k_i(\sigma^1(a_1, a_2)) - f_{opt}^2 \ge 0; \quad (6)$$

$$a_1\sum_{i=1}^{s}\omega_{1i}k_i(\sigma^1(a_1, a_2)) - a_1f_{opt}^1 \ge 0, \quad a_2\sum_{i=1}^{s}\omega_{2i}k_i(\sigma^1(a_1, a_2)) - a_2f_{opt}^2 \ge 0; \quad (7)$$

$$a_1\left[\sum_{i=1}^{s}\omega_{1i}k_i(\sigma^1(a_1, a_2)) - f_{opt}^1\right] + a_2\left[\sum_{i=1}^{s}\omega_{2i}k_i(\sigma^1(a_1, a_2)) - f_{opt}^2\right] =$$

$$= \sum_{i=1}^{s}(a_1\omega_{1i} + a_2\omega_{2i})k_i(\sigma^1(a_1, a_2)) - (a_1f_{opt}^1 + a_2f_{opt}^2) \text{ and} \quad (8)$$

$$\sum_{i=1}^{s}(a_1\omega_{1i} + a_2\omega_{2i})k_i(\sigma^1(a_1, a_2)) - (a_1f_{opt}^1 + a_2f_{opt}^2) \ge 0. \quad (9)$$

Remark 2. (6)–(9) are true for $\forall\sigma \in \sigma^1(a_1, a_2)$.

Inequalities (6), (7), (9) also hold for $\forall\sigma \in \Omega$ and therefore for $\forall\sigma \in \sigma^2(a_1, a_2)$. Since $a_1f_{opt}^1 + a_2f_{opt}^2 = const$, we reach the minimum $\min_{\sigma\in\Omega}\sum_{i=1}^{s}(a_1\omega_{1i} + a_2\omega_{2i})k_i(\sigma)$ for $\forall\sigma \in \sigma^1(a_1, a_2)$ and, consequently, we reach $\min_{\sigma\in\Omega}\left\{a_1\left[\sum_{i=1}^{s}\omega_{1i}k_i(\sigma) - f_{opt}^1\right] + a_2\left[\sum_{i=1}^{s}\omega_{2i}k_i(\sigma) - f_{opt}^2\right]\right\}$ for $\forall\sigma \in \sigma^2(a_1, a_2)$. Proven.

Corollary 1. We have reduced the problem

$$\min_{\sigma\in\Omega}\left\{a_1\left[\sum_{i=1}^{s}\omega_{1i}k_i(\sigma) - f_{opt}^1\right] + a_2\left[\sum_{i=1}^{s}\omega_{2i}k_i(\sigma) - f_{opt}^2\right]\right\} \quad (10)$$

solving to the problem (1) solving with the functional coefficients $\omega_i = a_1\omega_{1i} + a_2\omega_{2i}$, $i = \overline{1, s}$. Thus, if there is an efficient algorithm for the problem (1) solving, then this algorithm automatically solves the problem (10) efficiently.

Corollary 2. Suppose $L_1 = \sum_{i=1}^{s}\omega_{1i}k_i(\sigma_2) - f_{opt}^1$, $L_2 = \sum_{i=1}^{s}\omega_{2i}k_i(\sigma_1) - f_{opt}^2$, for $\forall\sigma \in \Omega$ $\Delta_1 = \sum_{i=1}^{s}\omega_{1i}k_i(\sigma) - f_{opt}^1$, $\Delta_2 = \sum_{i=1}^{s}\omega_{2i}k_i(\sigma) - f_{opt}^2$. Then, if $\exists\sigma \in \Omega$ for which $a_1\Delta_1 + a_2\Delta_2 < \min(a_1L_1, a_2L_2)$, then $\sigma_1 \vee \sigma_2 \notin \sigma^2(a_1, a_2)$. If there is no such feasible solution, then $\sigma^2(a_1, a_2) = \sigma_1$ if $\min(a_1L_1, a_2L_2) = a_2L_2$ or $\sigma^2(a_1, a_2) = \sigma_2$ if

$min(a_1L_1, a_2L_2) = a_1L_1$. If $a_1 = 1,\ a_2 = 1$, then $\sigma_1 \vee \sigma_2 \notin \sigma^2(a_1, a_2)$ if $\exists\sigma \in \Omega$ for which $\Delta_1 + \Delta_2 < min(L_1, L_2)$.

For convenience, we introduce the following notation:

$\sigma(\Delta_1, \Delta_2)$ is a feasible solution $\sigma \in \Omega$ for which $\Delta_1 = \sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1$ and $\Delta_2 = \sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2$. $\sigma(a_1, a_2, \Delta_1, \Delta_2)$ is some $\sigma \in \Omega$ such that $\sigma \in \sigma^2(a_1, a_2)$ for given coefficients $a_1 > 0,\ a_2 > 0$ and for which $\Delta_1 = \sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1$, $\Delta_2 = \sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2$.

Corollary 3. We can solve the problem (10) for cases $\forall a_1 > 0,\ a_2 = 1$ or $a_1 = 1,\ \forall a_2 > 0$. Indeed,

$$\arg\min_{\sigma\in\Omega}\left\{a_1\left[\sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1\right] + a_2\left[\sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2\right]\right\} =$$

$$= \arg\min_{\sigma\in\Omega}\left\{\left[\sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1\right] + \frac{a_2}{a_1}\left[\sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2\right]\right\} =$$

$$= \arg\min_{\sigma\in\Omega}\left\{\frac{a_1}{a_2}\left[\sum_{i=1}^{s} \omega_{1i} k_i(\sigma) - f_{opt}^1\right] + \left[\sum_{i=1}^{s} \omega_{2i} k_i(\sigma) - f_{opt}^2\right]\right\}.$$

Corollary 4. If the efficiency of a solving method for the problem (1) does not depend on the signs of the coefficients $\omega_i,\ i = \overline{1, s}$, then we can reformulate Statement 1 in an obvious way for the combinatorial optimization problem of the form

$$\max_{\sigma\in\Omega} \sum_{i=1}^{s} \omega_i k_i(\sigma). \tag{11}$$

Indeed,

$$\arg\max_{\sigma\in\Omega} \sum_{i=1}^{s} \omega_i k_i(\sigma) = \arg\min_{\sigma\in\Omega} \sum_{i=1}^{s} (-\omega_i) k_i(\sigma).$$

Corollary 5. Suppose that an efficient algorithm for the problem (1) exists only for $\forall\omega_i > 0,\ i = \overline{1, s}$. Then we reformulate Statement 1 in an obvious way for the problem

$$\max_{\sigma\in\Omega} \sum_{i=1}^{s} \omega_i k_i(\sigma),\ \omega_i > 0,\ i = \overline{1, s}.$$

$$\arg\max_{\sigma\in\Omega}\left\{a_1\left[f_{opt}^1 - \sum_{i=1}^{s} \omega_{1i} k_i(\sigma)\right] + a_2\left[f_{opt}^2 - \sum_{i=1}^{s} \omega_{2i} k_i(\sigma)\right]\right\} =$$

$$= \arg\max_{\sigma\in\Omega} \sum_{i=1}^{s} (a_1\omega_{1i} + a_2\omega_{2i}) k_i(\sigma), \quad a_1 > 0,\ a_2 > 0.$$

$$f_{opt}^1 = \max_{\sigma\in\Omega} \sum_{i=1}^{s} \omega_{1i} k_i(\sigma), \quad f_{opt}^2 = \max_{\sigma\in\Omega} \sum_{i=1}^{s} \omega_{2i} k_i(\sigma).$$

Statement 2. Suppose that $\sigma(a_1, a_2, \Delta_1, \Delta_2) \neq \sigma_1 \vee \sigma_2$, $\exists\sigma(a_1 + \Delta a_1, a_2, \Delta_1', \Delta_2') \neq \sigma_1 \vee \sigma_2$, and $\Delta_1' \neq \Delta_1$. Then, $\Delta a_1(\Delta_1' - \Delta_1) < 0$, $(\Delta_1' - \Delta_1)(\Delta_2' - \Delta_2) < 0$.

Proof of Statement 2 by contradiction. Suppose $\Delta a_1 > 0$ and $\Delta_1' > \Delta_1$. Since $\sigma(a_1 + \Delta a_1, a_2, \Delta_1', \Delta_2') \neq \sigma_1 \vee \sigma_2$, then $(a_1 + \Delta a_1)\Delta_1' + a_2\Delta_2' < \min(a_1L_1, a_2L_2)$. Then, $\Delta_2' < \Delta_2$ because otherwise we have $(a_1 + \Delta a_1)\Delta_1 + a_2\Delta_2 < (a_1 + \Delta a_1)\Delta_1' + a_2\Delta_2'$ which is impossible since $\sigma(a_1 + \Delta a_1, a_2, \Delta_1', \Delta_2') \in \sigma^2(a_1 + \Delta a_1, a_2)$ and therefore $(a_1 + \Delta a_1)\Delta_1 + a_2\Delta_2 \geq (a_1 + \Delta a_1)\Delta_1' + a_2\Delta_2'$. Since $(a_1 + \Delta a_1)\Delta_1 + a_2\Delta_2 \geq (a_1 + \Delta a_1)\Delta_1' + a_2\Delta_2'$, we have $(a_1 + \Delta a_1)(\Delta_1' - \Delta_1) \leq a_2(\Delta_2 - \Delta_2')$ and $a_1(\Delta_1' - \Delta_1) < a_2(\Delta_2 - \Delta_2')$. Then, $a_1\Delta_1' + a_2\Delta_2' < a_1\Delta_1 + a_2\Delta_2$, which is impossible because $\sigma(a_1, a_2, \Delta_1, \Delta_2) \in \sigma^2(a_1, a_2)$. Consequently, $\Delta_1' < \Delta_1$ and $\Delta_2' > \Delta_2$ (if $\Delta_2' \leq \Delta_2$, then $a_1\Delta_1' + a_2\Delta_2' < a_1\Delta_1 + a_2\Delta_2$ which is impossible). We can similarly prove that $\Delta_1' > \Delta_1$ and $\Delta_2' < \Delta_2$ if $\Delta a_1 < 0$. This completes the proof.

Corollary. Symmetric formulas are true for $\sigma(a_1, a_2 + \Delta a_2, \Delta_1', \Delta_2') \neq \sigma_1 \vee \sigma_2$, $\Delta_2' \neq \Delta_2$, namely: $\Delta a_2(\Delta_2' - \Delta_2) < 0$, $(\Delta_2' - \Delta_2)(\Delta_1' - \Delta_1) < 0$.

Statement 3. Suppose that $a_1L_1 > a_2L_2$ and $\sigma(a_1, a_2, \Delta_1, \Delta_2) = \sigma_1$. Then $\sigma^2(a_1', a_2) = \sigma_1$ for $\forall a_1' > a_1$.

Proof by contradiction. Suppose that $\sigma(a_1', a_2, \Delta_1', \Delta_2') \neq \sigma_1$ ($min(a_1L_1, a_2L_2) = a_2L_2$). Therefore, $a_1'\Delta_1' + a_2\Delta_2' \leq a_2L_2$. Hence, $a_1\Delta_1' + a_2\Delta_2' < a_1'\Delta_1' + a_2\Delta_2'$, since $a_1 < a_1'$. Therefore, $\sigma(\Delta_1, \Delta_2) \notin \sigma^2(a_1, a_2)$.

Corollary 1. If $\sigma^2(a_1, a_2) = \sigma_1$, then an increase in the first coefficient should not exceed the value of a_1 at a fixed a_2.

Corollary 2. Similar result holds for the case $a_2L_2 > a_1L_1$, $a_1 = const$, coefficient a_2 increases.

Statement 4. If $\sigma(a_1, a_2, \Delta_1, \Delta_2)$ satisfies the conditions $\Delta_1 > l_1$, $\Delta_2 > l_2$ for any $a_1 > 0$, $a_2 > 0$, then there is no feasible $\sigma(\Delta_1', \Delta_2')$ for which $\Delta_1' \leq l_1$, $\Delta_2' \leq l_2$.

Proof by contradiction. In this case, $a_1\Delta_1' + a_2\Delta_2' < a_1\Delta_1 + a_2\Delta_2$ and $\sigma(\Delta_1, \Delta_2) \notin \sigma^2(a_1, a_2)$.

Algorithms to solve the combinatorial optimization problem in the first formulation under uncertainty

1) The first condition: to find a feasible solution □ corresponding to $min(\Delta_1 + \Delta_2)$. We determine $\sigma^2(1, 1)$. If $\sigma^2(1, 1) \neq \sigma_1 \vee \sigma_2$, then the obtained solution $\sigma(1, 1, \Delta_1, \Delta_2) \in \sigma^2(1, 1)$ has $\Delta_1 + \Delta_2 < min(L_1, L_2)$ which is the minimum possible. Otherwise, the optimal solution according to this criterion is $\sigma_1 \vee \sigma_2$.

2) The second condition: to find a feasible solution □ for which

$$\Delta_1 \leq l_1, \ \Delta_2 \leq l_2. \qquad (12)$$

a) Suppose that $\sigma^2(1, 1) \neq \sigma_1 \vee \sigma_2$ (i.e., we have found $\sigma(1, 1, \Delta_1, \Delta_2)$ with $\Delta_1 + \Delta_2 < min(L_1, L_2)$) and $\sigma(1, 1, \Delta_1, \Delta_2)$ does not satisfy (12). Then, by virtue of Statements 2 and 3, we sequentially build solutions $\sigma(a_1, a_2, \Delta_1, \Delta_2)$, at each step first increasing a_1 at $a_2 = const$, then increasing a_2 at $a_1 = const$. As a result, we will either obtain a solution □ satisfying (12) or will build a set of solutions each of which does not satisfy (12). Then we select a compromise solution for which we have

$$min \sum_t C_{jt}(\Delta_{jt} - l_{jt}), \quad \forall t \ \Delta_{jt} > l_{jt}$$

where $C_j > 0, \ j = \overline{1, s}$ are expert coefficients.

b) Suppose that $\sigma(1, 1, \Delta_1, \Delta_2) = \sigma_1 \vee \sigma_2$. Since $l_1 < L_1, \ l_2 < L_2$, then $\sigma(1, 1, \Delta_1, \Delta_2) = \sigma_1 \vee \sigma_2$ does not satisfy the condition (12). Then, if $L_1 < L_2$, we find $\sigma^2(a_1, 1)$ where $a_1 = L_2 / L_1$. $\sigma^2(a_1, 1) \neq \sigma_1 \vee \sigma_2$ if there exists $\sigma(\Delta_1, \Delta_2)$ for which $a_1\Delta_1 + \Delta_2 < L_2$. Suppose that $L_1 > L_2$, then we find $\sigma^2(1, a_2)$, $a_2 = L_1 / L_2$, and obtain a non-trivial solution if $\exists\sigma(\Delta_1, \Delta_2)$ such that $\Delta_1 + a_2\Delta_2 < L_1$. Suppose that we have found a non-trivial solution $\sigma(\Delta_1, \Delta_2) \neq \sigma_1 \vee \sigma_2$. If $\Delta_1 \leq l_1, \ \Delta_2 \leq l_2$, then we have a solution. Suppose that $\Delta_1 \leq l_1 \vee \Delta_2 \leq l_2$ (if $\Delta_1 > l_1, \ \Delta_2 > l_2$, then there is no □ that satisfies (12)). Then, in accordance with Statements 2 and 3, we can organize an iterative procedure for obtaining solutions $\sigma(a_1, a_2, \Delta_1, \Delta_2)$ by sequential increase of a_1 at $a_2 = const$ and, vice versa, increasing sequentially a_2 at $a_1 = const$. As a result, we will either obtain a solution $\sigma(\Delta_1, \Delta_2)$ satisfying the condition (12) or a solution that violates the condition (12) as it minimally possible (see item (a)).

c) If $\sigma(1, 1) = \sigma_1 \vee \sigma_2$, $\sigma(a_1, a_2)$ from item (b) is equal to $\sigma_1 \vee \sigma_2$, then we choose a compromise from $\{\sigma_1, \sigma_2\}$ as a solution.

3) We can satisfy the condition $min \Delta_1, \ \Delta_2 \leq l_2$ or $min \Delta_2, \ \Delta_1 \leq l_1$ as a result of the implementation of the iterative procedure given in item 2 (a) or item 2 (b), since for any $\sigma(\Delta_1, \Delta_2) \in \sigma^2(a_1, a_2)$ we have: $\nexists\sigma(\Delta_1', \Delta_2')$ for which $\Delta_1' \leq \Delta_1, \ \Delta_2' \leq \Delta_2$.

We can find a feasible solution that satisfies conditions 4) or 5), that is $\min\limits_{\sigma\in\Omega}(a_1\Delta_1 + a_2\Delta_2)$ or $\min\limits_{\sigma\in\Omega}\{M\Delta = P_1\Delta_1 + P_2\Delta_2\}$, in an obvious way by solving one combinatorial optimization problem of the form (1).

Remark 3. We modify the above algorithms in an obvious way for the case of Statement 1, Corollary 5.

Combinatorial optimization under uncertainty. The second formulation

There are L sets of weights $\{\omega_i^l, \ i = \overline{1, s}\}, \ l = \overline{1, L}$. Each one may be a set of coefficients $\omega_1, \ldots, \omega_s$ of the problem (1) at the stage of fulfillment of its solution. We can specify probabilities $P_l > 0, \ l = \overline{1, L}$, $\sum\limits_l P_l = 1$, for each of the possible sets of weights (such probabilities do not exist if the uncertainty is not described by

a probabilistic model). We need to find a feasible solution $\sigma \in \Omega$ that satisfies one of the following conditions:

1) Let us denote: $f_{opt}^{l} = \min\limits_{\sigma\in\Omega} \sum\limits_{i=1}^{s} \omega_i^l k_i(\sigma)$, $\{\sigma_l\} = arg\min\limits_{\sigma\in\Omega} \sum\limits_{i=1}^{s} \omega_i^l k_i(\sigma)$,

$L_l = \sum\limits_{\substack{m=1 \\ m\neq l}}^{L} \left(\sum\limits_{i=1}^{s} \omega_i^m k_i(\sigma_l) - f_{opt}^{m} \right)$.

Remark 4. If $\{\sigma_l\}$ consists of more than one solution, we keep the one on which we have $\min\limits_{\{\sigma_l\}} L_l$ and denote this solution by σ_l (we show below how to obtain σ_l for the case when σ is finite).

Suppose that $L_p = \min\limits_{l} L_l$ (L_p corresponds to a solution σ_p). We need to find σ that reaches $\min\limits_{\sigma\in\Omega} \sum\limits_{l=1}^{L} \left(\sum\limits_{i=1}^{s} \omega_i^l k_i(\sigma) - f_{opt}^{l} \right)$.

2) Find a feasible solution $\sigma(\Delta_1, \ldots, \Delta_L)$ for which

$$\Delta_i \le l_i,\ l_i > 0,\ i = \overline{1, L}. \tag{13}$$

3) Let us introduce a random variable $F = \sum\limits_{i=1}^{s} \overline{\omega}_i k_i(\sigma) - \overline{f}_{opt}$ where s+1-dimensional discrete random variable $\overline{\omega}_1 \ldots, \overline{\omega}_s, \overline{f}_{opt}$ is specified by the table:

$$\begin{Bmatrix} \omega_1^l, \ldots, \omega_s^l, f_{opt}^l \\ P_l > 0,\ l = \overline{1, L} \end{Bmatrix}.$$

We need to find a solution to this problem:

$$\min_{\sigma\in\Omega} MF = \min_{\sigma\in\Omega} \sum_{l=1}^{L} P_l \left(\sum_{i=1}^{s} \omega_i^l k_i(\sigma) - f_{opt}^{l} \right).$$

4) Find a feasible solution that satisfies the condition

$$\min_{\sigma\in\Omega} \sum_{l=1}^{L} a_l \left(\sum_{i=1}^{s} \omega_i^l k_i(\sigma) - f_{opt}^{l} \right)$$

where $\forall a_l > 0$ are the coefficients set by experts.

Finding a solution that satisfies one of the four given conditions follows from the following Statement 5 which is a natural generalization of Statement 1.

Statement 5. The following is true for arbitrary $a_l > 0,\ l = \overline{1, L}$:

$$arg\min_{\sigma\in\Omega} \sum_{l=1}^{L} a_l \left[\sum_{i=1}^{s} \omega_i^l k_i(\sigma) - f_{opt}^{l} \right] = arg\min_{\sigma\in\Omega} \sum_{i=1}^{s} \left(\sum_{l=1}^{L} a_l \omega_i^l \right) k_i(\sigma). \tag{15}$$

Proof of Statement 5 is similar to the proof of Statement 1.

Corollary 1. Solving of the problem $\min\limits_{\sigma\in\Omega} \sum\limits_{l=1}^{L} a_l \left[\sum\limits_{i=1}^{s} \omega_i^l k_i(\sigma) - f_{opt}^{l} \right]$ reduces to solving of one problem of the form (1):

$$\min_{\sigma\in\Omega}\sum_{i=1}^{s}\left(\sum_{l=1}^{L}a_l\omega_i^l\right)k_i(\sigma). \tag{16}$$

Corollary 2. Suppose that a solution $\sigma(a_1,\ldots,a_L,\Delta_1,\ldots,\Delta_L)\neq\neq\sigma_1\vee\ldots\vee\sigma_L$ belongs to the set $\sigma^2(a_1,\ldots,a_L)$. Then, $\nexists\sigma(\Delta_1',\ldots,\Delta_L')\in\Omega$ for which $\Delta_i'\le\Delta_i$, $i=\overline{1,L}$, $\Delta^T=(\Delta_1,\ldots,\Delta_L)\neq\Delta'^T=(\Delta_1',\ldots,\Delta_L')$.

Corollary 3. To obtain a solution according to condition 1), it is necessary to set $a_l=1,\ l=\overline{1,L}$ in the problem (1). In this case, the solution to problem (15) does not coincide with the solution σ_p corresponding to $\min\limits_l L_l$ if there is such a feasible solution $\sigma(\Delta_1,\ldots,\Delta_L)$, $\Delta_l=\sum\limits_{i=1}^{s}\omega_i^l k_i(\sigma)-f_{opt}^l$ for which

$$\sum_{l=1}^{L}\Delta_l<L_p. \tag{17}$$

If there is no such a feasible solution $\sigma(\Delta_1,\ldots,\Delta_L)$ that $\sum\limits_{l=1}^{L}\Delta_l<L_p$, then $\sigma(1,\ldots,1)=\sigma_p$. So, without knowing the sets $\{\sigma_1\},\ldots,\{\sigma_L\}$ we automatically obtain σ_p. At $L=2$, solving two problems $a_1>0$ (a sufficiently large number), $a_2=1$ and $a_1=1$, $a_2>0$ (a sufficiently large number), we find σ_1, σ_2 that correspond to the minimum possible L_1, L_2 in case when σ is finite. In the general case, if Ω is finite, $\sigma_j=\sigma^2(1,\ldots,1,a_j,1,\ldots,1)$ for sufficiently large a_j.

Corollary 4. Suppose that $\sigma(a_1,\ldots,a_L,\Delta_1,\ldots,\Delta_L)\neq\sigma_1\vee\ldots\vee\sigma_L$ and $\exists\sigma(a_1,a_2,\ldots,a_{i-1},a_i',a_{i+1},\ldots,a_L,\Delta_1',\ldots,\Delta_L')\neq\sigma_1\vee\ldots\vee\sigma_L,\ a_i'\neq a_i$. Then an analogue of the Statement 2 is true:

$$(a_i'-a_i)(\Delta_i'-\Delta_i)<0,\ (\Delta_i'-\Delta_i)\left[(a_1\Delta_1'+\ldots+a_{i-1}\Delta_{i-1}'+a_{i+1}\Delta_{i+1}'+a_L\Delta_L')-\right.$$
$$\left.-(a_1\Delta_1+\ldots+a_{i-1}\Delta_{i-1}+a_{i+1}\Delta_{i+1}+a_L\Delta_L)\right]<0. \tag{19}$$

Proof of this inequality almost literally repeats the proof of Statement 2.

Corollary 5. Suppose that $\sigma(1,\ldots,1,\Delta_1,\ldots,\Delta_L)\neq\sigma_p$ and does not satisfy the condition 2). Then, by logic of the inequalities (19), we can organize a sequential procedure for the problem (16) solving by increasing $\forall a_i$ at each iteration if $\Delta_i>l_i$ and decreasing $\forall a_j$ if $\Delta_j<l_j$. As a result, we either find a solution □ satisfying the condition 2) or obtain a set of solutions $\{\sigma\}^1$ each of which violates the condition 2). It is true that $\sigma(1,\ldots,1,\Delta_1,\ldots,\Delta_L)\in\{\sigma\}^1$. Denote $\{\sigma\}^2=\{\sigma_1,\ldots,\sigma_L\}$. Then a compromise solution for the condition 2) is a solution $\overline{\sigma}\in\{\sigma\}^1\cup\{\sigma\}^2$ that reaches

$$\min\sum_t C_{jt}(\Delta_{jt}-l_{jt}),\quad \forall t\ \Delta_{jt}>l_{jt}$$

where $C_j>0,\ j=\overline{1,s}$ are expert coefficients.

Corollary 6. We can find a feasible solution σ satisfying the condition 3) or 4) by solving one problem of the form (16).

Corollary 7 (analogue of Corollary 5 to Statement 1). We can solve similarly in the obvious way the combinatorial optimization problem under uncertainty of the form

$$\max_{\sigma\in\Omega}\sum_{i=1}^{s}\omega_i k_i(\sigma),\ \omega_i > 0,\ i=\overline{1,s}. \qquad (18)$$

Corollary 8. If the efficiency of the solving method for the problem (1) does not depend on the signs of the coefficients ω_i, then we can similarly solve the following vector optimization problem: find a compromise solution for the problem

$$\min_{\sigma\in\Omega}\sum_{i=1}^{s}\omega_i^l k_i(\sigma),\ l=\overline{1,L},\ \max_{\sigma\in\Omega}\sum_{i=1}^{s}\omega_i^p k_i(\sigma),\ p=\overline{1,L}.$$

CONCLUSIONS

We formulate a sufficiently common class of combinatorial optimization problems under uncertainty. The latter means a possible ambiguity of the values of coefficients included in the optimality criterion at the time of fulfillment of the optimal solution. We also formulate criteria for a compromise solution obtaining and algorithms for its finding based on the well-known idea of linear convolution of criteria [3–7]. A distinctive feature of the presented algorithms is that their efficiency is unambiguously determined by the efficiency of solving the combinatorial optimization problem in a deterministic formulation.

REFERENCES

1. Garey M.R., Johnson D.S. Computers and Intractability: a Guide to the Theory of NP-Completeness. San Francisco: W.H. Freeman and Co., 1979. 347 p.

2. Zgurovsky M.Z., Pavlov A.A. Combinatorial Optimization Problems in Planning and Decision Making: Theory and Applications. 1st ed. Cham: Springer, 2019. 526 p. DOI: 10.1007/978-3-319-98977-8

3. Уткин Л.В. Лекции по курсу «Принятие решений в условиях неопределенности». Глава 6 «Многокритериальное принятие решений» [Електронний ресурс] // http://levvu.narod.ru. 2007. URL: http://levvu.narod.ru/Papers/Multicrit.pdf. Дата обращения: 15.02.2019

4. Ehrgott M. Multicriteria Optimization. 2nd edition. Berlin, Heidelberg: Springer, 2005. 336 p. DOI: 10.1007/3-540-27659-9

5. Ногин В.Д. Линейная свертка критериев в многокритериальной оптимизации // Искусственный интеллект и принятие решений. 2014. № 4. С.73-82.

6. Кравцов М.К., Янушкевич О.А. Линейная свертка критериев в бикритериальной оптимизации // Известия высших учебных заведений. Математика. 1998. № 12 (439). С.63-70 URL: http://mi.mathnet.ru/rus/ivm/y1998/i12/p63

7. Меламед И.И. Линейная свертка критериев в многокритериальной оптимизации // Автоматика и телемеханика. 1997. № 9. С.119-125 URL: http://mi.mathnet.ru/eng/at/y1997/i9/p119

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THE CONCEPT OF SYNTHESIS OF WALKING ROBOTS OF ARBITRARY ORIENTATION

Abstract: Robots of arbitrary orientation (Climber Robot) are a new modification of mobile robots. These robots are equipped with means of holding the robot on a surface of arbitrary orientation relative to the horizon of the technological space. The creation of this type of robotics is at the initial stage and is dictated by the need to perform technological operations for monitoring industrial facilities, installation and dismantling of building structures, repair and preventive maintenance of their components. The article proposed three basic principles for the synthesisof walking mobile robots: the accumulation and transformation of energy, the integration of motion drives and the use of a generator of reactive pneumatic thrust. The implementation of these principles helps to reduce the total power of the drives and to increase the reliability of the holding robots on the surface of an arbitrary orientation in the technological space. The results of mathematical modeling of constructive and technological parameters of mobile robots are described.

Keywords: mobile robots, walking mechanisms, robots of vertical movement, climbing robots

1. Introduction

The evolution of technical systems in the field of engineering science, as a rule, led to the emergence of new means of production. In the twentieth century scientific and technical thought created sufficiently reliable means of overcoming the gravitational force in the form of flying and reactive equipment. These funds are used as a reliable transport. However, up to the present time there are no industrial samples of equipment for performing contact technological operations while simultaneously overcoming the forces of gravity.

Mobile robots of arbitrary orientation are known in publications as robots of vertical movement or in international publications – under the term Climber Robot, are a new modification of mobile robots. These robots are equipped with means of fixation on the surface of arbitrary orientation relative to the horizon of the technological space. The creation of this kind of robotics is at the initial stage and is dictated by the need to perform technological operations in such areas of industrial activity as monitoring of industrial facilities, installation and dismantling of building structures, repair and prevention of their components. In the context of the fourth industrial revolution, "Industry 4.0" [1], with the focus on the use of robotic systems, information and communication tools, and the use of these robots becomes especially urgent in the extreme conditions of man-made disasters that are dangerous and even unacceptable for human presence.

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2. Prerequisites and means for solving the problem

The problem of creating this type of robots is the lack of a methodology for synthesizing the robot subsystems that compensate or overcome the gravitational load in order to ensure that the robot is held on an arbitrarily oriented surface during the execution of technological operations. Therefore, the purpose of this research is to develop principles for the synthesis of mobile robots and the introduction of modern computer modeling tools for the transition to the design and manufacture of prototypes of mobile robots.

Theoretical and experimental studies on the creation of robots of arbitrary orientation in the technological space began in the last decade of the twentieth century in the countries of Western Europe, Japan, the United States, Korea, China and Russia. To date, there are mainly experimental samples of such robots.

Mobile works [2–5] are equipped with devices to fix the robot on surfaces of arbitrary orientation, and in studies [6, 7] hybrid drives are proposed that can improve the energy efficiency of mobile robots. Technical solutions [8–11] allow the robot to move on surfaces oriented at different angles to the horizon, but only in 2D space, that is, in a plane. In the general case, the variations of the constructionsof the above-mentioned robots restrict their movement only in the Cartesian coordinate system.

Unlike the aforementioned technical solutions, the robot model [12] allows servicing objects in the cylindrical coordinate system, in particular, objects such as trees, but with a soft porous surface for the movement of the robot, which limits the technological capabilities of mobile robots. At a time when there are objects facilities that are also close to the cylindrical coordinate system, for example, electric grid posts, columns, pipes of thermal power plants and the like. In addition, the mobile robot should also work in a system of angular coordinates, which is typical for humans. The development of systems for connecting the robot to the surface of motion is a technical solution [13], which uses adhesion technology. However, current implementations of this technology are characterized by an extremely low speed of movement of the robot due to the effect of slow adhesion. This property still prevents the industrial use of adhesion as a method of fixing the robot to a surface of arbitrary orientation. Thus, the problem of synthesizing mobile robots capable of performing technological operations in a space of arbitrary orientation is topical.

3. Solution of the problem under consideration

In contrast to the above, the concept of improving robots of arbitrary orientation based on three fundamental principles of the synthesis of mobile robot designs is proposed:

1) Accumulation of potential energy at each previous step of the robot's movement and subsequent conversion to kinetic energy at the next step of the movement.

2) Integration of drives of longitudinal, vertical displacement, and also drives of change of orientation of the robot according to the set route.

3) The use of traction generators (aerodynamic lift forces) as a means of counteracting the gravitational force to increase the technological load while simultaneously reducing the power of clutch drives and the movement of robots.

As technical means of implementing these principles of synthesis, consider the corresponding models of robots of arbitrary orientation. In Fig. 1 shows a mobile robot [14] realizing the first of the above mentioned principles, namely having the ability to accumulate potential energy at each previous step and converting it into kinetic energy of motion at each subsequent step of displacement.

Then we will offer two fundamentally new solutions for mobile robots with energy accumulators that will allow you to accumulate potential energy at each first step and convert it into kinetic energy of motion at each subsequent step of the robot's movement. A first embodiment of such a robot [15] is shown in Fig.1. The body 1 is equipped with rotating pneumatic actuators 2 connected by means of gears 3 and 4 with stepping mechanisms made in the form of telescopic cylinders 5 and 6 and connected by a hinged parallelogram 7 with grippers 8 for engaging with the surface along which the robot moves. To overcome obstacles on the surface along which the robot moves, it is additionally equipped with rolling bearings 9.

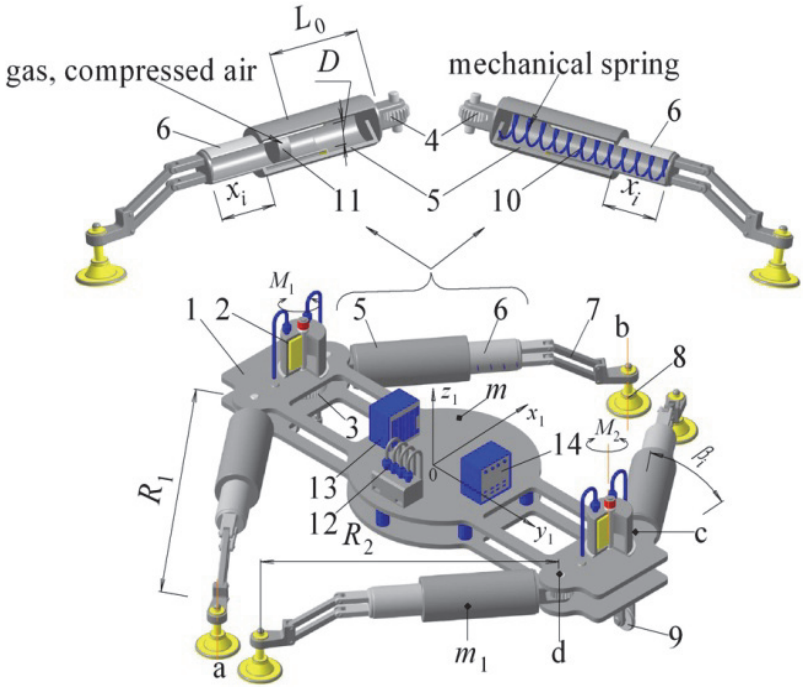

Fig.1. The robot model of arbitrary orientation with the accumulation and transformation of energy

Fig. 1 shows two versions of the walking mechanisms: with an energy storage module in the form of mechanical springs 10 and, alternatively, with a gas accumulator. In the latter embodiment, the energy storage device is a compressed air chamber. This chamber is formed by a cylinder 5 and a piston 11. In addition, the robot is equipped with pneumatic distributors 12, a power module 13 and a control unit 14.

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When the grippers 8 are connected to the surface along which the robot moves, the motors 2 rotate the legs of the robot with the radius R_1 around the axes "a" and "b" under the action of the moving torque M_1, compressing the elastic element: either the mechanical springs 10 or the gas in the chamber 5, depending on the embodiment. Because of this compression, the accumulation of potential energy in the first stage occurs at the angle of rotation of the legs of the robot $0 \le \beta \le 45^0$, and in the second stage $45^0 \le \beta \le 90^0$ the elastic elements expand and transform the potential energy of compression into the kinetic energy of the robot's movement. At the same time, another pair of legs with radius R_2 rotates freely through the angle βi. Then, according to the commands of the control system, the first pair of clamps 8 is disconnected from the displacement surface, and the other pair of clamps in turn is turned on and the cycle of motion is repeated.

If a mechanical spring is used to accumulate potential energy (see item 10, fig. 1), the force of the elastic element of the pedipulator will be

$$J = P_{\min} + jR_2\left(1 - \frac{\cos 45^0}{\cos(45^0 - \beta_1)}\right); \quad 0 \le \beta_1 \le 90^0, \tag{1}$$

where: P_{min} – preliminary compression and j – rigidity of the elastic element for accumulation of potential energy. In the case of accumulation of potential energy by compressing the gas in the cylinder 5 (Fig. 1), the force J of the elastic element (gas)

$$J = p\frac{\pi D^2}{4} - p_a\frac{\pi D^2}{4} = \frac{\pi D^2}{4}\left(p_o\frac{L_o}{L_o - x} - p_a\right)$$

$$0 \le \beta_1 \le 90^0 \tag{2}$$

$$x = R_2\left(1 - \frac{\cos 45^o}{\cos(45^o - \beta_1)}\right);\ L_o = \frac{p_{\max} x_{\max}}{p_{\max} - p_o}$$

where: D – internal diameter of the gas chamber; p_0, p_a, p_{max} are the current, atmospheric and maximum chamber pressures, respectively; L_0 - working length of the camera; x, x_{max} are the current and maximum compression of the elastic element, respectively.

This mobile robot is designed to move small loads, about 25 ... 50 kg, and without any special effort performs technological operations. When a large load capacity of a mobile robot is required, the construction shown in Fig. 2 is necessary. The walking mechanisms of this robot (pedals) are made in the form of hinged parallelograms with drives from hydraulic cylinders. As you can see in Fig. 2, on the diagonal of the robot body are two legs with gas cylinders and two legs with rotary actuators [16]. When one pair of legs of the robot - with gas cylinders adhere to the surface of the motion with the help of vacuum grippers, and the other pair of legs with rotary drives is not connected with the surface of motion, then the motors move the robot in the direction of the Y axis. Simultaneously with this motion, movement of the piston of the gas cylinder. As a result, the gas is compressed in the cylinder and the potential energy of the compressed gas accumulates.

After disconnecting the first pair of vacuum grippers and switching on another pair of grippers, the compressed gas in the gas chambers expands and converts the

potential energy into kinetic energy of the robot's motion, but with the electric motors switched off. This way of moving the robot allows you to save the energy of an autonomous power source, which always has a limited resource. In Fig. 2 shows all possible movements of the robot in the XYZ coordinate system. These motions include three translational movements Sx, Sy, Sz and two rotational motions ±α and ±β. As a result, the robot has five degrees of freedom, which is enough to perform any technological operations on surfaces of arbitrary orientation.

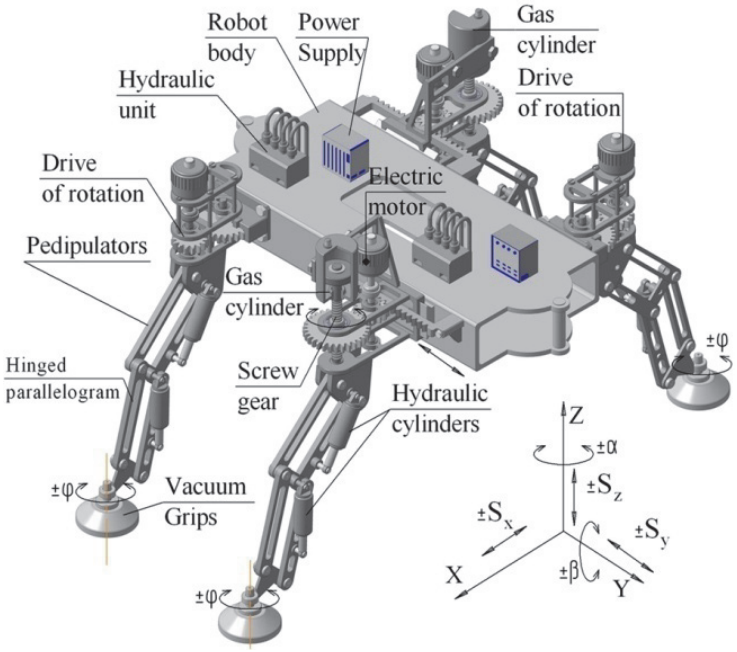

Fig.2. Walking mobile robot with energy accumulators

The use of each of the variants of robots is determined by the goals of production. Thus, it is recommended to use the first of these design options for performing operations controlling the strength of industrial facilities or video shooting of various objects. It is recommended to use the second version of the mobile robot with hydraulic drives to perform work with large technological forces. But both versions of mobile robots make a move by converting the accumulated potential energy into kinetic energy of motion.

The volumes of kinetic energy of the robot movement at different stages of displacement can be determined using the Lagrangian equations of the second kind. Since this method is classical, here for brevity we confine ourselves to the results of modeling. The expression of the kinetic energy of the robot body will have the form

$$T_k = \frac{mV^2}{2} = \frac{mR_2^2}{4\cos^4(45^0 - \beta_1)}(\dot{\beta}_1)^2 \qquad (3)$$

where: m is the robot's body weight; V and $\dot{\beta}_1$ – respectively linear and angular velocities of the robot legs. For the legs of the robot, in which there is no adhesion to the displacement surface, the kinetic energy T_1 will have a value:

$$T_1 = \frac{1}{2}\int (V_{x1}^2 + V_{y_1}^2) dm. \tag{4}$$

Substituting in expression (4) expressions for the projection of velocity and its value $V = \frac{ds}{dt} = \frac{R_2 \cos 45^0}{\cos^2(45^0 - \beta_1)}\dot{\beta}_1$ and $dm = m_1 dy / R_2$, after integration, we obtain the final formula for finding the kinetic energy of the free leg of the robot:

$$T_1 = \frac{m_1 R_2^2}{2}\left(\begin{array}{l}\frac{(\dot{\beta}_1)^2}{2\cos^4(45^0 - \beta_1)} + \\ + \frac{\dot{\beta}_1\dot{\beta}_2\sqrt{2}\cos(45^0 - \beta_2)}{2\cos^2(45^0 - \beta_1)} + \frac{1}{3}(\dot{\beta}_2)^2\end{array}\right), \tag{5}$$

where: m_1 is the mass of the pedipulator (legs) of the robot, and R_2 is the radius of its rotation.

The expression of the kinetic energy of the supporting leg (linked to the displacement surface) can be obtained from expression (4) after its integration, substituting the velocity of the translational motion of the robot $V = 0$ and the angular velocities $\dot{\beta}_2 = \dot{\beta}_1$ of the pedipulators:

$$T_2 = \frac{m_1 R_2^2}{6}(\dot{\beta}_1)^2 \ . \tag{6}$$

Then the total kinetic energy T of each pedipulator on the two halves of the robot's travel cycle, i.e. at the stage of accumulation of potential energy when the elastic elements are compressed and converted into kinetic energy of motion, will be:

$$T = \frac{R_2^2}{2}\left(\begin{array}{l}\frac{(2m_1 + m)(\dot{\beta}_1)^2}{2\cos^4(45^0 - \beta_1)} + \\ + \frac{m_1\dot{\beta}_1\dot{\beta}_2\sqrt{2}\cos(45^0 - \beta_2)}{\cos^2(45^0 - \beta_1)} + \\ + \frac{2m_1}{3}((\dot{\beta}_2)^2 + (\dot{\beta}_1)^2)\end{array}\right). \tag{7}$$

Thus, the movement of the robot at each second half of the cycle occurs due to the energy accumulated at each first half of the travel step. This allows you to save 40%...45% of the energy volume on the movement of the robot and sends the resulting energy reserve for the execution of technological operations.

The main characteristic of elastic elements is their rigidity j – parameter, which determines the force of compression of these elements, and hence the value of the accumulated potential energy in the first half of the step of the pedipulator. In Fig. 3 shows the dependence of the variation of work "A" on the stiffness of the elastic element $\boldsymbol{j}$ (N/m) and the forces of weight in the second stage $\beta_{1,2} > 45^o$ of displacement, that is, during the transformation of the potential energy into the kinetic energy of the robot's motion.

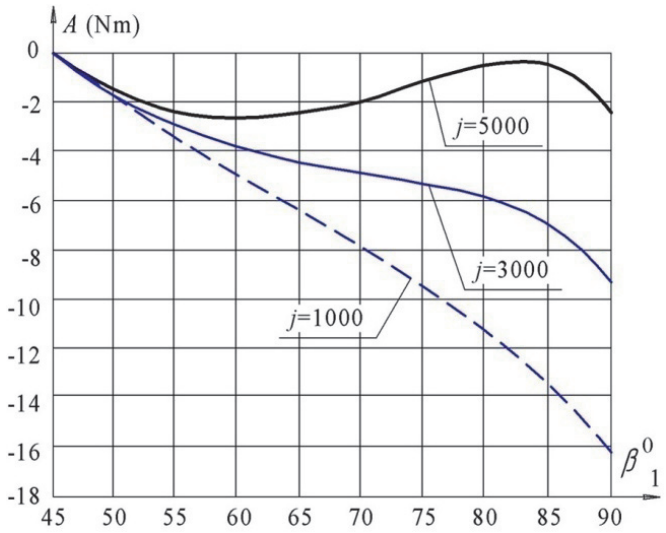

Fig.3. The effect of the elastic element *j* (N/m) on the work performed in the step $\beta_1 > 45^o$ of the robot movement

At the second stage of displacement $45^o \le \beta_{1,2} \le 90^o$ drive the of pedipulator is turned off to save energy resources of the robot, and it moves only due to kinetic energy. Analysis of these graphs shows that to increase the kinetic energy of the robot movement, it is advisable to increase the rigidity, despite the fact that in this case the counteraction to the drive increases in the first half of the step, that is, the efficiency of the drive decreases. However, this negative manifestation can be compensated for by an increase in the transmission ratio (see item 3 and 4, Fig.1) of pedipulators.

The second principle, as noted above, involves the integration of displacement drives [17] with the aim of reducing them, and hence of reducing the mass of the robot. It is known that in the Cartesian space we have six degrees of freedom – three translational movements and three rotational, each of which according to the classical solutions corresponds to an autonomous drive. The method of Fig. 4 – technical implementation of this principle eliminates the need for drives for each of the coordinate axes. To do this, the robot is equipped with flexible running mechanisms 2 mounted on the body 1. Each pair of legs of the robot through the transmissions 3 is provided with electric drives 4. The grippers 5 keep the robot on the surface moving, and the rotary actuators 6 change the position of the grippers relative to the displacement surface. The robot platform has a power supply unit 7, a hydraulic or pneumatic valve unit 8 and a gas or liquid pressure generator and a controller 9 for controlling the robot. Due to the fact that each foot of the robot is made in the form of a compressed set of hemispherical rings inside which corrugated pipes are placed under different pressures, the robot has the ability to work in different coordinate systems: rectangular Cartesian, spherical and cylindrical without additional drives on each axis of coordinates.

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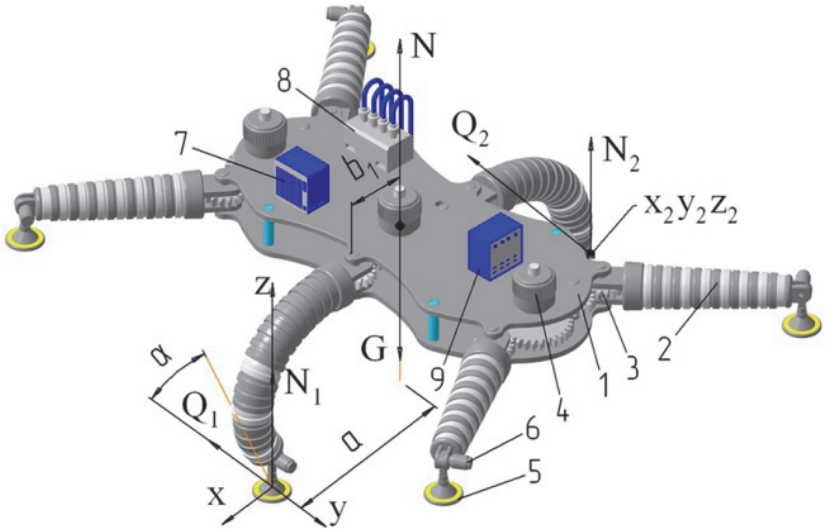

Fig.4. Model of the robot with flexible pedipulators

In each leg of the robot there are four corrugated pipes. Two pipelines with pressure p_1 p_2 are placed in a vertical plane and two other pipelines – in a horizontal plane with pressure p_3 and p_4. Due to the action of these pressures, forces appear that, while bending the robot's leg, orient the robot in the technological space:

$$F_1 = p_1 \frac{\pi d^2}{4}; F_2 = p_2 \frac{\pi d^2}{4}; F_3 = p_3 \frac{\pi d^2}{4}; F_4 = p_4 \frac{\pi d^2}{4}, \tag{8}$$

where d – the internal diameter of the corrugated tubes. Since the axes of the pipelines are offset from the pedipulator axis by the eccentricity e, there are moments M_1 and M_2 that flex the robot's leg:

$$M_1 = \frac{\pi d^2}{4}(p_1 - p_2)e; \quad M_2 = \frac{\pi d^2}{4}(p_3 - p_4)e \tag{9}$$

where: e – eccentricity of placement of corrugated pipelines in the plane of the coordinate system.

To develop a robot, it is necessary to establish a connection between the forces of adhesion of its legs to the displacement surface and the permissible technological load to ensure the reliability of its industrial operation. Having formulated the system of equilibrium equations (here we omit the record for brevity), we find the corresponding reaction forces $N_{1,2}$ and the frictional forces $Q_{1,2}$ by the robot foot to the displacement surface and then compare them with the technological load N in depending on the angle $\boldsymbol{\alpha}$ of the robot inclination to the horizon.

The reaction forces of N_2 and the frictional forces Q_{2y} of the robot supports with the displacement surface are determined as follows (the designation of the parameters, see Fig.4):

$$N_2 = Q_2 + a_3 G - b_3 N; \quad Q_{2y} = d_3 G + h_3 N, \tag{10}$$

where for the compactness of the incoming values of variables is denoted:

$a_3 = d_1 b_2 - b_1 d_2 / \Delta$; $b_3 = b_2 h_1 + b_1 h_2 / \Delta$; $d_1 = y_c \cos\alpha - z_c \sin\alpha$;

$b_2 = x_2 \cos(\varphi - \alpha)$; $d_3 = d_2 a_1 - d_1 a_2 / \Delta$; $h_3 = h_2 a_1 + a_2 h / \Delta$;

$a_1 = y_2\cos(\varphi-\alpha) + z_2\sin(\varphi-\alpha);\ a_2 = -x_2\sin(\varphi-\alpha);$

$d_2 = x_c\sin\alpha;\ b_1 = y_2\sin(\varphi-\alpha) - z_2\cos(\varphi-\alpha);$

$h_1 = y_c\cos\psi + z_c\sin\psi;\ h_2 = x_c\sin\psi;\ \Delta = a_1b_2 - b_1a_2;$ x2, y2, z2 – coordinates of the contact point of the second leg of the robot with the displacement surface; xc, yc, zc are the coordinates of the center of gravity of the robot; α, φ – angles of inclination to the horizon of surfaces on which the robot's legs rest; ψ is the angle of inclination of the central axis of the robot passing through its center of gravity G (see Fig.4). Then, from the same system of equilibrium equations, we find the remaining unknown reactions N1 and the frictional forces Q1y:

$$N_1 = Q_1 + Ga_4 - Nh_4;\quad Q_{1y} = Gh_5 + Nh_6, \tag{11}$$

where also for the compactness of writing variables is defined:

$$a_4 = \cos\alpha - a_3\cos(\varphi-\alpha) - d_3\sin(\varphi-\alpha);$$
$$h_4 = \cos\psi - b_3\cos(\varphi-\alpha) + h_3\sin(\varphi-\alpha);$$
$$h_5 = \sin\alpha - d_3\cos(\varphi-\alpha) + a_3\sin(\varphi-\alpha);$$
$$h_6 = \sin\psi - h_3\cos(\varphi-\alpha) - b_3\sin(\varphi-\alpha).$$

For the stability of the robot, the frictional forces of each of its legs must not exceed the boundary values:

$$Q_{1y} < \mu N_1;\quad Q_{2y} < \mu N_2;\ N_1 > 0;\ N_2 > 0, \tag{12}$$

where μ – the coefficient of friction of the grip of the robot's leg with the surface along which the robot moves. Substituting in expression (12) the expressions above the found reactions of forces (10) and (11), we find limitations for the technological load of the robot taking into account the forces acting on it:

$$N_1 > 0 \Rightarrow N < \frac{Q_1 + Ga_4}{h_4};\ N_2 > 0 \Rightarrow N < \frac{Q_2 + Ga_3}{b_3};$$
$$N < \frac{\mu Q_2 + G(\mu a_3 - d_3)}{h_3 + \mu b_3};\ N < \frac{\mu Q_1 + G(\mu a_4 - h_5)}{h_6 + \mu h_4}. \tag{13}$$

Among the values of the reaction N of the technological load calculated in accordance with conditions (13), we choose the largest, which simultaneously satisfies all inequalities, which allows to determine the maximum technological load of the robot, for example, for drilling, rivets, dowels, etc. technological operations.

As a result of the simulation, the limiting values of the technological load are obtained (see Fig.5): curves 1 and 2, respectively, determine the separation states from the displacement surface of the first and second legs of the robot, and curves 3 and 4 are the beginning of slippage of the said robot legs, respectively.

Simulation of the robot's behavior at different angles of inclination to the horizon and the magnitude of the gripping of the robot's grips with the displacement surface was performed under the following restrictions: the mass of the robot is 25≤m≤50 (kg), the weight is G = mg, and g = 9,8 m/c^2; leg length of the robot L = 0.5(m); 0.025≤e≤0.045(m); a = 2b$_1$; b$_1$ = Rsin(β), where R and β are the radius and bend angle of the robot leg (see Fig.4). These limitations are dictated by the industrial feasibility and parameters of the projected prototype of the robot.

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The robot of arbitrary orientation can be on such surfaces as a floor, a wall or a ceiling. Accordingly, if the robot is on the floor, then in the above dependences it is necessary to substitute the value $\varphi = 0^o$, $\alpha = 0^o$; if on a vertical wall, then $\varphi = 90^o$, $\alpha = 90^o$ and if on the ceiling, then $\varphi = 180^o$, $\alpha = 180^o$ and so on.

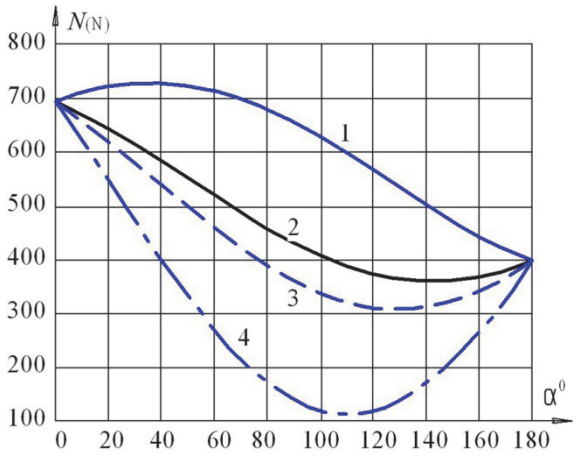

Fig.5. Graphs of the boundary values of the technological force *N* of the robot as a function of the angle ***α*** of the inclination to the horizon

And, finally, the third principle – the use of traction generators as a means of counteracting the gravitational force is realized by the robot [18], shown in Fig. 6. Like the previous one, it also has flexible pedipulators 1, grippers 2, gear 3 and electric drives 4 on the body 5. The main difference of this robot is the installation in the center of its masses suspension Cardan 6 with three degrees of freedom and a pneumatic generator of traction 7. The location of the thrust generator on the Cardan suspension allows the thrust generator to maintain the coincidence of the lines of action of opposing forces: the rise of G_1 and the gravitational force G, regardless of the position of the robot in the XYZ space. This principle allows us to differentiate the approach to regulating the lifting force of the robot, depending on its orientation in space.

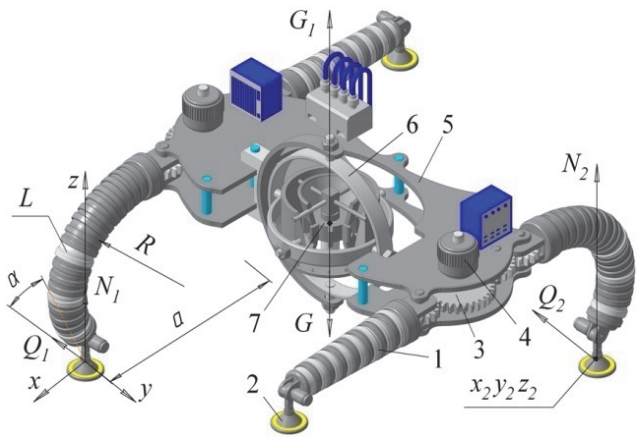

Fig.6. Mobile robot with pneumatic generator of aerodynamic lift

Similarly to the previous case, from the system of equilibrium equations of the robot determine the forces of normal reactions N_i of the legs of the robot and the corresponding frictional forces Q_i (see Fig.6):

$$N_2 = b_{12}(G - G_1), \tag{14}$$

where: G – the weight of the robot; G_1 – traction force; α - angle of inclination of the plane of movement of the robot to the horizon $b_{12} = \cos\alpha y_c - \sin\alpha z_c / 2y_2$; y_c, z_c – coordinates of the center of gravity of the robot; y2 – coordinate of contact with the moving surface of the second part of the robot. The frictional force Q_{1y} and the normal reaction N_1 are determined as

$$Q_{1y} = (G - G_1)(-\mu b_{12} + \frac{1}{2}\sin\alpha); \quad N_1 = (G - G_1)(-b_{12} + \frac{1}{2}\cos\alpha). \tag{15}$$

As can be seen from the graphs of Fig. 7 with positive reactions N_1 and N_2 with the angle of inclination of the displacement surface $\alpha \leq 54^o$, the weight of the robot increases the technological load. This means that the inclusion of the jet engine is more suitable for the values of the angle of inclination of the robot to the horizon at $\alpha \geq 54^o$. Of course, the critical angle of inclination depends on the other centrifugal characteristics of the robot. However, using the generator of aerodynamic forces ensures reliable retention of the robot on surfaces of arbitrary orientation with any structural and technological parameters of the robots. To calculate the critical angle of inclination to the horizon and, accordingly, to regulate the force of the reactive thrust, that is, the aerodynamic force of the pneumatic generator, it is necessary to take into account other characteristics of the robot.

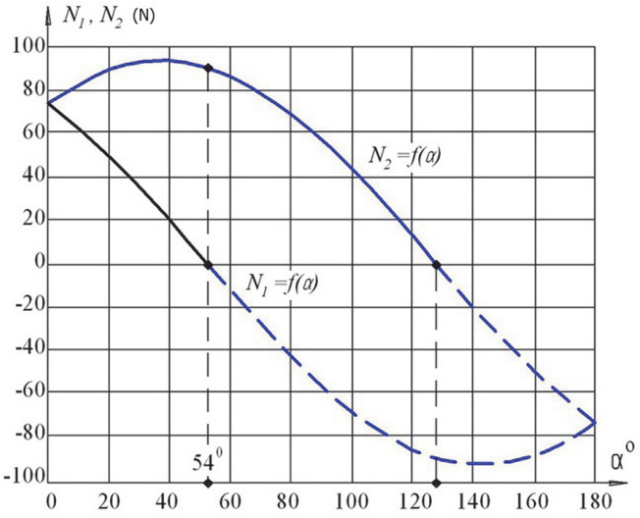

Fig.7. Graphs of the dependence of the normal reactions N_1, N_2 of the robot on the angle α of its inclination to the horizon

4. Results and discussion

The creation of means for accumulating the potential energy of the drives, and then transforming them into kinetic energy of the robot's motion, and also the inte-

gration of drives for longitudinal and vertical movement, can significantly reduce the total power that is of fundamental importance for mobile robots of arbitrary orientation in space, since reduces the gravitational load.

The use of a pneumatic motor as a means of counteracting the gravitational force makes it possible, when adjusting the traction force, depending on the angle of the robot's inclination to the horizon, to increase the reliability of holding the robot on the surface of an arbitrary orientation, which in turn makes it possible to reduce the power of the clutch actuators of the robot with the surface.

A fundamentally new realization of the legs of mobile robots in the form of a set of hemispherical rings and corrugated pipelines at different gas or liquid pressures makes it possible to achieve an arbitrary orientation of the mobile robot in different working spaces: a rectangular Cartesian, spherical and cylindrical coordinate system. This effect ensures the expansion of technological capabilities of mobile robots of arbitrary orientation in the technological space.

5. Conclusion

The concept of the synthesis of mobile robots is based on three principles of constructing their designs. These principles can be used autonomously and in combination, depending on the technological purpose of the robot and its profitability, which, in turn, is determined by the area of industrial operation. The proposed approach to the synthesis of mobile robots can reduce the weight of structures by reducing the total number of drives. This increases the energy resource for improving the efficiency of both transport and technological operations performed by the robot in various areas of industry. The next stage of the research is the experimental approbation of this concept of the synthesis of mobile robots.

References

1. Kuznetsov Yu.N. (2017). Challenges of the fourth industrial revolution "Industry 4.0" in front of scientists of Ukraine. *Vestnik KhNTU, Kherson*. 2(61),pp. 67–75.

2. Raju D.D., Jaju S.B. (2014). Developments in wall climbing robots: a review. *International journal of engineering research and general science*. 12 (2(3)), p. 37.

3. Gradetskii V.G.,Veshnikov V.B.and Kalinichenko S.V. (2001). *Controlled movement of mobile robots over arbitrarily oriented surfaces in space*. Moscow: Nauka. 360p.

4. Chernous'ko F.L. Bolotnik N.N. and Gradetskii V.G. (2017). *Mobilerobots: research, development, prospects*. Available: http://www.ras.ru/news/ /shownews.aspx?id=f5c75bcf-2fa5-40e6-b067-4492c5ab22&print=1. Last accessed 20 iyulya 2018.

5. Polishchuk M.N. (2018). Modernization of the vacuum gripper of the mobile walking robot. *Mechanics and Advanced Technologies*. 2(80), pp. 59–64.

6. Kuznjecov Ju.M., Shybecjkyj V.Ju (2012). *Robotic systems complexes of pharmaceutical and biotechnological productions*. Kiev: GhNOZIS. 335 p.

7. Pavlenko I.I. (2007). *Industrial work: calculation basics and design*. Kirovoghrad: KNTU. 420 p.

8. Sinev A.V. Gradetskii V.G. and Kravchuk L.N. (2005). The vehicle for moving along the surfaces arbitrarily oriented in space. State Register of Patents of Russia, Pat. № 2262461, 6 p.

9. Baranov V. E., Vagin S.G., Zatsepin V. A. and Kokorin A. G. (2006). Vehicle for moving on inclined and vertical surfaces. State Register of Patents of Russia Pat. № 2267434, 2006, 8 p.

10. Chashchukhin V.G.. (2011). Investigation of the movement parameters of a robot with a sliding seal. *Vestnik Nizhegorodskogo universiteta im. N.I. Lobachevskogo*. (4(2)), pp. 347–349.

11. Shamim Hasan, Khalid Hossain Jewel, Niaz Mostakim, Nabil Hossain Bhuiyan, M.K. Rahman, Sheikh Dobir Hossain and Khalid Hossain. (2017). Smartphone Controlled Spy Robot with Video Transmission and Object Collector. *International Journal of Engineering and Manufacturing (IJEM*. 120 (7(6)), pp.50–58.

12. Tin Lun Lam, Yangsheng Xu (2012). *Climbing Robot: Design, Kinematics and Motion Planning*. New York: Springer Heidelberg. pp. 37–46.

13. Yehya M, Hussain S, Wasim A, Jahanzaib M and Abdalla H A. (2014). Unipolar Electroadhesion Pad Technology for Adhesion Mechanism of Wall Climbing Robot. *International Journal of Robotics and Mechatronics*. 120 (2(1)), pp. 1–10.

14. Yampolskiy L.S., Polishchuk M.N. and Persikov V. K. Method and device for movement of pedipulators of walking robot. State Register of Patents of Ukraine, Pat. 111021, 2016, p. 11.

15. Polishchuk M., Oliinyk V. (2018). Mobile climbing robot with elastic energy accumulators. *Mechanics and Advanced Technologies*. 120 (1(82)), pp.116 – 122.

16. Kuznetsov Yu.M., Polishchuk M.M. (2018). Walking mobile robot Kuznetsova – Polishchuka. Ukrainian Institute of Intellectual Property, Ukraine, application for a patent № 201807976, p.16.

17. Polishchuk M., Opashnianskyi M., Suyazov N. (2018). Walking Mobile Robot of Arbitrary Orientation. *International Journal of Engineering and Manufacturing (IJEM)*. 8(3), pp.1–11.

18. Polishchuk M.N. (2018). Principles of designing mobile robots. *Norwegian Journal of development of the International Science*. No 22, pp. 31-37.

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MATHEMATICAL MODEL OF NPP UNITS POWER GENERATON TO SOLVE THE PROBLEMS OF UKRAINIAN POWER SYSTEM DEVELOPMENT

Abstract: A mathematical model is offered for production processes implemented at NPPs of SE NNEGC "Energoatom", which is suitable for predicting the monthly dynamics of electricity generation volumes by power units in various scenario conditions for the development of nuclear power generation.

Keywords: system, model, NPP, long-term forecasting.

Introduction

Currently, a comprehensive analysis of various scenarios for the development of power systems is carried out using computer systems for energy modeling and an increasing number of the researchers around the world is involved in the development of them [1-2]. Sufficiently complete and adequate mapping of a set of interrelated processes in mathematical models of energy systems allows us to formulate and solve complex problems of the development of such systems by conducting computational experiments.

Modern systems of modeling of electric power industry of Ukraine are developed on the basis of mathematical models of decentralized control of interrelated processes of production, transmission, distribution and consumption of electric energy [3-4]. The completeness and adequacy of such models is achieved by reflecting in them the characteristic features of the behavior of the main participants of the electric energy market and the production processes that are under their control.

NNEGC "Energoatom" is the largest producer of electricity in Ukraine and, therefore, plays a special role in the electricity market. As an integral part of the modeling system of the electric power industry of Ukraine, the mathematical model of the generation processes implemented at the NPPs of this company should be suitable for predicting the monthly dynamics of the volumes of electricity generation by NPP units in various scenario conditions for the development of the country's nuclear power industry.

Below the model of the state enterprise NNEGC “Energoatom” is presented, which satisfies the requirement stated above. The model was developed on the basis of a comprehensive analysis of the available data on the installed capacities of power units [5], the volumes of electricity generation by them [6–9], the frequency and duration of previously completed major and intermediate maintenance of the main equipment of NPPs [10–17].

1. Model of production processes at nuclear power plants

The utilization rate of the installed capacity C_h^{UR} of the power unit h is an integral indicator of the efficiency of the safe production of electricity on it [18]. At an arbitrary time t, the value of this coefficient is determined by the ratio of the volume of electricity

$$S_h = S_h(t, \Delta t) = \int_{t-\Delta t}^{t} g_h(\tau) d\tau, \quad (1)$$

generated over the reporting period Δt, to the volume of its output by the installed capacity for the same period of time, i.e.

$$C_h^{UR} = C_h^{UR}(t, \Delta t) = S_h(t, \Delta t)/(G_h \Delta t), \quad (2)$$

where $g_h(\tau)$ and G_h are the capacities of the unit h, respectively, developed at the time $\tau \in [t - \Delta t, t]$ and installed.

From the definition (2) follows the equation

$$S_h(t, \Delta t) = C_h^{UR}(t, \Delta t) G_h \Delta t, \quad (3)$$

which can be used for predictive estimates of the volumes of electricity generation $S_h(t, \Delta t)$ if the function $C_h^{UR}(t, \Delta t) \in [0, 1)$ can be predetermined.

As a result of the research [18], it was established that the frequency and duration of preventive and predictive maintenance (hereafter referred to as PPM), i.e. the planned organizational and technical measures to check and restore the availability and service life of the systems, equipment and individual components of the power units, have a decisive influence on the behavior of functions of the type $C_h^{UR}(t, \Delta t)$. According to the reports of the current state of operational safety of nuclear power plants in Ukraine with VVER-1000, the contribution of scheduled maintenance of power units to the overall decrease in the $C_h^{UR}(t, \Delta t)$ function values reaches 84%. The rest of the decrease in the values of this function is due to unplanned outages, load reductions, violations of the units operation, accidents and other factors.

Therefore, the utilization ratio of the installed capacity $C_h^{UR}(t, \Delta t)$ of the power unit h can be decomposed into two factor multipliers and represented as

$$C_h^{UR}(t, \Delta t) = C_h^{PM}(t, \Delta t) C_h^{OS}(t, \Delta t), \quad (4)$$

where $C_h^{PM}(t, \Delta t)$ is the capacity reduction coefficient as a result of the implementation of the strategy of PPM, and $C_h^{OS}(t, \Delta t)$ is the capacity reduction ratio due to the performance of the current maintenance works and operational service.

The formation of plans for the implementation of maintenances of NPP power units is carried out on the basis of diagnostic models that implement various methods for analyzing the technical condition of equipment, as well as models for optimizing the processes of preparing and performing of PPM [18-19]. Such approaches to the formation of plans for the implementation of maintenance work are scientifically based and are regularly used in practice. As a rule, their usage has a very limited planning horizon - most often from one year to four years [20], less often up to ten years [21].

To draw up long-term maintenance plans and, as a result, determine the $C_h^{PM}(t, \Delta t)$ functions, it is suggested to use a generalized model of production

processes related to the diagnostics of the state of systems, equipment and components of the power unit and optimization solutions to restore their performance. The basis for building a generalized model is the start and end dates of maintenances carried out in previous years.

Let us estimate the periods (time between the initial dates of two consecutive equipment maintenances) $T_{\text{с}}$ and $T_{\text{к}}$, as well as the duration $d_{\text{с}}$ and $d_{\text{к}}$ of intermediate and major maintenances of the main equipment of nuclear power plants in Ukraine. To do this, we use the annual schedules for such maintenances at each NPP power unit for the eight-year period from 2011 to 2018 [10–17].

The minimum, maximum and average values of the periods and durations of maintenance companies are presented in tables 1 - 2. Here, the average values of $\bar{T}_{\text{с}}$, $\bar{T}_{\text{к}}$, $\bar{d}_{\text{с}}$, $\bar{d}_{\text{к}}$ characterize the sets of values $\{T_{\text{с}}\}$, $\{T_{\text{к}}\}$, $\{d_{\text{с}}\}$, $\{d_{\text{к}}\}$, moreover, values such that are not significantly different from each other and, therefore, are representative for the corresponding sets.

Note that the alternation of intermediate and major maintenances of each NPP power unit occurs sequentially in time according to the scheme $3(\text{с}) + 1(\text{к})$ [18]. Due to the limitedness of the analyzed set of maintenance companies conducted from 2011 to 2018, for the separately considered power unit, we have no more than two values of the periods $T_{\text{к}}$ and durations $d_{\text{к}}$ of major maintenances, which makes it difficult to estimate their average values $\bar{T}_{\text{к}}$ and $\bar{d}_{\text{к}}$. Therefore, the formal averaging of the sets of the values $\{T_{\text{к}}\}$ and $\{d_{\text{к}}\}$ is carried out in cases where such values are close. In other cases, the average values of $\bar{T}_{\text{к}}$ and $\bar{d}_{\text{к}}$ are estimated by the totality of values from the sets $\{T_{\text{к}}\}$ and $\{d_{\text{к}}\}$ and by close values from the sets from $\{T_{\text{с}}\}$ and $\{d_{\text{с}}\}$, respectively.

Table 1.

Duration of maintenance, day

Name of NPP	Unit number	Intermediate maintenance			Major maintenance		
		$d_{\text{с}}^{\min}$	$d_{\text{с}}^{\max}$	$\bar{d}_{\text{с}}$	$d_{\text{к}}^{\min}$	$d_{\text{к}}^{\max}$	$\bar{d}_{\text{к}}$
Zaporizhzhya	1	60	107	88	60	107	88
	2	76	114	95	76	114	97
	3	52	114	77	74	75	75
	4	52	86	70	72	86	79
	5	60	104	77	60	107	78
	6	52	104	69	75	96	86
South Ukraine	1	52	95	69	50	90	70
	2	64	120	86	64	120	75
	3	57	153	106	57	153	98
Rivne	1	45	78	54	55	72	64
	2	45	72	55	55	85	70
	3	62	66	64	62	85	69
	4	52	52	52	65	65	65
Khmelnytska	1	49	67	55	85	96	91
	2	52	66	58	80	80	80

Table 2.

Periods of maintenance, days

Name of NPP	Unit number	Intermediate maintenance			Major maintenance		
		$T_{\text{с}}^{\min}$	$T_{\text{с}}^{\max}$	$\bar{T}_{\text{с}}$	$T_{\text{к}}^{\min}$	$T_{\text{к}}^{\max}$	$\bar{T}_{\text{к}}$
Zaporizhzhya	1	378	414	395	378	414	403
	2	373	434	405	373	475	423
	3	389	412	398	364	373	369
	4	363	392	381	396	428	412
	5	335	454	378	335	526	403
	6	360	410	397	351	432	392
South Ukraine	1	296	565	393	296	565	387
	2	360	440	383	327	440	371
	3	358	513	430	358	513	434
Rivne	1	358	566	385	358	425	381
	2	353	401	376	353	434	386
	3	403	416	409	403	527	432
	4	316	432	389	355	412	384
Khmelnytska	1	362	507	434	395	463	429
	2	316	419	377	371	377	374

Within the average values of $\bar{T}_{\text{с}}$, $\bar{T}_{\text{к}}$, $\bar{d}_{\text{с}}$, $\bar{d}_{\text{к}}$, for each power unit h, it is possible to make the projected schedules for the implementation of intermediate and major maintenances with indication of the calendar dates of the beginning and the end of maintenance in the long term. In particular, we have compiled a sequence of schedules for the implementation of PPM under the $3(\text{с}) + 1(\text{к})$ alternation scheme for the forecast period 2019-2040, originating from a maintenance company approved by the Ministry of Energy and Coal Industry of Ukraine in 2018 year [10].

Note that the sequence of schedules of maintenance execution must be formed with a daily step D fixing the planned events in time t. In this case, you can define integer values $C_h^{PM}(t_D, \Delta t_D) \in \{0,1\}$ of functions $C_h^{PM}(t, \Delta t)$ on a discrete set t_D of time t with an estimated period Δt_D, equal to the day.

The sets of actual values $\{T_{\text{с}}\}$, $\{T_{\text{к}}\}$, $\{d_{\text{с}}\}$, $\{d_{\text{к}}\}$, calculated from the start and end dates of maintenance companies that have already taken place, allow us to expand the domain of definition of $C_h^{PM}(t_D, \Delta t_D)$ values of functions $C_h^{PM}(t, \Delta t)$ for the corresponding periods of time in the past with the same daily detail.

In addition, daily sequences of $C_h^{PM}(t_D, \Delta t_D)$ functions of $C_h^{PM}(t, \Delta t)$ can be averaged, respectively, on monthly (M) and annual (Y) time intervals Δt_M and Δt_Y and represent the sequences of values $C_h^{PM}(t_M, \Delta t_M)$ and $C_h^{PM}(t_Y, \Delta t_Y)$, defined on the discrete sets t_M and t_Y of time t.

Using time sequences of the values of the coefficients $C_h^{PM}(t_D, \Delta t_D)$ and the values of the installed capacities G_h of the power units, in the idealized case, when the factors of capacity reduction that are not associated with PPM do not work, i.e. the values of all coefficients $C_h^{OS}(t_D, \Delta t_D)$ are equal to one, you can first estimate the dynamics of the total volumes $S_\Sigma(t_M, \Delta t_M)$ of the monthly electricity generation

by all NPP units during the forecast period. So, following (3) - (4), we have

$$S_{\Sigma}(t_M, \Delta t_M) = \sum_h \sum_{t_D \in t_M} C_h^{PM}(t_D, \Delta t_D) G_h \Delta t_D. \quad (5)$$

Since the sequence of values of $C_h^{PM}(t_D, \Delta t_D)$ are periodic and have alternating periods T_{ch} and $T_{кh}$ such that are not generally equal to the duration of the calendar year, the summation of these sequences with weights $G_h \Delta t_D$ results to the formation of a sequence of values $S_{\Sigma}(t_M, \Delta t_M)$, which does not repeat the annual seasonal fluctuations of the volumes of electricity produced by all NPPs, and the corresponding schedules of maintenance companies do not reflect the priority of summer periods for their implementation in each forecast year.

For the formation of adequate sequences of $S_{\Sigma}(t_M, \Delta t_M)$ values, the dynamics of which would be close to the dynamics of the monthly sequence of averaged values of $\bar{S}_{\Sigma}(t_M, \Delta t_M)$ calculated from the statistical data on the production volumes of nuclear power plants for a number of past years, it is necessary to solve quadratic programming problems

$$\min_{\{\Delta T_h(Y)\}} \sum_{t_M \in Y} \left[\bar{S}_{\Sigma}(t_M, \Delta t_M) - \sum_h \sum_{t_D \in t_M} C_h^{PM}(t_D + \Delta T_h(Y), \Delta t_D) G_h \Delta t_D\right]^2, \quad (6)$$

$$\{\overline{\Delta T}^- \le \Delta T_h(Y) \le \overline{\Delta T}^+\}. \quad (7)$$

and within each forecast year Y, find the offsets $\Delta T_h(Y)$ of the argument t_D of the functions $C_h^{PM}(t_D + \Delta T_h(Y), \Delta t_D)$, which is identical to the search for the refined values of the periods $\bar{T}_{ch}$ or $\bar{T}_{кh}$ maintenance companies, the implementation of which was initially planned to begin in the same forecast year. Here, the boundaries $\overline{\Delta T}^-$ and $\overline{\Delta T}^+$ of admissible changes of the desired quantities $\Delta T_h(Y)$ are set equal to the average values of the quantities from the sets $\{T_{\text{с}}^{\min} - \bar{T}_{\text{с}}\} \cup \{T_{\text{к}}^{\min} - \bar{T}_{\text{к}}\}$ and $\{T_{\text{с}}^{\max} - \bar{T}_{\text{с}}\} \cup \{T_{\text{к}}^{\max} - \bar{T}_{\text{к}}\}$, respectively. Referring to the data presented in Table 2, we determine the values $\overline{\Delta T}^- = -40$ and $\overline{\Delta T}^+ = 56$ (in days).

Problems (6) - (7) are solved sequentially for the entire set $\{Y\}$ of forecast years, starting from the first year. The values $\Delta T_h(Y)$ found allow us to form the offset sequences $\check{C}_h^{PM}(t_D, \Delta t_D) = C_h^{PM}(t_D + \Delta T_h(Y), \Delta t_D)$ and the corresponding their averaged sequences are $\check{C}_h^{PM}(t_M, \Delta t_M)$ and $\check{C}_h^{PM}(t_Y, \Delta t_Y)$.

The presence of the sequence of values of the coefficients $\check{C}_h^{PM}(t_M, \Delta t_M)$ and $\check{C}_h^{PM}(t_Y, \Delta t_Y)$, as well as data on monthly and annual electricity generation $S_h(t_M, \Delta t_M)$ and $S_h(t_Y, \Delta t_Y)$ over the past years makes it possible to retrospectively evaluate the sequence of values of the coefficients $C_h^{OS}(t_M, \Delta t_M)$ and $C_h^{OS}(t_Y, \Delta t_Y)$ for reducing capacity of the power unit h due to the performance of its current maintenance and operational service. The basis for obtaining such estimates are relations (3) and (4), with which you can determine the values

$$C_h^{OS}(t_M, \Delta t_M) = S_h(t_M, \Delta t_M) / \left[\check{C}_h^{PM}(t_M, \Delta t_M) G_h \Delta t_M\right]$$

and

$$C_h^{OS}(t_Y, \Delta t_Y) = S_h(t_Y, \Delta t_Y) / \left[\check{C}_h^{PM}(t_Y, \Delta t_Y) G_h \Delta t_Y\right]. \quad (8)$$

Analysis of the values of the coefficients $C_h^{OS}(t_M, \Delta t_M)$ and $C_h^{OS}(t_Y, \Delta t_Y)$, calculated on the basis of retrospective data, showed the impossibility of extrapolating them for the forecast period. It was also impossible to extrapolate the average estimates of the power reduction factors of a species.

$$C_H^{OS}(t_Y, \Delta t_Y) = \frac{1}{|H|} \sum_{h \in H} S_h(t_Y, \Delta t_Y) / \left[\check{C}_h^{PM}(t_Y, \Delta t_Y) G_h \Delta t_Y\right], \quad (9)$$

calculated for the set of H power units of each NPP. Graphs of changes in the values of these coefficients are presented in Figure 1.

Therefore, to perform predictive calculations, it is necessary to use the averaged values of these coefficients in the form of estimates

$$C_H^{OS}(\Delta Y) = \frac{1}{|\Delta Y|}\sum_{Y\in\Delta Y} C_H^{OS}(t_Y, \Delta t_Y), \qquad (10)$$

obtained on the set ΔY of previous years.

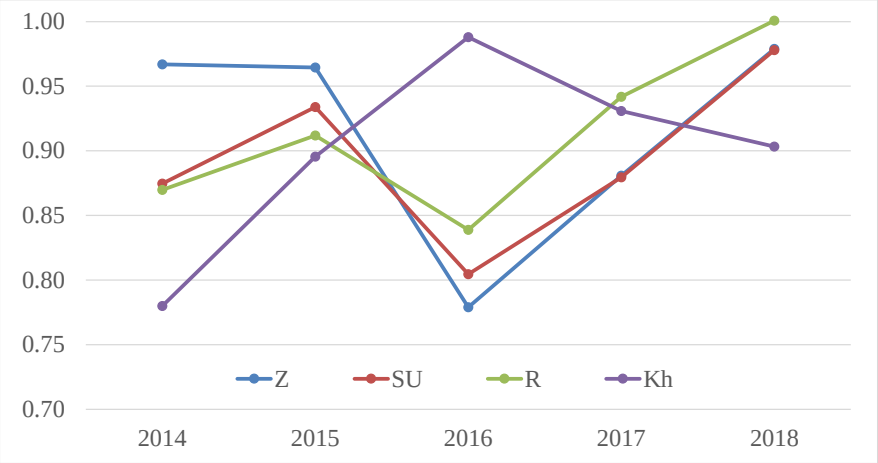

Fig. 1. The dynamics of the reduction coefficients of the annual electricity production volumes at the Zaporozhzhya NPP (Z), South-Ukraine (SU), Rivne NPP (R) and Khmelnytska (Kh) under the influence of factors not related to the implementation of PPM.

2. Algorithm for forecasting the production of electricity by NPP units

The above research results are the basis of the following algorithm for long-term forecasting of electricity production volumes by NPP units:

1. Based on the schedules for the implementation of intermedium and major maintenances of the main equipment of NPPs, we form sets $\{T_{\text{с}}\}$, $\{T_{\text{к}}\}$ and $\{d_{\text{с}}\}$, $\{d_{\text{к}}\}$ of the actual values of the periods and durations of maintenance companies carried out over a number of previous years.

2. For each power unit, we calculate the average values of $\bar{T}_{\text{с}}$, $\bar{T}_{\text{к}}$ and $\bar{d}_{\text{с}}$, $\bar{d}_{\text{к}}$ of the periods and durations of previously performed maintenances, and also determine their boundary values $T_{\text{с}}^{\min}$, $T_{\text{к}}^{\min}$, $T_{\text{с}}^{\max}$, $T_{\text{к}}^{\max}$, $d_{\text{с}}^{\min}$, $d_{\text{к}}^{\min}$, $d_{\text{с}}^{\max}$, $d_{\text{к}}^{\max}$.

3. We form sets of values $\{T_{\text{с}}^{\min} - \bar{T}_{\text{с}}\} \cup \{T_{\text{к}}^{\min} - \bar{T}_{\text{к}}\}$ and $\{T_{\text{с}}^{\max} - \bar{T}_{\text{с}}\} \cup \{T_{\text{к}}^{\max} - \bar{T}_{\text{к}}\}$ for which we calculate the average values $\overline{\Delta T}^{-}$ and $\overline{\Delta T}^{+}$.

4. Starting from the dates of the last actually performed maintenances, using average values of $\bar{T}_{\text{с}}$, $\bar{T}_{\text{к}}$, $\bar{d}_{\text{с}}$, $\bar{d}_{\text{к}}$, we form a sequence of schedules for the implementation of intermediate and major maintenances of power units according to the $3(\text{с}) + 1(\text{к})$ alternation scheme for the forecast period.

5. Based on the formed sequence of schedules for the maintenance of power units, we determine the sequence of values $C_h^{PM}(t_D, \Delta t_D)$.

6. According to statistical data on NPP production volumes for a number of past years, we form a sequence of average values of production volumes $\bar{S}_{\Sigma}(t_M, \Delta t_M)$.

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7. For the entire set $\{Y\}$ of forecasting years, we sequentially, starting from the first year, solve problems (6) - (7) and find the values $\Delta T_h(Y)$.

8. Form the shifted sequences of the values of the coefficients $\check{C}_h^{PM}(t_D, \Delta t_D) = C_h^{PM}(t_D + \Delta T_h(Y), \Delta t_D)$ and the corresponding average sequences $\check{C}_h^{PM}(t_M, \Delta t_M)$ and $\check{C}_h^{PM}(t_Y, \Delta t_Y)$, respectively.

9. Using the data of previous years on the annual volumes $S_h(t_Y, \Delta t_Y)$ of electric power generation by each unit, according to the formulas (8) - (10), as well as on the found values of the coefficients $\check{C}_h^{PM}(t_Y, \Delta t_Y)$ we calculate the values of the coefficients $C_H^{OS}(\Delta Y)$.

10. Using relations (3) - (4), the found values of the coefficients $\check{C}_h^{PM}(t_M, \Delta t_M)$ and $C_H^{OS}(\Delta Y)$, as well as the data $\{G_h\}$ on the installed capacity of the set H of power units of each NPP, we calculate its monthly and annual electricity production volumes for the forecast period, respectively,

$$S_H(t_M, \Delta t_M) = C_H^{OS}(\Delta Y) \sum_{h \in H} \check{C}_h^{PM}(t_M, \Delta t_M) G_h \Delta t_M \qquad (11)$$

and

$$S_H(t_Y, \Delta t_Y) = C_H^{OS}(\Delta Y) \sum_{h \in H} \check{C}_h^{PM}(t_Y, \Delta t_Y) G_h \Delta t_Y. \qquad (12)$$

The combination of relations (6) - (7), (9) - (12) is a mathematical model of the production processes implemented at NPPs of the company NNEGC "Energoatom". This model is suitable for predicting the monthly dynamics of electricity generation by NPP units in various scenario conditions of the company's development.

According to the scenario of the planned decommissioning of NPP power units [22], presented by Y.Nedashkovsky, President of NNEGC “Energoatom”, at the Committee hearings in the Verkhovna Rada of Ukraine on July 12, 2018, model calculations of annual and monthly electricity production volumes were performed for the period forecasting 2019 - 2040 years. The simulation results are presented in Figures 2 - 4.

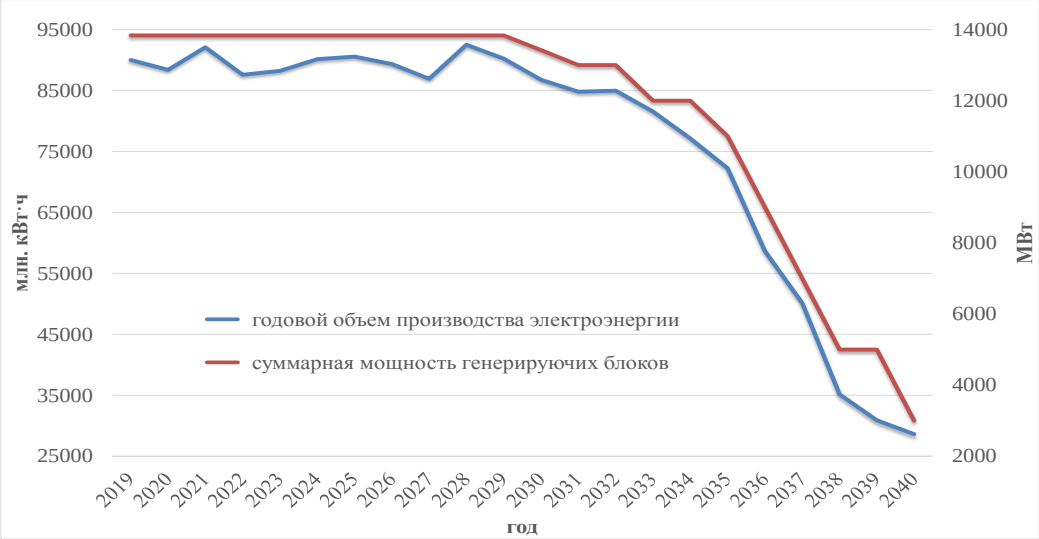

Fig. 2. Dynamics of the total capacity of power units and annual volumes of electricity production at NPPs of the company NNEGC “Energoatom”

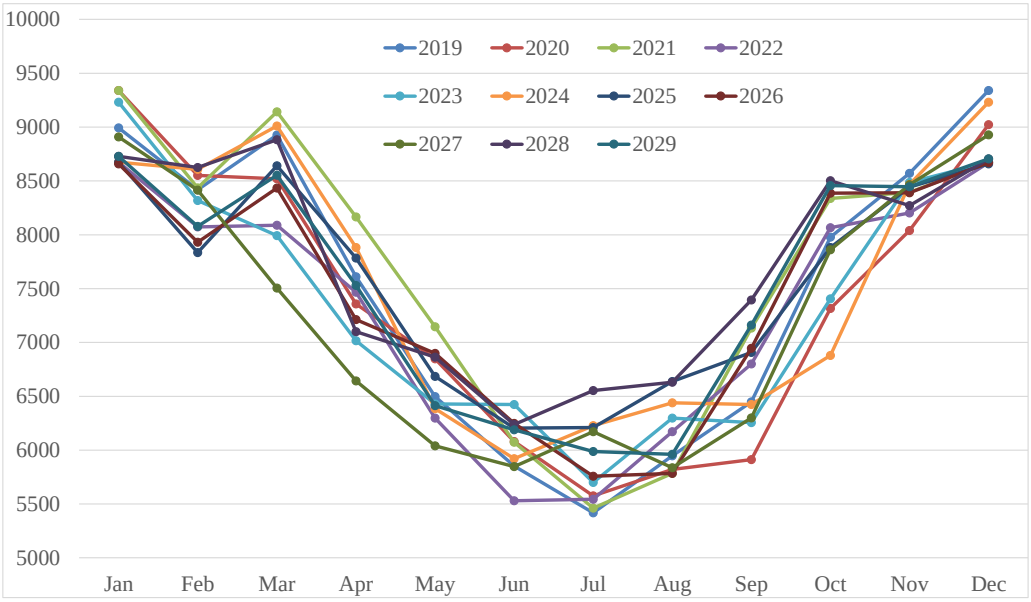

Fig. 3. Dynamics of monthly electricity production volumes at NPPs of GP NNEGC “Energoatom” (forecast for 2019-2029), mln.kWh.

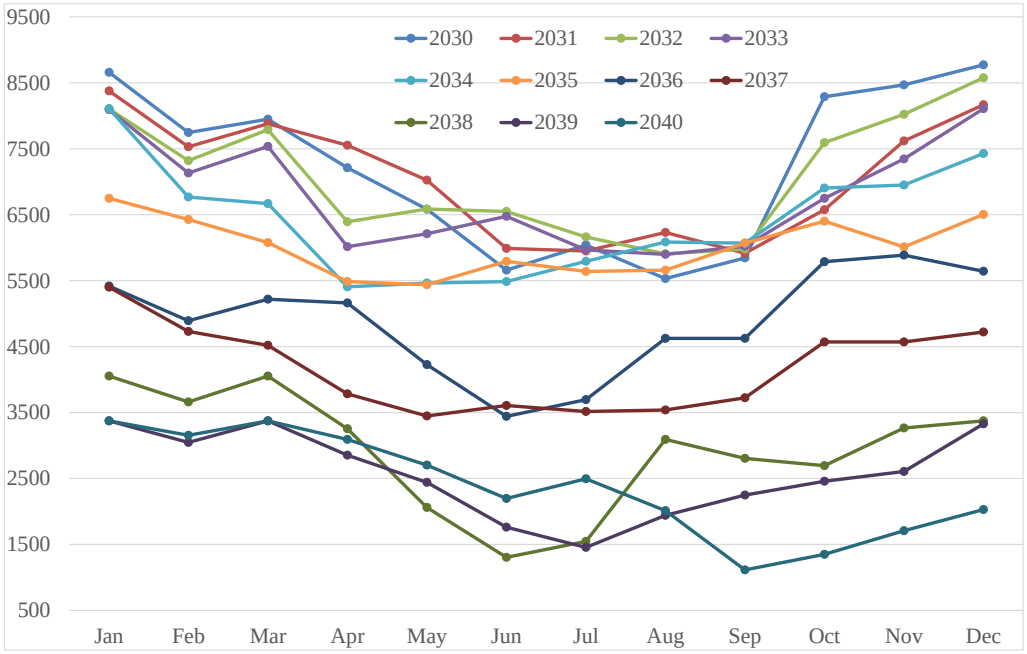

Fig. 4. Dynamics of monthly electricity production volumes at NPPs of GP NNEGC “Energoatom” (forecast for 2030-2040 years), mln.kWh

Here you can see not only the rate of decline in monthly and annual electricity production, but also the loss of the possibility of seasonal regulation of production volumes.

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Findings

1. A mathematical model of production processes implemented at NPPs of the company NNEGC "Energoatom" has been developed. The model adequately reproduces the general characteristics of the PPM of the equipment of power units, and their impact on the monthly electricity production volumes of each NPP in the medium and long term.

2. The mathematical model is focused on the use as a part of Ukrainian power industry modeling systems and makes it possible to take into account various development strategies of the company NNEGC “Energoatom” in such systems, in particular, the commissioning of new power units with regulated characteristics of periodicity and duration of preventive maintenance.

3. After the accident at the Fukushima nuclear power plant, there has been a steady increase in safety requirements for nuclear power facilities. The analysis of scenarios for increasing the duration of maintenance work and replacing the existing power units with new facilities with high reliability and safety parameters is becoming a relevant area of research. The presented model makes it possible to take into account the influence of such scenarios of the development of nuclear industry on the monthly dynamics of the volumes of electricity generation by NPP units.

List of references

1. Connolly D., Lund H., Mathiesen B.V., Leahy M. A review of computer tools for analysing the integration of renewable energy into various energy systems. –Applied Energy, 2010. 87(4): P. 1059 - 1082. https://doi.org/10.1016/j.apenergy.2009.09.026

2. Machado P.G., Mouette D., Villanueva L.D., Esparta A.R., Mendes Leite B., Moutinho dos Santos E. Energy systems modeling: Trends in research publication. – WIREs Energy Environ, 2018; e333. – 15p. https://doi.org/10.1002/wene.333

3. Борисенко А.В., Саух С.Є. Модель функціонування та розвитку генеруючих потужностей в ринкових умовах // Праці Інституту електродинаміки Національної академії наук України. Випуск 25. – 2010. – С. 21 – 32.

4. Саух С.Е. Методология и методы математического моделирования энергетики в рыночных условиях // Электронное моделирование. – 2018. – N 3. – С. 3 – 32.

5. https://ua.boell.org/sites/default/files/transition_of_ukraine_to_the_renewable_energy_by_2050_1.pdf

6. http://www.npp.zp.ua/Home/Production

7. https://www.sunpp.mk.ua/uk/activities/tep/chart

8. http://www.rnpp.rv.ua

9. http://www.xaec.org.ua/store/pages/ukr/techekparams/latest

10. http://document.ua/pro-pidgotovku-obladnannja-elektrostancii-i-teplovih-merezh--doc324051.html

11. http://consultant.parus.ua/?doc=0ANAN7F275

12. http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=66114

13. http://consultant.parus.ua/?doc=09VFD68889

14. http://mpe.kmu.gov.ua/minugol/doccatalog/document?id=244950494

15. http://mpe.kmu.gov.ua/minugol/doccatalog/document?id=229324

16. http://zakon.rada.gov.ua/rada/show/v0578732-12/sp:max10

17. http://zakon.rada.gov.ua/rada/show/va006732-11

18. Скалозубов В.И., Коврижкин Ю.Л., Колыханов В.Н. и др. Оптимизация плановых ремонтов энергоблоков атомных электростанций с ВВЭР/под ред. Скалозубова В.И.; НАН Украины, Ин-т проблем безопасности АЭС. - Чернобыль (Киев, обл.): - Ин-т проблем безопасности АЭС, 2008. - 496 с.

19. Ефимов А.В., Потанина Т.В., Кравец В.Л. и др. Применение методов интервальной статистики для диагностики технического состояния оборудования и планирования продолжительности ремонтов энергоблоков ТЭС И АЭС // Энергосбережение. Энергетика. Энергоаудит. – 2012. – N 5. – С. 20 – 26.

20. https://zakon.rada.gov.ua/laws/show/z1224-16

21. http://www.rosenergoatom.ru/upload/iblock/376/37644e5aa93eec0702537d60b9511e84.pdf

22. http://www.energoatom.kiev.ua/ua/press_centr-19/presentations-39/p/vistup_prezidenta_energoatoma_uria_nedaskovs_kogo_na_komitets_kih_sluhannah_na_temu_aderna_energetika_ukraini_vikliki_ta_perspektivi-3521

UDC 681.5

V. Smoliy

MANAGEMENT CONCEPTION DESIGNER PREPRODUCTION OF ELECTRONIC VEHICLES

Abstract: As a result of undertaken studies new conception of management is worked out by designer preproduction of electronic vehicles, leaning against single informative space of arrangement of electronic vehicle, operative management designer preproduction and control system by the resources of enterprise, allowing to promote management efficiency designer preproduction of electronic vehicles.

Key words: designer preproduction, electronic vehicle, management conception, informative space, arrangement of electronic vehicle, operative management, resources of enterprise, system of support of making decision.

Introduction

The offered conception of management embraces the next stages of creation of electronic vehicle designer preproduction of electronic vehicles : arrangement, constructing, preproduction, test and directly production of preproduction model of good [1, 3 - 5].

The feature of the offered conception of management of designer preproduction of electronic vehicles is that, leaning against single informative space of arrangement of electronic vehicle, operative management designer preproduction and control system by the resources of enterprise, a cost and prime price of preproduction model of electronic vehicle cutout is arrived at; reduction of terms of producting of new electronic vehicles; the competitiveness of enterprise rises at upgrading of electronic vehicles, reliability, oscillation and resonant stability [2, 6, 14].

An achievement such of results is maybe by means of application of the developed system of support of making decision, realizing a management the systems of arrangement and designer preproduction and their cooperation in single informative space, that changes maintenance of designer preproduction in a root, orients a management arrangement of electronic vehicle on the resources of enterprise, providing management efficiency designer preproduction on the whole [5, 8, 16].

Objects and problems

For realization of management conception it is necessary designer preproduction of electronic vehicles without the changes of technical equipped of production on the whole to modernize control system only. It is necessary to work out the system of support of making decision, providing with a managing personnel facilities, methods and instruments, providing possibility to realize the offered conception of management [7 – 11, 15].

For an enterprise - producer of electronic vehicles there is providing of management efficiency, including minimization of material production inputs new good or good with the parameters of quality and reliability, excelling analogues,

reduction of duration of process of production etc., maybe by the decision of management task exactly designer preproduction by means of choice of arrangement, parameters and properties of producible block of electronic vehicle(exactly as the completed structurally executed good).

The conceptual model of the automated management of designer preproduction of electronic vehicles looks like, brought around to a fig. 1. The designer preproduction implies producing of pre-production model of good with the parameters of quality, excelling analogues on condition of cost and unit cost cut out and reduction of terms of producing of good [16 - 19].

By analogy with existent classification of CASS of planning, making, tests of and other, the functions of components of the developed system of support of making decision of designer preproduction of electronic vehicles are analogical to the functions of ERP -, MES -, PDM - systems, applied on the enterprises of instrument-making industry [12, 20]. Application of the functions realized in the developed system of support of making decision analogical to the functions executable PDM - by the system, provides integration of data about arrangement of electronic vehicle, got as a result of planning and design. The constituent of the developed system of support of making decision of designer preproduction, realizing the functions of PDM, are the systems, executes a management data about electronic vehicles, including the design of electronic vehicle as an object of designer preproduction and management by arrangement of electronic vehicle [13 - 15].

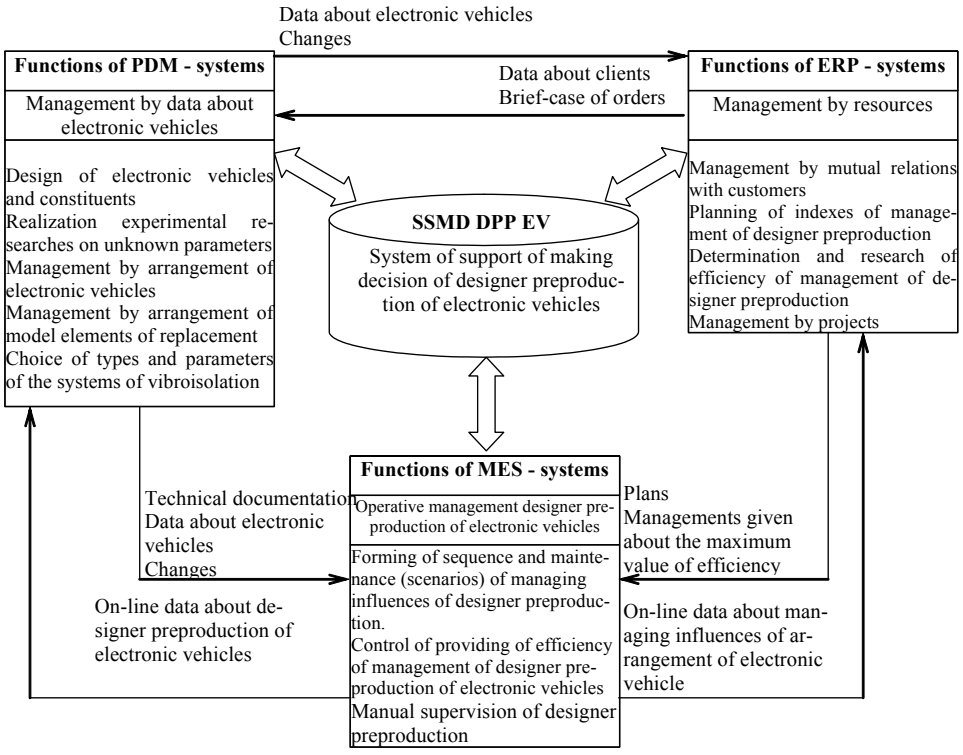

Fig. 1. Conceptual model of the automated management of designer preproductionof electronic vehicles

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Functions of MES - the systems in the developed system of support of making decision of designer preproduction of electronic vehicles suppose implementation of operative management designer preproduction of electronic vehicles on the basis of generated by the system of support of making decision of management scenarios realizing optimal maintenance and sequences of operations of arrangement on condition of observance of condition of management efficiency designer preproduction on the whole [14].

The constituent of the developed system of support of making decision of designer preproduction, realizing the functions of ERP, are the systems, organizes interrelation with the customer of company-producer of electronic vehicles, management by the developed projects and determines the possible size of management efficiency designer preproduction of electronic vehicles, that will allow to the company to produce competitive good, save the markets of sale and get a profit at minimum material production inputs preproduction model of good.

The developed system of support of making decision of designer preproduction of electronic vehicles supposes an association and active cooperation of functions of the examined systems with the purpose of achievement of the required properties, quality, reliability, to resonant and oscillation stability of electronic vehicles on condition of minimization materially - technical production inputs, achievement of cost expended on retraining and in-plant training of personnel effectiveness, expenses on consultative services of experts etc.

The system of support of making decision designer preproduction of electronic vehicles supposes implementation of functions of design of electronic vehicle taking into account setting and supposed external environments with the purpose of receipt of great number of effective decisions on a management by arrangement of electronic vehicle for the achievement of the required parameters of quality, reliability, oscillation and resonant stability of electronic vehicles. Realization of similar arrangement is possible by the managing affecting of designer preproduction, providing the achievement of financial viability of production of preproduction model of good, exception of tests, returns, revision of good, reduction of time, material production inputs and formalizations of knowledge and experience of experts.

In the conceptual model of the automated management the designer preproduction of electronic vehicles is distinguish next basic essence: management efficiency designer preproduction, electronic vehicle, model element of replacement. Every type of essence at the construction of conceptual model appears as a separate rectangle with the name inwardly, thus the dependent types of essences are represented in a double scope.

The attributes of essence appear as ellipses with the name of the attributes connected by a continuous line with corresponding essence (or by a relation). Every type of relation is shown as a rhombus with the name of relation inwardly. Thus a rhombus is surrounded by a double line, if a relation is set between a dependent type to essence, from existence of that it is in dependence. The separate elements of

diagram unite continuous lines (determined raising of management task designer preproduction of electronic vehicles) or dotted lines (stochastic raising of management task). Because connections(relations) of corresponding types of essence are not binary, therefore they are connected by no directional ribs.

It should be noted that for a management the designer preproduction of electronic vehicle is examine the technical and economic indexes of management (management efficiency) and stochastically up-diffused selections of managing influences, divided by teaching and verification for formalization of management process.

The conceptual model of management efficiency is brought designer preproduction of electronic vehicle around to a fig. 2. On a fig. 2 the attributes of essence are not shown, because we deal with a management designer preproduction of electronic vehicle a few levels of organization are distinguished in that, each of that includes elements from different levels, therefore in detail relations are explained in description to the conceptual model of the system of support of making decision.

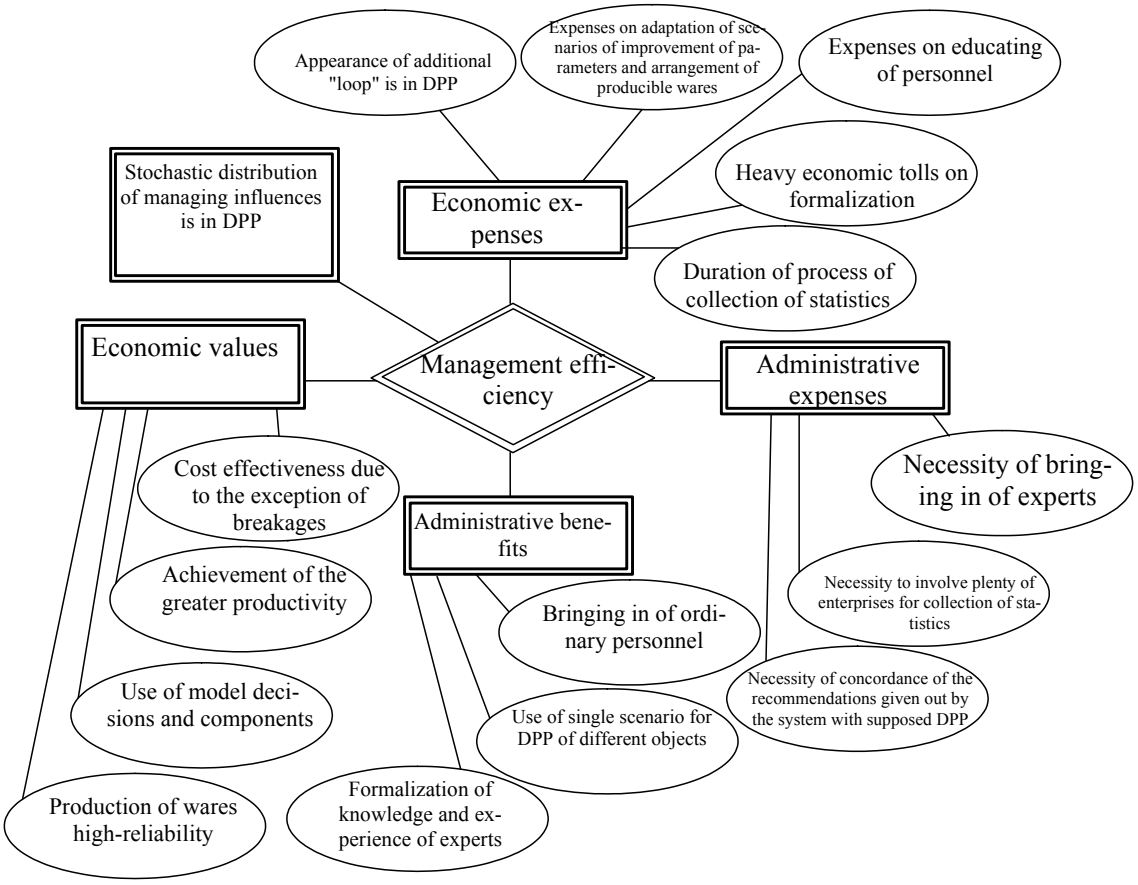

Fig. 2. Conceptual model of management efficiency
designer preproductionof electronic vehicle

Here it should be noted that for a management the designer preproduction of electronic vehicle is examine the technical and economic indexes of management

(management efficiency) and stochastically up-diffused selections of managing influences, divided by teaching and verification for formalization of management process.

Management process implementation of certain sequence and maintenance of the managing influences sent both to arrangement of electronic vehicle implies designer preproduction of electronic vehicles and operative management by a personnel and resources of enterprise.

Thus, both for modern firms - producers of domestic electronic technique and for scientific and production enterprises airplane and rocket productions, a management process has identical procedure leaning against subjective presentations and skills of personnel in this area designer preproduction of pre-production model of good.

The unstructured and semistructured multicriterion tasks decide by means of the developed system of support of making decision of designer preproduction of electronic vehicles. The decision of the examined multicriterion tasks will allow not only to improve quality, reliability, resonant and oscillation stability of electronic vehicles, but also to provide financial viability of production of preproduction model of good, eliminate tests, returns on the revision of good, to shorten time, material production inputs and formalized knowledge and experience of experts [15].

In the examined automated management [16] subsystems are distinguished: creations of preliminary character of good, implementation of design of object of designer preproduction, realizations of experimental researches on authentication and research of failing parameters, estimation of quality, reliability, oscillation and resonant stability of electronic vehicle, estimations of management efficiency designer preproduction of electronic vehicles, system of support of making decision, including the subsystems of receipt and treatment of knowledge.

It should be noted that each of them is fully independent and universal for the different sort of tasks, and also each of subsystems is characterized the high degree of no interaction, that allows to realize the different variants of the parallel including of components of the system and organize an interface for a few users with the simultaneous processing of data.

Examining the computer integrated production of electronic vehicles, characterized by the high degree of automation and application of computer-aided designs, it should be noted that, the object of designer preproduction is characterized repetition, concurrent execution of operations of arrangement and constructing, difficult internal organization.

On an electronic vehicle as an object of designer preproduction is laid on row of requirements on the parameters of quality, reliability, oscillation and resonant stability, it is here necessary to execute the requirements of financial viability and management efficiency designer preproduction, characteristic for the electronic vehicles of the different setting and external environments. All requirements, touching both arrangement and properties of electronic vehicle and management efficiency

designer preproduction of electronic vehicle, must be realized in developed system of support of making decision [15].

It should be noted presence and variants of differentiation of the developed system of support of making decision and degree of her use for different on purpose and to composition of objects of designer preproduction.

In the process of functioning the system of support of making decision carries out:

– Ground of necessity of initializing of management process;
– Task of type of object;
– Choice of setting of object;
– Analysis of external environments;
– Prognostication of the possible states of object by means of probabilistic criterion leaning against the base of knowledge and rule of support of making decision;
– Maps the state of object to his components and vice versa;
– Offers methodologies of upgrading, reliability, resonant and oscillation stability of electronic vehicle by means of the offered criteria of arrangement of block of electronic vehicle and constituents;
– Provides the selection of instruments of mathematical design;
– Contains explanations about that, how to work with the instruments of mathematical design;
– Identifies the unknown parameters of mathematical models by realization of experimental researches on a corresponding chart, methodology of the programmatic and technical providing of experiments;
– By means of the worked out criterion of management quality the designer preproduction of electronic vehicles (management efficiency) is watch rationality made alteration in a management designer preproduction of electronic vehicle and their influence is determined on the technical and economic indexes of management on the whole;
– Provides subsequent treatment of control program for a technological equipment, tuned to the same not only under a corresponding technological equipment but also under quality parameters, reliability, oscillation and resonant stability of electronic vehicle.

On the other hand this single cycle of management is mapped to some association of making electronic vehicles, subject to strict hierarchicalness, being with each other in different conceptual relations. It does not allow to talk about possibility of successive implementation of each of operations above some certain object, and supposes the presence of possibility of application of separate operation on the package(great number) of objects or great number of operations on one object, not except possibility of the simultaneous processing of great number of objects.

In the offered conception of management it is assumed designer preproduction, that the type of object for that make an electronic vehicle determines not

only external environments but also possibility of bringing of modifications in a management his designer preproduction(management effect), assuming variations of technical and economic indexes and some variations on speed implementations of designer preproduction. The base of knowledge and mechanism of receipt of decision are related to setting of object and object of exploitation, determined by the probabilistic criterion of management efficiency, that systematizes knowledge of experts and experience of specialists engaging in the problem of upgrading and reliability of electronic vehicles.

The variants of terms are possible exploitations that is taken into account in the mathematical model of object, that gives universality in-process designer preproduction the offered management. There is transformation of indexes of quality, reliability, to oscillation and resonant stability of electronic vehicle depending on the results of design on the basis of criteria of arrangement of object of designer preproduction. At changing of mathematical model of electronic vehicle management methodology is applicable designer preproduction either for other external environments or for other objects.

The hierarchy of the prospected objects of designer preproduction is characterized encapsulation, when the elements of subsequent levels consist of great number of elements of previous levels. Such the organization is possible for different objects, what universality of the offered algorithm allows to mark and to reflect his principles on a management by other systems.

Requirements to instrumental part are conditioned by realization of mathematical model as a complex of programmatic and technical facilities, supporting a receipt and transformation of informative character of electronic vehicle in accordance with the criteria of his arrangement. Also the distinguishing feature of instrumental part is methodology plugging in the arsenal of tools of the experimental setting equipped by rigging for authentication of failing parameters of object of designer preproduction.

A return to the management is needed designer preproduction, because virtual building on in form system of support of making decision, including designing complexes, brings in some changes in a structure and parameters of electronic vehicle, that must be passed on a management by designer preproduction and to watch rationality made alteration on the criterion of management quality designer preproduction of electronic vehicles (management effect).

A single algorithm taking into account all these facts differs in large universality and flexibility, because allows to reform on control system designer preproduction of any electronic vehicles without depending on their informative filling.

In respect of task of type of object, then it the simplified enough classification and scientific and practical interest here present not classification, and standing after it components of probabilistic criterion of management efficiency. The values of components of probabilistic criterion are identified in the process of educating of the system of support of making decision determine, take into account and visualize the base of knowledge of probabilistic descriptions of frequencies of refuses,

reasons of refuses, influencing active factors and correlation of technical and economic parameters for a management designer preproduction for the certain type of electronic vehicle and external environments.

The automated management designer preproduction of electronic vehicles is based mainly on dialogue instructions acting on behalf of accepting decision. In order that realization of such possibility took place, it is necessary to supply a person, a decision-making, by instruments, allowing to get, process and analyze information, and mechanism, for preparation of decision-making. To that end it is necessary to build the row of informative, programmatic, technical and intellectual subsystems of the developed system of support of making decision of designer preproduction of electronic vehicles.

Management process implementation of certain sequence and maintenance of the managing influences sent both to arrangement of electronic vehicle implies designer preproduction of electronic vehicles and operative management by a personnel and resources of enterprise. Thus, both for the modern firms of producers of domestic electronic technique and for scientific and productive enterprises airplane and rocket productions, a management process has identical procedure leaning against subjective presentations and skills of personnel in this area designer preproduction of pre-production model of good [16, 19, 20].

The unstructured and semi structured multicriterion tasks decide by means of the developed system of support of making decision of designer preproduction of electronic vehicles. The decision of the examined multicriterion tasks will allow not only to improve quality, reliability, resonant and oscillation stability of electronic vehicles, but also to provide financial viability of production of preproduction model of good, eliminate tests, returns on the revision of good, to shorten time, material production inputs and to build an algorithm knowledge and experience of experts.

Integration of the developed system of support of making decision is arrived at by implementation of row of functions of the systems of production of electronic vehicles, presenting the results of modulating, arrangement and management designer preproduction as data, mechanisms of processing of data and receipt of knowledge making the base of knowledge of the system of support of making decision.

The managing affecting process of designer preproduction acts from outside, in particular on behalf of decision making, in order to ratify the offered scenarios of managing influences of arrangement of electronic vehicle, corresponding to the condition of management efficiency designer preproduction. In a fundamental chart the variant of the use of the developed system of support of making decision is envisaged also for the design of electronic vehicles of the different setting and external environments with the use of the experimental setting for research of failing parameters or additional research of electronic vehicle and constituents.

The offered fundamental chart of the system of support of making decision of designer preproduction of electronic vehicles will realize the mechanism of edu-

cating of the system of support of making decision, sent to adaptation of scenarios of achievement of necessary parameters, properties and arrangement of electronic vehicle under the existent terms of financial viability of production and corresponding technical and economic indexes of making of pre-production model of electronic vehicle.

Facial, decision making as the making developed system of support of making decision, it is necessary to distinguish the row of functions:

– preparation of information;
– input of information;
– implementation of design;
– preparation and input of information in the system of support of decision-making;
– analysis of the results got from the system of support of making decision;
– implementation of directive management directly designer preproduction of electronic vehicle, including of necessity executions of the given out recommendations.

For the decision of existent productive situations it is necessary formally to describe the actions of face of decision making, consisting in that his activity is presented by the task of great numbers of requests for implementation: designs, arrangements, operative management designer preproduction, research of management efficiency [14, 17 - 20].

Query on behalf of decision making can touch implementation of design, task of preliminary variant of arrangement, research of resources of enterprise on making of pre-production model of good and their variation.

Person an accepting decision, leaning against subjective knowledge and experience, can obtain the certain indexes of efficiency for some period of time and amount of heuristic iterations, however the developed system of support of making decision, leaning against the mechanisms of educating and multicriterion optimization, allows to bring down expenses and prime price of pre-production model of electronic vehicle; to reduce the terms of producing of new electronic vehicles; to promote the competitiveness of enterprise at upgrading of electronic vehicles, reliability, oscillation and resonant stability; to economize the facilities expended on retraining and in-plant training of personnel, expenses on consultative services of experts etc.

On results a design the system of support of making decision forms the components of criteria of arrangement of electronic vehicles, on results processing of statistical data are criteria of arrangement, on the basis of questioning of experts, from literary sources and statistics are management scenarios designer preproduction, coming from the analysis of technical and economic, skilled and other of indexes of production of electronic vehicles is management efficiency. Synthesizes all these indexes, the system of support of making decision prospects and processes, preparing information facial decision making [14 - 16].

Except the functions of search of optimal scenarios of achievement of the re-

quired parameters of quality, reliability, to oscillation and resonant stability of electronic vehicle in the process of designer preproduction the offered system of support of making decision, both produces variants and adapts existing before methodologies oscillation, shock and other variants of defense of electronic vehicles from external influences to the existent economic terms and market mechanisms of development of production of electronic vehicles.

Similar family systematization is possible by means of statistical treatment of results of the expert questioning, formalization of procedure of management and forming of case frames for the certain types of electronic vehicles. Introduction of the offered innovations in the existent chart of management of designer preproduction of electronic vehicles will give an opportunity to tune the prospected management under the certain setting of the produced good and condition of exploitation, to attain optimal combinations of economic and administrative parameters of management designer preproduction of electronic vehicles.

For the achievement of the put aim it is necessary to organize questioning of experts concerning the estimations of priorities of results of application of the offered methodology of management of designer preproduction for different objects with subsequent statistical treatment of results of questioning. It is also necessary to estimate adequacy of the got experimental data, define priorities of parameters and their functional intercommunications and on them to produce the analysis of the got results with organization of feed-back for the estimation of efficiency of management of designer preproduction of electronic vehicles. As a method of decision of this task the method of analysis of hierarchies is applied.

Integration of the developed system of support of making decision is arrived at by implementation of row of functions of the systems of production of electronic vehicles, presenting the results of modulating, arrangement and management designer preproduction as data, mechanisms of processing of data and receipt of knowledge making the base of knowledge of the system of support of making decision [14 - 16].

The managing affecting process of designer preproduction acts from outside, in particular on behalf of decision making, in order to ratify the offered scenarios of managing influences of arrangement of electronic vehicle, corresponding to the condition of management efficiency designer preproduction. In a fundamental chart the variant of the use of the developed system of support of making decision is envisaged also for the design of electronic vehicles of the different setting and external environments with the use of the experimental setting for research of failing parameters or additional research of electronic vehicle and constituents.

The offered fundamental chart of the system of support of making decision of designer preproduction of electronic vehicles will realize the mechanism of educating of the system of support of making decision, sent to adaptation of scenarios of achievement of necessary parameters, properties and arrangement of electronic vehicle under the existent terms of financial viability of production and corresponding technical and economic indexes of making of pre-production model of electronic vehicle.

Conclusions

1. New conception of management is worked out by designer preproduction of electronic vehicles, leaning against single informative space of arrangement of electronic vehicle, operative management designer preproduction and control system by the resources of enterprise, allowing to promote management efficiency designer preproduction of electronic vehicles.

2. First it offers to examine designer preproduction of electronic vehicles as system determined and stochastic constituents, allowing depending on setting of object of designer preproduction to determine management scenarios for the achievement of the required parameters and arrangement of electronic vehicles.

3. Decision of stochastic task of management the receipt of functional dependences supposes designer preproduction for research of management efficiency including quality and amount of management cycles, allows to optimize the technical and economic and administrative indexes of management, that it is necessary to realize supports of making decision in the developed system.

4. The worked out conceptual model of the system of support of making decision, leaning against single informative space of arrangement of electronic vehicle, operative management designer preproduction and control system by the resources of enterprise, allows to provide the required properties, quality, reliability, resonant and oscillation stability of electronic vehicles on condition of minimization of material and technical production inputs, achievement of cost expended on retraining and on effectiveness.

5. Worked out informative and algorithmic providing of management, including the criteria of arrangement and management quality designer preproductionof electronic vehicles, designer preproduction of electronic vehicles, it is necessary to realize supports of making decision in the developed system.

6. Worked out algorithms of management designer preproduction, choice of types of objects and construction of model of electronic vehicle, including the stages arrangements, constructing, preproduction and tests of electronic vehicle, support intercommunication with the experimental setting with the corresponding rigging, allow to get failing information about the object of designer preproduction and estimate his parameters and arrangement without producing of pre-production model of good.

References

1. Aglietti G.S. 1999.: Development of the MiniSIL^{TM} Structural design / G.S. Aglietti, A. Wicks, A.J.Barrington-Brown // Journal of Aerospace Engineering. - Vol 213 part G. - pp. 255-263. - ISSN 0954-4100.

2. Aglietti G.S. 2002.: A Lighter Enclosure for Electronics for Space Applications / G.S. Aglietti //Journal of Aerospace Engineering. - part G, Vol. 216-3. – pp. 131-142**.**

3. Basu K. 1992.: Soft sets: an ordinal formulation of vagueness with some applications to the theory of choice/ K.Basu, R.Deb, P.K.Pattanaik // Fuzzy Sets and Systems. – №45. – P. 45 – 58.

4. Ivakhnenko A.G. 1985.: Samoorganyzatsyya of the forecasting systems / A.G. Ivakhnenko, I.F. Myuller. − Kyiv: Technique, 1985. − 223. (in Russian)

5. Jampolskyy L.S. 2005.: Flexible computerized systems: planning, design and management / L.S. Jampolskyy, P.P. Melnychuk, B.B. Samotokin, M.M. Polishuk, M.M. Tkach, K.B. Ostapchenko, O.I. Lisovichenko.- Shytomyr: SNTU, - 680 P. + CD. (in Russian)

6. La Malfa S. 2000.: Use of a Dynamic Absorber in the case of a Vibrating Printed Circuit Board of Complicated Boundary Shape / S.La Malfa, P.A.A.Laura, C.A.Rossit, O.Alvarez // Journal of Sound and Vibration. - Vol. 230(3). -pp.721-724.

7. Laura P.A.A. 1995.: Dynamic Stiffening of a Printed Circuit Board / P.A.A.Laura, L.Ercoli, and.,// Acustica. - Vol. 81. – pp. 196-197.

8. Lim G.H. 1999.: Effect of Edge and Internal Point Support of a Printed Circuit Board Under Vibration/ G.H.Lim, J.H.Ong, J.E.T.Penny // ASME Journal of Electronic Packaging. – Vol. 121, №2. - pp. 122-126.

9. Ong J.H. 2000.: Simple Technique for Maximising the Fundamental Frequency of Vibrating Structures/ J.H. Ong, Lim G.H. // ASME Journal of Electronic Packaging. - No 4, Vol. 122. - pp. 341-349.

10. Royzman V. 2001.: The dynamic effects and shocks in electronics / V. Royzman, E. Nester // Experience of designing and application of cad systems in microelectronics. 6th International Conference of CADSM 2001, FEB 12-17. – P. 256-259.

11. Saaty T. 1993.: Decision-making. Method of analysis of hierarchies / T. Saaty. – M.: Radio and svyaz, 1993. – 320. (in Russian)

12. Saaty Thomas L. 1990.: Eigenweinghtor an logarithmic lease sguares/ Thomas L. Saaty // Eur. J. Oper. Res. –- V. 48, № 1. - 156-160. (in Russian)

13. Saaty T.L. 1990.: Multicriteria Decision Making. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation/ Thomas L. Saaty. – University of Pittsburgh, - 359. (in Russian)

14. Smoliy V.N. 2006.: Automation of processes of production of blocks of electronic vehicles: Monographija. – Lugansk: East Ukrainian National University named after V.Dal. – 124. ((in Ukrainian).

15. Smoliy V.N. 2010.: Case frame by production of electronic vehicle of military purpose // Scientific Papers of Donetsk National Technical University. Series «Informatics, Cybernetics and Computer Science» (ICCS - 2010). – Donetsk: DNTU. - Issue 11(164) – 188 - 193 . (in Ukrainian)

16. Smoliy V.N. 2010: Hierarchy of criteria in the operations managementof electronic vehicles / V.N. Smoliy // Praci Lugansk Branch of InternationalInformatization Academy. – Lugansk: East Ukrainian National University named after V.Dal. – №1(21). - 64 - 69. (in Ukrainian)

17. Steinberg D.S. 2000.: Vibration Analysis for Electronic Equipment. - John Wiley &Sons.

18. Suhir E. 2000.: Predicted Fundamental Frequency of Vibration of a Heavy Electronic Component Mounted on a Printed Circuit Board / E. Suhir // ASME Journal of Electronic Packaging. – Vol. 122, No 1. - pp. 3-5.

19. Valiani A. 2002.: Case Study: Malpasset Dam-Break Simulation using a Two-Dimensional Finite Volume Method/ A.Valiani, V.Caleffi, A.Zanni// Journal of Hydraulic Engineering. – May,– Vol.128, №. 5. – P. 460-472.

20. Ulshin V.A. 2011: Automated management by designer preparation of production of electronic vehicles/ Vitaly Ulshin, Victoria Smoliy // TEKA Kom. Mot. I Energ. Roln. - 11A. - 276 – 281.

21. Ulshin V.A. 2011.: Case-based reasoning method for diagnostic decision support system of bridge cranes/ Vitaly Ulshin, Sergey Klimchuk // TEKA Kom. Mot. I Energ. Roln. - 11A. - 266 – 275.

22. Wong T.-L. 1999.: Experimental Modal Analysis and Dynamics Response Prediction of PC Boards With Surface Mounted Electronic Components / T.-L. Wong, K.K.Stevens, G. Wang // ASME Journal of Electronic Packaging. – Vol. 113. - pp. 244-249.

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NEUROSEMANTIC APPROACH TO BUILDING AUTOMATED INFORMATION RETRIEVAL SYSTEMS

Annotation. The original method of implementing logic based on genetic algorithm, which processes replenish the knowledge base and improving each generation «genes» by weighting the semantic data based on the superposition of the reference response to the situation and assess the situation the current generation of «genes». The implementation of this method involves the construction of a neural network with neurons, memory and built-in logic.

Keywords: intelligent multi-agent system, neural network, genetic algorithm, knowledge model, subject area

Introduction

It is obvious that the variety of semi-structured information on the Internet can’t be successfully used in practice without effective access. Thus, according to experts, about 79% of journalists go to the Internet in search of news, and only 20% find the information they need. This is true for scientific research. Despite the abundance of work to improve the methods of information retrieval (*IP*), the problem can hardly be solved with the help of traditionally used methods, such as Boolean model, vector model, interactive model, etc. [1-4]. Even if we imagine that all the existing problems of IP in their traditional formulation will solved, the majority of users, and primarily developers of information retrieval systems (*IPC*), will still be dissatisfied, because the information they have will relate to the search query, not the current issues.

To overcome this contradiction, the W3C Interest Group Note consortium is developing Web semantic [2]. According to its creators, the implementation of this paradigm on the Internet will allow information systems to some extent understand the content of information and act as intellectual intermediaries capable of independently manipulating it on the instructions of a person [5].

In addition, automation of the search process for the above information is also problematic. Currently, in the sense of automation of IP, work is actively underway to develop algorithms that automatically generate intermediary programs or, in other words, intelligent agents (*IA*).

The intellectual multi-agent system (*IMS*) proposed in this paper is connected with the solution of the problem of reducing the time spent on finding the necessary data and improving their semantic quality.

Problem statement

The formalized IMC model can be represented by three main functional components $MAS = (S, AG, env)$, where

– S – a finite set of States of the external environment;

– $AG = \{ag_1, \dots, ag_n\}$ – a finite set of agents, each represented by an advanced intelligent agent model;

– $env: S \times A_{ag_1} \times \dots \times A_{ag_n} \to 2^s$ – a function that describes the possible reaction of the environment to the actions of all agents of the system. The set of all possible joint actions of the system is denoted by $ACS = A_{ag_1} \times \dots \times A_{ag_n}$ [6].

It is known [7], the set *S* develops evolutionarily, being distributed uniformly on different logical categories of knowledge. Hence, the model of knowledge (*MK*), which, taking into account the general state of the sets of *AG, env, ACS* and the conditions of the importance of the development of their individual components, constantly updates and clarifies its semantic content. The set of *AG* connect with creation of ontology’s for descriptions of extended models and modular addition of agent models. Many *ACS* dynamically update, taking into account all the changes in the environment perceived by agents on their integral experience. The low efficiency of the existing automated systems of collection and analysis of specialized data for the formation of knowledge models of subject areas is associated with the lack of adaptive intellectual mechanisms of constant information update of knowledge models. One of the variants of its solution is the generalized model of IMC proposed in this paper.

Synthesis of generalized IMC model

Structurally, IMC is a neural network with neurons with memory and integrated logic. The adaptation of IC to changes in the external environment base on the principles of the genetic algorithm [7]. Intelligent agents in this IMC provide integration of neural network with decision-making logic based on multi-agent method of decision trees synthesis [8]. In the proposed IMC modification of this method is, agents move from node to node is not by random selection, and genetic selection of the best offspring. The learning process in IMC realize with feedbacks on different acceptors, which connect the IMC core with the modules of processors of different acceptors and distributed databases, selected and built under the IMC architecture. This IC provides for the systematization of these models of knowledge and the possibility of varying the logical text construction. For the implementation of the decision element makes use of the experience acquired so-called actual touch field (*ATF*). ATF is the association of relevant fields of sensors with the usual and cognitive memory. Next, a logical add-on made over the associative storage field (*ASF*). To do this, at the initial stage of obtaining information, the rules of building this system taking into account its semantic meaning are formed, as well as information for the hidden latent layer. Encryption of information base builds on the scheme of probabilistic generation of a numerical sequence of random code words from a certain set of keywords, which transmit asynchronously in each data package with a «hash key match». After the transaction is completed and the data packet transmits, the key destroyed and a new sequence automatically generated with a new key calculated from the new sequence. In case of violation is used separately constructed sample selected on the strongest generation of «genes».

For the formation of the logic of action of IA there are two options for describing semantics [6]:

– *dynamic of mental state.* In this case, it assumed that the agent updates its mental state at each step of interaction with the external environment.

– *static of mental state.* In this case, it assumed that the mental state of the agent does not change over time.

An important component of the system is the integrated action of the interpreters of both variants of semantics descriptions. For this purpose, the algorithm of automatic (or automated) creation of ontology’s and their recording in a distributed database (*DB*) is used. This database use by the interpreters of the MK with automatic allocation of categories in the field of axioms of building patterns, which characterize by the following mandatory ontological relationships:

– meta-description of the database (the conceptual schema);

– description of knowledge about database elements;

– knowledge of the relationship of database concepts with the concepts of natural language).

All domain knowledge consists of a set of Ξ^s terms (keywords/queries) and is described in the form of regularities based on different types of relations (direct and inverse), which are divided into eight groups. Such a partition makes it possible to form the first level of «ontological representation» of information, i.e. conceptual basis of specifications. In fact, it is the formation of an associative series over the basis of axioms with the mapping of integral and differential estimates of reality and the allocation of random and domain-oriented information to a hidden layer stored in a separate database.

Any decision of IMC is a logically reasonable general account of estimates of all relations with weighted coefficients of groups of relations and their priority effects on the environment and on each other. The « intention» is determined by the goal set for the intellectual agent, which is determined by the sequence of assessments of the priorities of the impact of certain logical groups with the involvement of a reference model that takes into account all the estimates and «perturbations» of the sets *S, AG, env, ACS.* «Perturbation» is the changed state of the basic model in relation to the reference model.

Each subsequent level of choice of ontological representation of information is formed taking into account the specifics of the previous and integrated assessment of the system States at a given time, in which the reference model remains stable [9]. The algorithm of formation realize on the index of specificity of decision-making, determined by the formula:

$$i = F(l_j, s_k, h(j,k)). \qquad (1)$$

Here:

i – a coefficient denoting the integral ratio of the situation index $s_k = f(h)$;

k – a type of situation;

f – determined by the intersection of sets(k and k*) to the index of specificity

l_j (j – the specificity of logic);

h – a superposition estimate (the base of event probabilities is taken into account);

n – the maximum number of types of situations for the group of vectors;

$\bar{S}$ – a situation vector; $\overline{SL}$ – a guiding vector in the logic space, type of situation, and their superposition estimate h. The following is a formalization of measures j, k, h:

$$k = \bar{S} \times n,$$
$$j = k \times \overline{SL},$$
$$h = (k, j) \circ (k^*, j^*). \quad (2)$$

The type of situation determined by the number of vectors of situations. It affects the choice of a group of vectors, which depending of the type IA. IA can belong either to one unique group of vectors or to a set of groups with similar vectors. The choice of a certain group vector is first based on expert assessments, and then, gaining experience, the IMC forms a knowledge base (BK) of guiding logics, from which, depending on the group of IA, a selectable situation vector is formed that determines the behavior of the agent. It should be noted that one guiding vector may be transitively correlated with a set of situation vectors, and vice versa. Formally, this as follows: $\overline{SL_5}^1 = \overline{SL_5}^4 = \overline{SL_6}^1 = \ldots$ The base of association of the guides of the vectors is part of the BK logic guides.

The essence of the binary (0 and 1) guide vector is that it zeros those points of the vectors of situations (certain groups), which IA should not «pass» to solve the problem, the points of vectors, these are the points-actions of the space BK guiding logic (actions of network agents). BK includes guides vector, a variety of specification logic, the vector and the types of situations corrected estimates of experts for the $\bar{S}$ and $\overline{SL}$ respectively, and temporary behavioral characteristics on the number of times of applications of logic and quality assessments (as an expert, and systemic agents, appraisers). The operation of the IC according to the formula (1) is as follows. Index of specificity of the level of ontological representation

$$l_j = L(k, j, h), \quad (3)$$

what determined $b(k,j) \cap (k^*, j^*)$y. If there is such an intersection, then it allocated to the estimated measure h and is with k, j – three measures of the behavior function IA for the «current» situation in the behavior space, i.e. the behavior of the agent determines the index of logic specificity.

$\overline{SL}$ coefficients are the priorities linked through the differential component of the genetic code of the offspring G, used in determining the index of logic specificity

$$l_j = \int G(s_k) dl, \quad (4)$$

based on selection. Each new perturbation creates a new moment and translates the static mental state into a dynamic one, taking into account the estimates of all perturbations, allowing the transition to a new time stage of the system. The state of offspring of the genetic code G defines of estimate of the possible increase or fall in the offspring on the vector of the space of solutions of the three-dimensional

behavior function of the agent (the measures are sets (k, j, h)). This measure consider complete (that is, the coefficient at the point of the vector $\overline{SL} = 1$), if and only if:

$$\begin{cases} dh \neq 0, \\ dj > 0, \\ dk > 0. \end{cases} \quad (5)$$

Conclusion

In this paper, a generalized model of IC data collection and analysis with a decision-making algorithm based on the genetic approach and multi-agent method of synthesis of decision trees and neural network using the index of decision-making specificity synthesize. Decrease of search time in IMC cause by the algorithm of selection of control decisions using estimates of sets of types of situations and specifics of logics, instead of sets. Improving the quality of information is achieved at each iteration by a selection of behaviors with a high frequency of a cutoff region of the superposition is estimated by the index of the specifics of the logic and the index of the situation that raises the level of ontological representation of the information.

REFERENCES

1. Kozlov, D. D. IPS in the Internet: current state and ways of development. – M.: Moscow state University. 2000, 28p.

2. Luciano Floridi. Web 2.0 vs. the Semantic Web: a Philosophical Assessment // Episteme.– 2009. – Vol. 6, № 1, pp. 25 - 37.

3. Manning. K. Introduction to information retrieval. – M.: Williams, 2011, 200 p.

4. Lande D. V. Knowledge Search on the Internet. – M.: Dialectics, 2005, 272 p.

5. Braley A. J. Intelligent Packaging in Pursuit of Customer Needs // Packaging Technology and Science.–1993–Vol. 6 – №3. – pp. 115-121.

6. Bugaichenko, D. Y., Soloviev I. P. Logic-formal specification of multiagent real-time systems. Bulletin of St. Petersburg University, Ser. 1, Issue. 2, 2007, pp.49-57.

7. Rutkovskaya D., Pilinsky M., Rutkovsky L. Neural networks, genetic algorithms and fuzzy systems, 2nd ed.– M: Hotline-Telecom, 2008, 452 p.

8. Subbotin S. A., Oleinik An. A., Gofman E. A. Intelligent information technologies of automated diagnostic and pattern recognition systems design : monograph. – Kharkov: Company «SMIT», 2012, 133p.

9. Nikonova L. V., Evdokimova I. S. Methods and algorithms for translation of natural-language queries to SQL-queries database.– Ulan-Ude: VSGTU2, 2004, 148p.

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OPTIMAL CONTROL OF COMPLEX TECHNICAL OBJECTS BASED ON THE PREDICTIVE MODEL

Annotation: Optimal methods of control of complex technical objects using a predictive model are considered. A structural and functional scheme for the implementation of automatic optimal stabilization of a given motion of autonomous robotic underwater based on the original methods of parametric identification of predictive models and modal synthesis of optimal regulators on separate forecast horizons is proposed.

Keyword: optimal control, predictive model, parametric identification, ACOR, prediction horizon, modal synthesis

Introduction

Optimization of processes by classical methods and, in particular, the construction of optimal systems, despite the developed theory, encounters difficulties in the implementation of control systems (solution of boundary value problems on the principle of maximum, to reproduce the surface or hypersurface switching, to solve transcendent equations, etc.). However, the acceleration of management processes can be achieved in another way, namely by using the forecasting method. This method began to develop in the 60-ies for the control of processes and equipment in the petrochemical and energy production, for which the use of traditional methods of synthesis was extremely difficult due to the exceptional complexity of their mathematical models. A characteristic feature of this approach is to consistently determine the final result of the impact of the control chosen at the moment.

The method of forecasting was first used in the work of J. Coles and A. Noton [1], further developed X. Chestnut, W. Sollecito and P. Trutmann [2], for optimal control of second order objects with time-varying switching lines. A characteristic feature of these works is the prediction in computer systems with the repetition of the solution of the set of optimal trajectories of the object with the allocation of the trajectory that corresponds to a given final position of the object, as well as the use of logic designed for no more than one switching control action.

In [3] the forecasting method was used to determine the control action by solving the equations of the object dynamics and the Euler variational equation for it in an accelerated time scale. In this case, from the set of integral curves, the one that corresponded to the desired final state of the object was chosen. Features of application of a forecasting method in the mentioned works do not allow to extend them on objects above the second order and on the objects having additional restrictions on coordinates.

To eliminate this drawback in the work [4], a method of optimal or close to optimal control of one class of objects based on predictive devices operating in an accelerated time scale is proposed. The essence of this method of control with forecasting is that the control action is formed on the basis of the results of forecasting the future behavior of the control object. Depending on the assessment of the discrepancy between the final state obtained as a result of such a decision and the specified state. The control is determined at the current time. Therefore, forecasting requires, on the one hand, knowledge of the mathematical description of the dynamics of the object and its current state, and on the other hand, solving the problem of determining the final state of the object with a certain control action. Forecasting in the sense of extrapolation of system dynamics is carried out implicitly in any control system, where, in addition to the mismatch signal, derived control is used.

Since such extrapolation is usually approximate, it does not allow to accurately estimate the final result of the control and determine the optimal solution to the problem. Meanwhile, the creation of computing systems operating in an accelerated time scale and with the repetition of the solution process allowed to obtain qualitatively new results in solving forecasting problems [5]. These computing systems, solving at a fast pace the equations of the object dynamics with the initial conditions corresponding to its current state, at a certain control action, allow us to trace the entire control process up to the final state of the object. It gives an opportunity to choose the best in a certain sense the control action, at least from that class, which can be seen in the prediction.

On the other hand, knowledge of the final results of management allows to avoid exceeding the coordinates of the object of certain boundaries, which established for one reason or another . Together, these factors enable prediction of computers greatly enhanced the process management without risk of the transition of the object into an invalid state.

With the advent of advanced mathematical software for modern computer systems, new approaches in the use of predictive models for optimal control of dynamic objects.

Optimization of complex technical objects by MPC-approach

One of the modern formalized approaches to the analysis and synthesis of control systems based on mathematical methods of optimization is the theory of control of dynamic objects using Model Predictive Control (MPC) [6].

The idea of optimizing the predicted movement, which is the basis of the MPC approach, arose within the framework of two independent, but essentially similar approaches. The first of them, called Dynamics Matrix Control (DMC), was developed by the efforts of Shell Oil specialists in the mid-60s [7], and the second – Model Algorithmic Control (MAC) – was developed by French engineers of the chemical industry in the late 60s [8]. On the basis of the latter approach, a commercial software package IDCOM (Identification and Command) was created for the first time, which to a certain extent served as a prototype of modern software support for predictive control methods.

The package of application programs Model Predictive Control Toolbox (MPC Tools)[9] is a set of tools for research and design of control algorithms in

discrete and continuous systems based on predictions of the dynamics of their behavior. The package includes more than 50 specialized functions for the design, analysis and simulation of dynamic systems using predictive control.

At the same time, the authors of the package, taking into account its purpose for the initial development of the ideology of the MPC approach, included in the working tools only those tools that are quite easy to learn and practical application. Model Predictive Control Toolbox is a package for research and design of control algorithms with dynamics prediction. Allows you to create adaptive control systems for complex systems with one or more inputs (outputs) and various restrictions. The package allows you to implement a control principle in which the input impact is calculated at each step based on the internal model of the object. Quadratic programming is used to optimize control.

Currently, the MPC-approach is in the stage of intensive development, as evidenced by the extensive bibliography of scientific works published in recent years on this issue. The development of control ideas with forecasting occurs in the direction of the use of nonlinear models, ensuring the Lyapunov stability of controlled movements, giving robust properties to the closed control system, the use of modern optimization methods in real time, etc. [10,11]. Moreover, the scope of practical application of the MPC approach has expanded significantly, covering a variety of processes in the chemical and construction industry, light and food industries, in aerospace research, in modern energy systems, etc.

The main advantage of the MPC approach, which determines its successful use in the practice of construction and operation of control systems, is the relative simplicity of the basic scheme of formation of the feedback, combined with high adaptive properties. The latter circumstance makes it possible to control multidimensional and multi-connected objects with a complex structure, including nonlinearities, to optimize processes in real time within the constraints on the control and controlled variables, to take into account uncertainties in the assignment of objects and perturbations. In addition, it is possible to take into account the transport delay, taking into account changes in the quality criteria during the process and sensor failures of the measurement system.

The essence of the MPC approach is the following scheme of control of dynamic objects on the principle of feedback.The scheme can be combined with the preliminary identification of the equations of the model used to perform the forecast (Fig.1).

The implementation of this approach is as follows:

We consider some (relatively simple) mathematical model of the object, the initial conditions for which is its current state. With a given program control, the equations of this model are integrated, which gives a forecast of the object movement on a certain finite period of time (forecast horizon).

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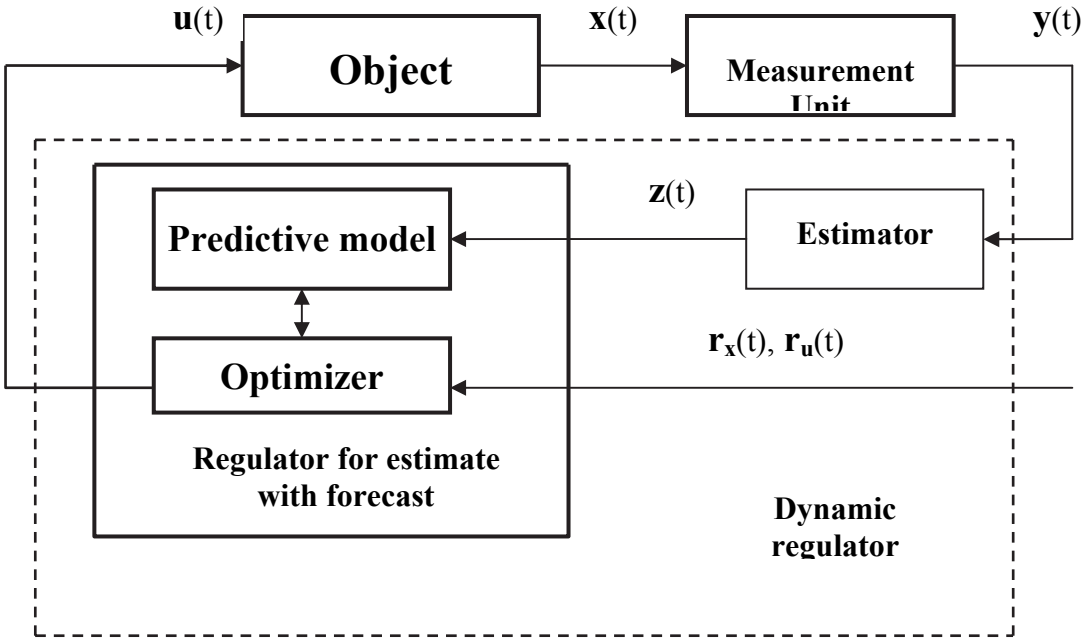

Fig.1. Scheme of implementation of the MPC- approach to the synthesis of optimal control systems with predictive models

After that, the program of optimization of object motion control is developed, the purpose of which is the approximation of the controlled variables of the forecast model to the corresponding given signals on the forecast horizon. Optimization is carried out taking into account the whole complex of restrictions imposed on the control and adjustable variables.

At the calculation step, which is a fixed small part of the forecast horizon, the found optimal control is realized and the actual state of the object is measured (or restored by the measured variables) at the end of the step.

The forecast horizon moves one step forward, and points 1 - 3 of this sequence of actions are repeated.

Optimal stabilization of a given motion of an Autonomous underwater robot

It is known that all real Autonomous robotic underwater vehicles (ARPA) to some extent are nonlinear and non-stationary. One of the urgent tasks in the management of the ARPA is to stabilize the software (given) motion. Analysis and synthesis of systems of optimal stabilization of ARPA program motion, in General, is a rather complex mathematical problem. However, since the majority of ARPA allows you to take as a mathematical model of their dynamics in the stabilization modes of the linearized system of equations, it allows to apply time-vity mathematical apparatus for the solution of linear stationary and non-stationary differential equations to the solution of problems of management of the ARPA. Despite this, the synthesis of optimal stabilization systems for ARPA remains a challenge.

In General, linear non-stationary model of dynamics of the ARPA in the modes of stabilization can be represented in the form:

$$\dot{\bar{x}}(t) = A(t)\bar{x}(t) + B(t)\bar{u}(t),\ t \in [t_0, T_f],\ \bar{x}(t_0) = \bar{x}^{(0)}, \qquad (1)$$

где $A(t) = \{a_{ij}(t)\}$, $B(t) = \{b_{ik}(t)\}$ – dimension $(n \times n)$ and $(n \times m)$ matrices, respectively, whose coefficients have a constant sign

$$sign[a_{ij}(t)] = const,\ sign[b_{ik}(t)] = const\ , \tag{2}$$

and monotonous

$$sign[da_{ij}(t)/dt] = const,\ sign[db_{ik}(t)/dt] = const \tag{3}$$

and there are pre-unknown functions that have continuous first derivatives and are bounded in the domain of determination on the stabilization interval. Linear stationary and quasi-stationary dynamic models will be special cases of the model (1). We also assume that the control vector in solving the problem of stabilization of the ARPA program motion is not limited

The problem of optimal stabilization of program motion the ARPA is formulated as follows: find the control that transforms the system (1) under conditions (2) and (3) from an arbitrary initial state to zero and minimizes the functional:

$$I = \int_{t_0}^{t_k} \left[\overline{x}^T(t) Q \overline{x}(t) + \overline{u}^T(t) R \overline{u}(t) \right] dt, \tag{4}$$

where t_k – fixed, Q и R – positive definite matrix**es** of size $(n \times n)$.

This formulation of the problem with functional (4) is known in the literature as the linear-quadratic optimization problem.

The solution of the problem

For accurate realization of ARPA movement along a given path, an automated optimal stabilization of the programmed motion is required. We consider that on ARPA the onboard control system (BSC) with the corresponding mathematical and software is established. On the basis of such BSC the structural and functional scheme of automation of the process of optimal stabilization of ARPA motion can be realized (Fig.2.).

Marked: BFPT – block of forming unit programmed trajectory; CMD – complete model of the dynamics of the ARPA; BUC –block of unit calculation program management; BSP1, BSP2 – blocks of sensors of parameteres; BIP – block identifying the parameters of forecasting models lactation; BSSL – block for the synthesis of stabilization laws.

According to this structural and functional scheme, the automation of the process of optimal stabilization of the motion ARPA is carried out as follows. By the time of performance of some planned mission to the input of the BSC, a given program trajectory of ARPA motion receive in the form of a discrete series of spatial coordinates (or in analytical form) in certain areas of motion. In the first case, the BFPT block approximates a discrete series of coordinates by an analytical representation, in particular, pro-

posed by the authors in [12] spline approximation. In the second case, the need for this disappears. Software trajectory through CMD is included in the BUC and via BS1 is supplied to ARPA. In addition, for certain areas of the software movement the ARPA on the basis of the information management program and a program path in BIP may be construct corresponding plots of the linearized model of the dynamics of ARPA, and evaluation of its parameters according to the work of the authors [13] in the form of a series of Walsh using the algorithm of the adaptive partitioning of the time interval of movement. The adaptive algorithm, in contrast to the fixed partitioning, allows to approximate the original ARPA model at individual sites with a given accuracy in the form of quasi-stationary predictive models.

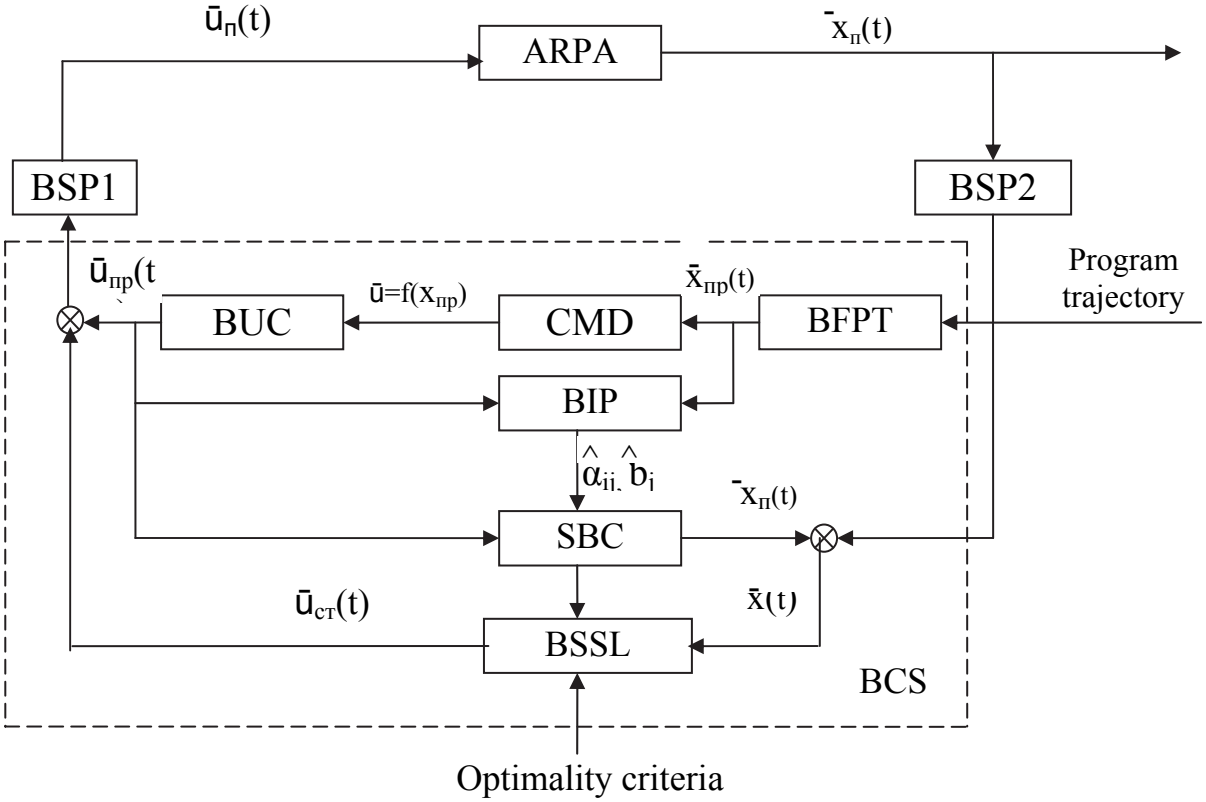

Fig.2. Structural and functional scheme of automation of the process of optimal stabilization of motion ARPA

As an example, the problem of parametric identification of ARPA with the dynamics of the second order is considered

$$\begin{aligned} \dot{x}_1(t) &= a_{12}(t)x_2(t), \\ \dot{x}_2(t) &= b_2(t)u(t), \ t \in [0,100], \end{aligned} \tag{5}$$

where $x_1(0) = 30, x_2(0) = 50, b_2(t) = 1, u(t) = -1$. Let the exact value of the estimated parameter be $a_{12}(t) = 0,000012t^3 - 0,0014t^2 + 0,033t + 2$. Parameters for comparison of constant and adaptive algorithms were set as follows: $L = 10; P = 5; \delta^{'} = 1; \delta_l = 1$ *для всех* l; $\eta_0 = 10; \varepsilon = 0,2; \mu = 0,5$. The results of the

evaluation $\hat{a}_{12}(t)$ for a fixed $(L=10)$ and adaptive partitioning of the interval are given in Fig.3, where curve 1 is the exact value $a_{12}(t)$; curve 2 – evaluation $\hat{a}_{12}(t)$ for a fixed partition; curve 3 – evaluation $\hat{a}_{12}(t)$ at adaptive partitioning. The accuracy of the parameter estimation $a_{12}(t)$ is characterized by the value of

$$\delta^2 = \sum_{m=0}^{M}[\delta\hat{a}_{12}(t_m)]^2 / \sum_{m=0}^{M}[a_{12}(t_m)]^2.$$

Comparison of the estimates obtained by the fixed and adaptive algorithms for the considered system (5) allows us to conclude that the parameter estimation accuracy can be increased using an algorithm with adaptive selection of the quasi-stationarity interval.

Further, from the analysis of the approximation of all parameters of the quasi-stationary model by piecewise constant Walsh functions, we determine the minimum partition interval, which is taken as the forecast horizon, since all parameters of the predictive models are simultaneously constant on it. Thus, we form stationary predictive models with the selected forecast horizon.

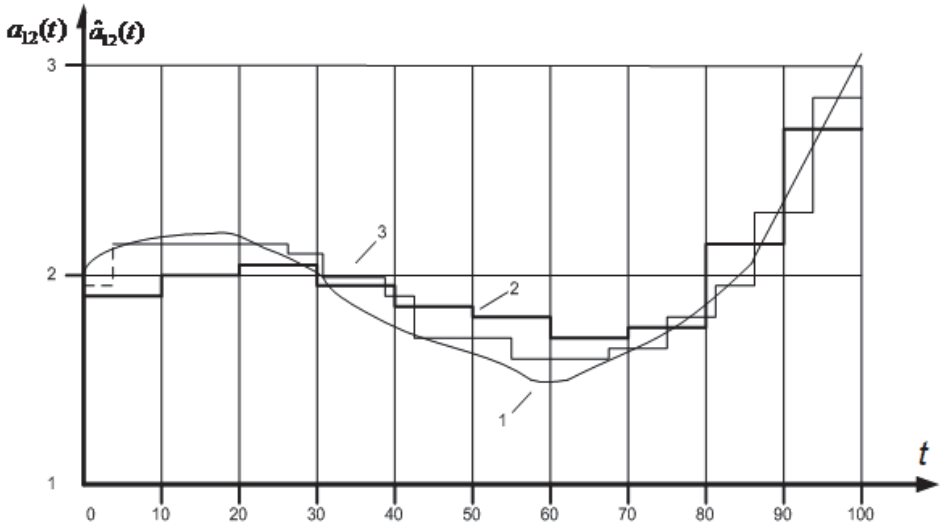

Fig. 3. The results of estimation of parameter $a_{12}(t)$ with a fixed and adaptive partitioning of the time interval

These data are used in the obtained quasi-stationary models of CMD ARPA dynamics, at the output of which a given trajectory is formed and compared with the current trajectory coming through BS2. The appearance of inconsistency between the program and the current trajectories is included in the block BSSL, which, taking into account the optimality criteria set from the outside, automatically generates in real time the optimal stabilization law for this interval. In this case, the problem of ACOR can be successfully solved in real time, proposed in the authors ' work by the method of modal synthesis based on the method of uncertain coefficients [14], which allows to provide the specified indicators of transients.

Summary

The solution of optimal control problems with predictive models is one of the modern methods of research of control systems and is easily implemented with the help of such systems as Matlab, which with its packages has great opportunities and tools for solving problems of analysis, synthesis and simulation of such control systems. A sequential approach to parametric identification of predictive ARPA models and modal synthesis of optimal regulators based on the method of uncertain coefficients allows for automatic optimal stabilization of ARPA in real time.

References

1. Coales J., Noton A. An On-Off Servo Mechanism with Predicted Change-Over. IEE, pt. B. v. 103, No. 10, July 1956.

2. Chestnut H., Sollecito W., Troutman P. Predictive Control System Application. Appl. and Jnd., No. 55, July 1961.

3. Eckman D., Lefkowitz I. A report on optimizing control of a chemical process. Control Eng-ng., No. 9, September, 1957.

4. Гулько Ф. Б. On one property of the structure of optimal processes. Technical cybernetics, № 1, 1963.

5. Gulko F.B., Kogan B. Y., Lerner A.Y., Mikhailov, N. N., Novoseltseva Z. A. Predictive control methods using high speed analog computers and its applications, Avtomatica and Telemekhanica, 1964, Volume 25, Issue 6, pp. 896–908

6. Camacho E., Bordons, C., Model Predictive Control, Springer-Verlag, 2004, 405p.

7. Dougherty,D., Cooper D. A practical multiple model adaptive strategy for multivariable model predictive control. Control engineering practice. Elsevier Science Publishing Company. Vol.11, №6,2003, pp.649-664.

8. Holkar L., Waghmare M. Overview of Model Predictive. Control International Journal of Control and Automation International Journal of Control and Automation Vol. 3 No. 4, December, 2010 Vol. 3 No. 4, December, 2010 December, 2010, pp.47-63

9. Åkesson J. MPC tools 1.0 – Reference Manual Department of Automatic Control. Lund Institute of Technology, January, 2006.-30 p.

10. Camacho E., Bordons C. Model predictive control. London: Springer-Verlag, 2004. 405 p.

11. Aggelogiannaki E., Doganis Ph., Sarimveis H. An Adaptive Model Predictive Control configuration for Production-Inventory Systems // International Journal of Production Economics. 2008. V.114. pp. 165 – 178.

12. Stenin A. A., Melkumyan E. Y. Approaching the variables of the dynamic management objects based on the polynomial spline-functions Krivogradskaya national University " Galuzeva mashinobuduvannya, automation" Issue 27 - Kirovograd:KNTU,2014. P. 305-311.

13. Mikhalev A. I., Stenin A. A., Pasko V. P., Soldatov M. A.. Identification of kwathestationery systems based on spline-functions, and Walsh functions. System technologies. - Dnepr: Nmetau, IVK "System technologies", №5 (100) 2015. – mop. 53-60.

14. Stenin, A. I. Lisovichenko, O. I., Tkach, M. M., Pasko, V. P. Modal synthesis of optimal laws of stabilization of linear stationary systems Bulgarian Journal for Engineering Design, issue. Mechanical Engineering Faculty, Technical University–Sofia.№ 30, 2016.pp.11-16.

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INFORMATION TECHNOLOGY FOR WEB-APPLICATIONS DESIGN AND IMPLEMENTATION

Abstract: The problem of the rapid creation of effective web-applications of one class with using formal means are considered. The conceptual approach to its solution is offered on the basis of analysis of the peculiarities of web-applications construction. The approach is based on defining the standard web application architecture and selecting its components using formal methods in accordance with user requirements. A formal logical system is used, which uses the design of web-applications as a process of outputting the formula specified according to the needs of the user, which defines the schemes of execution of the modules of the system. An important feature of the approach is the ability to 3D-visualize the process of designing the system, which creates conditions for effective interaction between developers and machine development tools.

Keywords: web-applications; application construction; business processes; mathematical logic.

Introduction

The creation of information systems today is based on modern methodological concepts that inherited the most important ideas of classical methodologies such as SADT, IDEF0, while enriching them with new ideas. Classical methodologies were characterized, first of all, by a combination of the perfect implementation of the system approach with detailed elaboration of the design stages and taking into account the features of the management object based on the triad "model - algorithm - program".

The most important directions for improving classical methodologies were:

1) structuring software that opened the way for programmer’s teamwork and reuse of software code;

2) describing the created system possibilities using languages of conceptual modeling, which was accompanied by the development of automated design systems;

3) structuring the design process, which enriched the industry with the concept of the system life cycle, repository and unified models of role design systems;

4) prototyping, on the basis of which the concept of parallel development of parts of the system, design and implementation of the system by parts were developed.

By and large, modern methodologies for information systems design, for example Agile-methodology, only successfully use different combinations of these concepts, filling them with real content and complementing the elements of psychology. This conclusion can be made by analyzing the rich experience of using Scrum, Kanban and other technologies.

Such features of modern methodologies as the minimum of documentation, the various schemes of communication of developers and the variety of roles played by them is only a tribute to the time and form of the inclining of the tendency to change.

Formalization is very specific in modern methodologies [1-4]. In classical methodologies it was considered as the basis of automation, CASE-tools. In essence, formalization then seemed to be an inalienable ability of each technology that implemented the methodology, the tool for automatic production of components of the information system, primarily software, databases, based on their formal descriptions. Today, formalization is more related to describing the architecture of the system and descriptions are mainly used to set tasks for project participants, discuss intermediate results, define the next steps [1,2].

But there is a real opportunity to give formalization a more important role in modern methodologies for the creation of information systems. First, this is facilitated by the standardization of architecture and components of information systems. Secondly, within the framework of standardized architectures, many components have been developed that can be used to design new systems. Thirdly, the development of mathematical logic and artificial intelligence in recent years provided as tools for the formal description of systems designed in terms of "what needs to be implemented" and the description of components in terms of "what has already been implemented." Fourthly, the methodology of spatial visualization of designed systems appeared, which can be transferred to the creation of information systems based on the component-based approach.

This paper attempts to use the developed formal models and effective methods for building the technology of automated generation of software systems on the basis of modern methodologies.

As this problem has enormous scales, we have identified one of the most advanced components of modern information systems - the development of systems with web-presentation.

The essence of the problem

The expediency of this tasks class automation is explained by the considerable complexity of design and implementation of subtasks, to which they decompose. Subproblems are duplicated in each project, and changes are subject to data but not their main transformation.

Developers should agree on a universal architecture. Then the application will have the same overall appearance and differ from others only by the presence or absence of one or another component depending on the functional requirements for application.

Adhering to the principles of the three-tier architecture, in the typical application we will allocate levels - representation, business logic and access to data. The level of data access determines the ability to work with data and in general, it is the implementation of the template "Repository". The access to data, if necessary, from the business logic we define in the traditional way: 1) with each entity, we associate

certain generalized behavior, inherent in all elements of the level of access to data; 2) expanding behavior by adding unique methods for the current entity.

Accordingly, a specific repository class inherits its interface, obtaining basic methods common to all and its own methods from its own interface, and also inherits the class that implements the basic behavior, the fact of which contains the implementation of only their methods. The template has a specific architecture and is expanded by adding new classes and interfaces to work with each entity.

Business logic is responsible for processing data obtained from the level of access to data, through the use of behavioral patterns, such as strategy, behavioral classes, in certain cases of commands. Each component implements the end-user functionality that the user expects. According to the incorporated concept, components can be expanded by adding classes with narrowly oriented behavior.

The "Strategy" template aims to implement a set of different behaviors depending on the needs of the component that is level higher and appeals to this strategy. A strategy is described with an appropriate method that takes on input the required parameters, and several implementations of the method.

The "Command" template provides the implementation of a certain behavior on demand, allowing abstract from the logic of the command itself inside the mechanism.

Another mechanism that is used is an interface with behavior descriptions and a implementation class that contains the elements of data processing and the formation of the result required for a component that is in the architecture of the level above.

A web-presentation is a system component that is accessible from the outside and visible to all users. It is intended for receiving and analyzing queries and performing necessary actions by means of calling business logic methods, as well as displaying data on a client side. This component is mainly built on an MVC template, consisting of representations and directly methods invoked when processing client requests.

As the MVC template is built according to its purpose: the model determines which data should be displayed; representation is a graphical component capable of displaying a particular model; the controller determines how to get the model, which presentation to submit it and how to process the request.

This template is designed to differentiate between logic and representation using a model. This allows you to structure components in accordance with naturally defined assignments and expand the capabilities of one component without altering others.

By following the description, the task of creating any web-application can be considered as a task of filling in a particular template. But building even a template of correct architecture, writing monotone and long code require a lot of time. Therefore, the problem of automating the creation of a software system through the automated implementation of the system template based on user requirements. Solving this prob-

lem involves the following steps: designing a database model and generating access levels to it; realization of data processing by built-in strategies on the user's request; generation of presentation. Therefore, the problem of automating the creation of a software system appears by automated implementation of the system template based on user requirements. Solving this problem involves the following steps: designing a database model and generating access levels to it; realization of data processing by built-in strategies on the user's request; generation of presentation.

The structure of the process determines the structure of the program, its general appearance. For the model structure of the program we will use a state diagram.

For many applications in this chart, it's enough to highlight user (U), representation (P), controller (C), business logic (L), data access level (A), data source (D). The natural chain of state changes in the forward direction is caused by the following events: data request (from U to P); create a thread to handle the query and instance of the controller (from P to C); create an instance of the behavioral class and call its method (from C to L); create an instance of the repository and call its method (from L to A); forming a request and sending it to execution (from A to D). In the reverse direction for the construction of the program, it is expedient to select the following transitions: return the result of executing the data request (from D to A); return of access data model (from A to L); processing of selected data (from L to C); transferring results to the user and releasing resources (from C to P); return the result (from P to U).

A wide class of business processes is supported by web applications, authorization and processing of which may be described in a similar way. The difference lies in methods called at the level of business logic, interfaces, classes, and objects required by the user.

Another example is a business processes that require quality, speed, performance, and other characteristics of various objects. Here is a toolkit for performing such calculations.

To create popular today's transactional systems, the components of aggregation of orders data according to the chosen criterion would be acquired, control of transaction execution, system return to the previous state, etc.

A component to support the business process for processing discounts on vouchers could also be an integral part of a broad class of systems. The description of this business process is quite standardized, and the construction of the relevant component would be very similar to the one discussed above.

Consequently, for broad classes of systems of similar purpose, the only one distinguishing the implementation of tools for supporting standardized business processes is behavioral strategy at the level of business logic. It is advisable to implement the system in such cases in such a way that, depending on the conditions that were given when creating a particular component, the program code was generated according to different schemes corresponding to the specified conditions, but the system guaranteed a unique issue of this code for each design request.

Existing Approaches To Creating Web-Based Applications

Attempts to automate the creation of web-applications are made a long time ago.

Of course, it's worth mentioning already made solutions like CMS. The logic of the behavior of these constructors is to use the finished system for the entire range of tasks at the expense of the means of choosing exclusively the theme of the graphic design and adding or disconnecting those or other pages. This entails a number of shortcomings. First, the predominant use of PHP in addition, without differentiating the levels of architecture is not accompanied by the use of templates. The consequence is a huge layer of NOT readable and hard-edited code. Secondly, loading individually each component, which is often superfluous for this site, since it is built on a template designed for the entire functionality, negatively affects performance. Third, there is no system setup at different levels.

Another solution is the composite automation of the capabilities of individual modules through the use of frameworks built on one or another technology. The system is created by composing modules, and modules - by composing projects, and projects - by composing classes, etc. This approach differs by the complexity of the process of templating in the entire solution, in contrast to the template of the pattern and the module, which are quite simple tasks. And in many cases, it creates the need to manually edit the code. On the other hand, templating a solution based on a common template framework group generates new features for expanding functionality quickly through the use of formal methods.

The report considers other approaches to automating the creation of web-applications and concludes that they are partially compliant with the solution to the problem of generating the code of web-applications taking into account the possibility of managing the automation process at each level and the appropriate capability of selecting and integrating existing components based on formal user requirements and descriptions of these components.

For more detailed consideration of the architecture of web-applications, an appropriate alternative to their rapid creation is to template the process of their implementation at each level of the architecture using existing frameworks developed for this or that technology.

But there are several obvious aspects of solving this problem. The level of access to data is subject to templating based on the entities of the database as a separate component. Similarly, you can customize the creation of a REST API based on process descriptions. But the level of business logic requires a detailed description of the effective implementation of template-based capabilities, taking into account the architectural level of the frameworks and component descriptions, in order to ensure their choices, integration, and sufficient flexibility within the settings.

The automation of the rapid creation of web-applications in the case of this approach leaves programmers one of the key issues - combining the resulting fragments into a general application, requiring appropriate changes to the autogenerated product code.

Problem Statement

It is necessary to develop an approach to the creation of software systems, which provides: reducing the cost of writing template code, during the full development cycle from the process of formalizing requirements and ending with the testing process of this code; designing applications based on components of various implementation technologies; Expansion of the functionality by making minor changes to the components.

Conceptual foundations for creating web-applications based on templates

The key idea behind the development is to build a real model based on the basic notion of architecture, to model the application development process. Speaking of the concept of basic architecture we mean the model shown in Fig. 1.

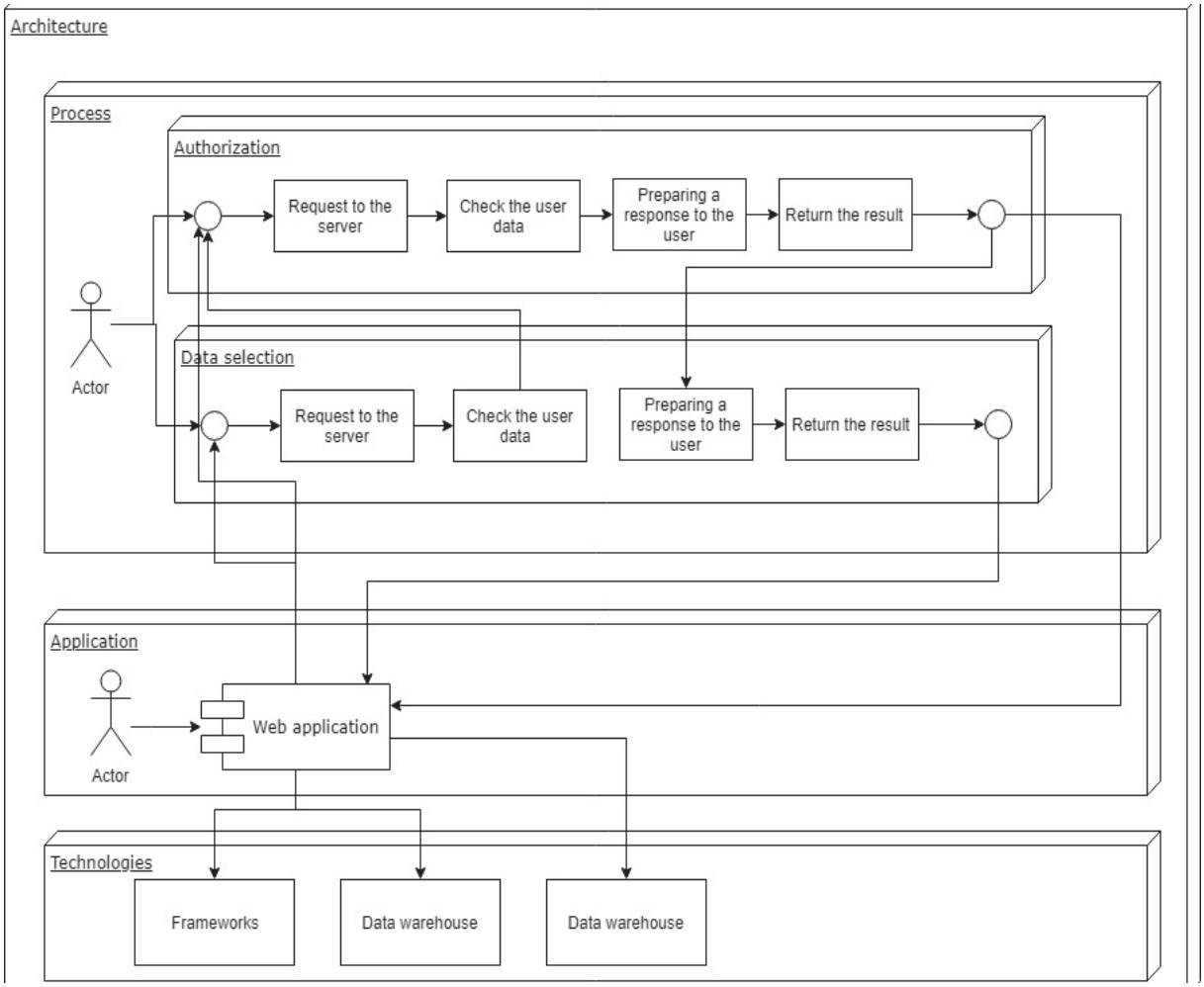

Fig. 1. Basic architecture of the system

A set of template processes can be implemented with one application at the expense of means of using the frameworks and specifications of one or another technology. The application is multilevel and consists of template modules. Each module is constructed of classes and interfaces that have their own structural units

and the corresponding appearance and methods depending on the tasks to be solved in accordance with the requirements of users.

The design of any system begins with the implementation of business processes and the structure of the data warehouse, which will meet the objectives. The user has to put the schema model for the database - to describe the entities and indicate their links.

After this stage, the system builds the basic functionality in the form of a data model of scripts for database generation at the level of data access, using scenarios for work with users and authorizations that the user can choose depending on the needs.

The next stage of the user's work is the generation of the data component directly, namely data selection, data preparation with a number of conditions by combining conditions using the proposed template or creating your own.

After this stage, you need to set the conditions and create a semantic description of the corresponding transformation and processing of data in accordance with the current business process.

The final stage is to generate the presentation with the appropriate selection and editing the most suitable template from the proposed.

The result is a ready-made application, generated on the basis of the composition of the generated modules of the system.

Mathematical model for constructing basic functionality

To select and integrate components in the complete solution, we will use the first-order causal logic, the structural elements of which are described by the authors for the integration of applications in the work [1].

Symbols:

service: (,), [,], {, }, :, <, >, ,;

constant:

1) *individual*, of primary types (int, real, char, bool) - a_1^1, a_2^1, …, a_1^2, a_2^2, ... where each constant a_i^k pertains to type (primary type) k; structural type (construct) - c_1, c_2, ...; procedural type (method) - d_1, d_2, ...; objective type (problem, entity, relation) — e_1, e_2, ...;

2) *functional i-place*, for individuals of type k - h_1^1, h_2^1, …, h_1^2, h_2^2, ...;

3) *predicate i-place*, for individuals of type k - A_1^1, A_2^1, …, A_1^2, A_2^2, ... (this class includes taxonomic, relational and other predicates, as well as traditional relations, at least equality = and order ≥);

variable: for individuals of type k - x_1^1, x_2^1, …, x_1^2, x_2^2, ..., where every variable x_i^k pertains to type k;

logical: $\neg, \wedge, \vee, \leftarrow, \exists, \forall, \Leftrightarrow$.

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Individual terms of type *k*:

1) each individual constant a_i^k of type *k* is an individual term of type *k*;

2) each free variable x_i^k for individuals of type *k* is an individual term of type *k*;

3) if h_i^j is a certain functional constant for individuals of type *k* and $\tau_1, \ldots, \tau_j$ are terms for individuals of type *k*, then h_i^j $(\tau_1, \ldots, \tau_j)$ is an individual term of type *k*;

4) there are no other individual terms of type *k*.

Formulas for individuals:

1) if A_i^j is a predicate constant for individuals and $\tau_1, \ldots, \tau_j$ are terms for them, then A_i^j $(\tau_1, \ldots, \tau_j)$ is the atomic formula for individuals;

2) the atomic formula for individuals is the formula for them;

3) there are no other formulas for individuals.

Hereinafter we consider only the systems of Horn clauses (with a single $\rightarrow$ symbol, atomic formulas to its left and right, and an implicit quantifier $\forall$).

Specifiers are constructions of type τ_1, where τ_1 is a term for an individual object. The construct specifiers are:

1) if $e_1^e \ldots e_i^e$ are individual terms of type entity, and $e_1^r \ldots e_i^r$ are individual terms of type relation, and $A_1^j(a_1^1 \ldots a_j^{\ 1}) \ldots\ A_i^j(a_1^k \ldots a_j^{\ k})$ are atomic formulas for the individuals of primary types, and τ is an individual term of type construct, then τ: $(e_1^e \ldots e_i^e, e_1^r \ldots e_i^r, A_1^j(a_1^1 \ldots a_j^{\ 1}) \ldots\ A_i^j(a_1^k \ldots a_j^{\ k}))$ is a construct specifier.

2) there are no other construct specifiers.

Preconditions:

1) if c_1 is a specifier of construct, and Π is a sequence of atomic formulas, then $<\tau_1:(c_1,\Pi)>$ is the elementary precondition;

2) elementary precondition - precondition;

3) if $<\tau_1>$ is a precondition, and τ_2 is an elementary precondition, then $<\tau_1,\tau_2>$ is the precondition;

4) there are no other preconditions.

Post-conditions:

1) if τ_1 is a construct specifier, and Π is a sequence of atomic formulas, then $<\tau_1:(c_1,\Pi)>$ is the elementary post-condition;

2) elementary post-condition - post-condition;

3) if $<\tau_1>$ is a post-condition, and a τ_2 is an elementary post-condition, then $<\tau_1,\tau_2>$ is the post-condition;

4) there are no other post-conditions.

Specifiers of methods:

1) if τ is an individual term of type method, and $<\tau_1>$ is a precondition, and $<\tau_2>$ is a post-condition, then τ: $(<\tau_1>, <\tau_2>)$ is a method specifier;

2) the arity by constructs of method precondition must not be lower than the arity by constructs of method post-condition;

3) there are no other method specifiers.

Specifiers of problems:

1) if $<\tau_1>$ is a precondition, and $<\tau_2>$ is a post-condition, and τ is a term for an individual object of type Problem, then τ: $<<\tau_1>,<\tau_2>>$ is the problem specifier;

2) there are no other problem specifiers.

Clause is an expression of type $\Pi \rightarrow \Lambda$, where Π is a sequence of atomic formulas; Λ is a single atomic formula.

The system’s knowledge base consists of the three main parts. In the first part, ontological axioms describe the methods and other components of the framework available for use. The second part provides an ontology of the system, described using OWL-based languages based on RDF. The third part summarizes the output rules needed to get the desired result for the user. There are rules for the output of two types. The first type output rules are used to integrate many methods and other components into a single application. They take into account the peculiarities of the problem, the preconditions, the stages, the descriptions of methods and other components of the system. Realized with the desired output proof in a certain way defines the architecture of the application that is being created within a defined class of architectures.

Inference rules of first type:

1. If d_1: $(<\tau_1>,<\tau_2>)$ and d_2: $(<\tau_3>,<\tau_1>)$ then d_1: $(<d_2>,<\tau_2>)$

2. If d_1: $(<\tau_1>,<\tau_2>)$ and d_2: $(<\tau_3 \wedge \tau_4>,<\tau_1>)$ then d_1: $(<d_2>,<\tau_2>)$

3. If d_1: $(<\tau_1 \wedge \tau_2>,<\tau_3>)$ and d_2: $(<\tau_4>,<\tau_1>)$ and d_3: $(<\tau_5>,<\tau_2>)$ then d_1: $(<d_2 \wedge d_3>,<\tau_3>)$

4. If d_1: $(<\tau_1>,<\tau_2>)$ and d_2: $(<\tau_3 \vee \tau_4>,<\tau_1>)$ then d_1: $(<d_2>,<\tau_2>)$

5. If d_1: $(<\tau_2 \wedge \tau_2>,<\tau_1>)$ then d_1: $(<\tau_2>,<\tau_1>)$

6. If d_1: $(<\tau_1,\tau_2>,<\tau_3>)$ and d_2: $(<\tau_4>,<\tau_1>)$ and d_3: $(<\tau_5>,<\tau_2>)$ then d_1: $(<d_2,d_3>,<\tau_2>)$

7. If d_1: $(<\tau_1>,<\tau_2,\tau_3>)$ and d_2: $(<\tau_2>,<\tau_4>)$ and d_3: $(<\tau_3>,<\tau_5>)$ then d_2: $(<d_1>,<\tau 4>)$ and d_3: $(<d_1>,<\tau_5>)$

The second type inference rules are used to speed up the inference process. They take into account the semantics of the user’s problem and the semantics of methods and other components of the system, expressed in terms of the system’s ontology. In essence, these rules are used to reduce the search for rules and axioms of the first part of the knowledge base of the system. They describe semantically acceptable at the level of input and output the variants of combining methods and other components of the system in more functionally complete combinations. These combinations can be used to deduce in the space of rules of the first type. The meaningful use of the second type inference rules can be illustrated by the process of 3D visualization of the combination of methods and other components of the system in spatial structures based on common entities on their inputs/outputs.

The semantically controlled inference mechanism

For the inference we will use the approach proposed by the authors in the paper [1]. It's about the procedures for inference and restoring the inference tree. But we will add to this approach the preliminary procedure for searching the spatial

structure of the associated by input/output methods and other components of the system, which at inputs has entities defined by the user as input information, and at its outputs we have the entities defined by the user as the source information. Define the necessary concepts.

Naturally, we focus on the means of knowledge representation and to reduce the search, we use the knowledge base, especially information on effective inference schemes for frequently performed queries and its ability to structure, factorize and abstract. This is a combined inference strategy, at the lower levels of which the birth of a lossy resolvents is blocked. Formally it is a question of combining the approach of R. Kowalski [3] and the analogue method of D. Playsted [4]. In this case, the proof in the abstract space, the result of which is then used to control the inference in the initial search space, is based exclusively on the axioms and inference rules of the knowledge base.

We cut off the hopeless branches of the inference in the initial space in two stages. At the first stage, we formulate the constructions of the associated by input/output methods and other components of the system. At the second stage, we use the inference in the abstract space. For the reflection of the transition to the abstract space, we will use taxonomic connections. Then the inference in the abstract space will be reduced to the inference in the system of types (classes of entities) with a gradual deepening of the system of subtypes up to individuals. As before, to reduce the search in both the abstract (for classes and types) and in the initial (for individuals) spaces, we will use modifications to the Robinson resolution strategy. The properties needed for the mutual adaptation of the method of analogy and modification of the resolution strategy the used reflection do naturally acquire in a responsibly structured knowledge base.

For the analogy method, we use the concept of a multiclause (m-clause) as a multiset of atomic formulas (atomic formula L will be recorded in m-clause as many times as it is repeated). The operations $\cup$ (unification), $\cap$ (intersection), — (difference), $\cdot$ (concatenation) and relation $\subseteq$ (occurrence) for multisets are naturally performed (note that the operations are performed for the left and right parts of the clause separately).

Suppose $A_1 \in C_1$, $A_2 \in C_2$ and α_1, α_2 are substitutions, which allow us to obtain the most common unifier for atomic formulas A_1 and A_2. Then the clause obtained from unification of clauses $C_1\alpha_1$ and $C_2\alpha_2$ by removing L to the left and right of symbol $\rightarrow$ is called m-resolvent of m-clauses C_1 and C_2. If the m-clauses C_1 and C_2 are ordered and m-resolvent is obtained by eliminating the non-underlined atomic formula in both parts, and on the left after it there is no other atomic formula, then we get the ordered linear m-resolvent. If the last atomic formula to the left of the symbol $\rightarrow$ of the ordered m-clause is unified with the underlined atomic formula to the right of the symbol $\rightarrow$ of the same m-clause the ordered linear m-resolvent is obtained by the m-clause reduction.

Definitions of *m*-clauses and *m*-resolvents are used to define the ordered linear *m*-resolutional proof. Let's start with the definition of the *m*-resolutional proof T_m as a pair of $<V,T_h>$, where V is the set of proof vertices, T_h is the set of vertices triples. In the future, the first and second components of T_m will be allocated using the *s*-

$N(T_m)$ and $s\text{-}M(T_m)$ selector functions respectively. Each vertex $n \in s\text{-}N(T_m)$ of the proof T_m is characterized by the mark $s\text{-}L(n)$ and the depth $s\text{-}D(n)$. If $<n_1, n_2, n_3> \in s\text{-}M(T_m)$, then $s\text{-}L(n_3)$ is the *m*-resolvent $s\text{-}L(n_1)$ and $s\text{-}L(n_2)$, and each triple of this type is called *m*-resolution. In the proof T_m, the vertex $n \in s\text{-}N(T_m)$ is called the initial if it is not the third component of any of the triples of $s\text{-}M(T_m)$ (its mark is the initial *m*-clause), or terminal if it is not neither the first nor the second component of any of the triples of $s\text{-}M(T_m)$ (its mark is the terminal *m*-clause).

Now, let's call the *m*-resolutional proof T_m the proof from *S*, if the marks of the initial vertices Tm belong to the set of m-clause *S*. From *S* we deduce *C* if T_m is a proof from *S*, and *C* is a mark of one of the vertices of T_m.

Finally, the ordered linear *m*-resolutional proof from *S* is called *m*-resolutional proof Tm from *S*, all *m*-clauses of which are ordered and for an arbitrary triple $<n_1, n_2, n_3>$ from $s\text{-}M(T_m)$ $s\text{-}L(n_3)$ is an ordered linear *m*-resolvent $s\text{-}L(n_1)$ and $s\text{-}L(n_2)$.

To manage an ordered linear inference, we will use the typification abstraction proposed in [4]. Suppose *f* is such mapping from the set of *m*-clauses into the set of *m*-clauses that: 1) if *m*-clause C_3 is the *m*-resolvent of *m*-clauses C_1 and C_2, while $D_3 \in f(C_3)$, then exist such $D_1 \in f(C_1)$ and $D_2 \in f(C_2)$ that the result of the substitution of some *m*-resolvent D_1 and D_2 belongs to D_3; 2) $f(\varnothing) = \{\varnothing\}$; 3) if the result of some substitution of *m*-clause C_1 belongs to *m*-clause C_2, then for any abstraction D_2 for C_2 exists such abstraction D_1 for C_1 that the result of D_1 substitution belongs to D_2. Such mapping is called *f m*-abstraction mapping, while any *D* from *f*(*C*) is called *m*-abstraction. The typification mapping is understood as a certain mapping ϕ from a set of literals into a set of literals, which reflects each atomic formula into the formula whose terms have the type closest to the basic types in the hierarchy.

Construction of the proof begins with the formulation of the problem by the user. In essence, the possibility of executing the request is checked, taking into account all available resources. Having access to the descriptions of all modules and other components and axioms that determine the possibilities of their application, the inference mechanism combines the modules and other components into a structure (proof), which ensures the receipt of the result from the input data.

Let the ordered linear *m*-resolutional proof be obtained by definition as a pair of sets: vertices $V = \{k_1, k_2, k_3 .. k_n\}$ and vertices triple $Th = \{<k_1, k_2, k_3>, <k_3, k_4, k_5> ... <k_{n-2}, k_{n-1}, k_n>\}$, where k_i, $i = 1,\ldots,n$ are the vertices of proof, k_n is the terminal vertex. The proof is formed, taking on the initial vertices of the problem postcondition and, as a lateral vertex, the appropriate axiom from the knowledge base. The axiom is appropriate if the sequence of atomic formulas corresponding to this vertex of the proof, or any part of it, is an axiom postcondition. The third vertex of this triple is obtained by applying the axiom to the formula postcondition, taking into account the inference rules. The third vertex of the first triple becomes the first vertex of the second triple, and the process repeats until the terminal vertex is reached - the problem precondition. If the atomic formula corresponding to the third vertex of the

triple can be simplified by applying one of the inference rules, it is simplified in the next triangle, which will have only two vertices - a vertex with a formula, which must be simplified, and a vertex with a simplified formula.

The search for the corresponding axioms is done by comparing the construct of the postcondition, which is being processed at the moment, with the axioms constructs from the ontology. Thus, from the ontology a set of axioms is chosen that describe the methods that process the type and format of the objects we need.

If in the knowledge base for the next vertex the corresponding axioms are several, then each of these axioms is used to further build its own "parallel" version of the proof. Thus, during the operation of the inference mechanism, a number of proofs of varying length and complexity can be formed. Upon completion of the inference mechanism work, the proof from the set of proofs is selected with the smallest number of triples of vertices and the smallest number of applied axioms.

To shorten the search, we can pre-select the structures of related methods and other components, the entities of which inputs and outputs are common. And only in the second stage, when the structures are already selected, the preconditions and postconditions are checked and the architecture of the solution is determined.

A set of formulas and a clause that corresponds to the vertices of the proof triples and reflects the application of the axiom of the first part and the inference rules of the first type is the output of the inference mechanism. To restore the structure, we use the proof tree recovery algorithm proposed by the authors in the paper [1].

Then, using the constructor, we are generating by the finished elements the user representation, to which, in the form of a data source, the output points of the business logic of the application are tied.

Implementation of the technology

The technology is realized using modern tools. The user-friendly web-interface allows the end-user to build a database model based on which the base framework of the application is generated (CRUD data operations with the subsequent generation of the interface as a REST API). The next step is to display this general view of the application with the ability to generate by means of a semantic assignment of relationships between the relevant models of one or another application logic behavior and implementation of the business processes of the required application.

Ready templates are integrated into the application with pointing inputs and outputs. Additional functionality is the ability to create and store by user own templates as well as the ability to put them in the public domain. Formally, the template integration can take place at different levels of architecture, ranging from method integration to integration of entire component that consists of classes.

The applications are a composition of modules, which, in turn, are a composition of classes, which, in turn, are a composition of methods, etc. Defining by the user of input and output entities and their characteristics allows you to find the necessary methods and their interconnections and get the template model of the lowest architectural level, presented in the form of classes.

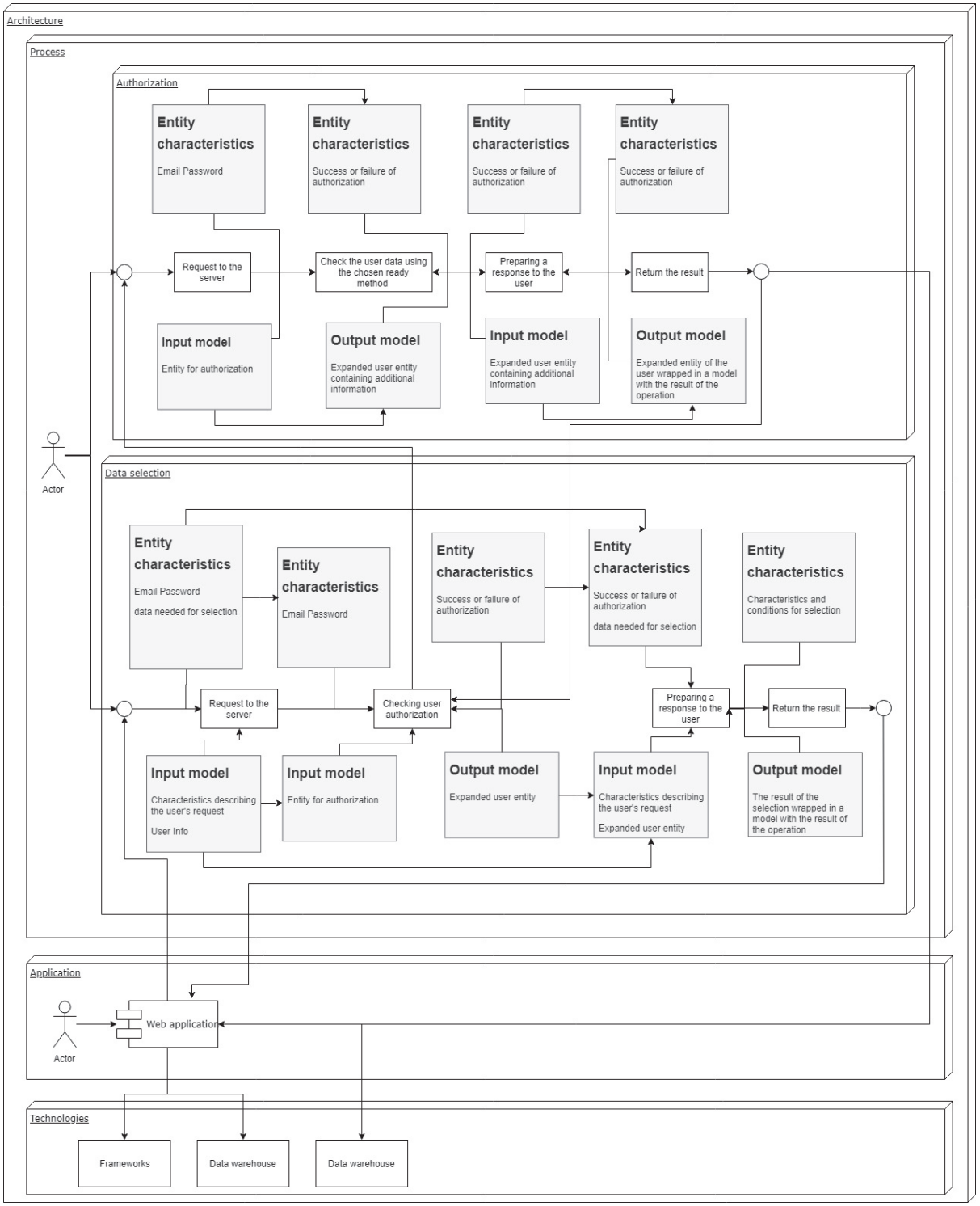

Fig. 2. Composition of business processes elements

At the highest level, the composition model is maintained, but the corresponding classes are already merged through the calls of other methods and the generation of behavior classes, which is the source of the module. Accordingly, the combination of modules follows from the composition of their outgoing points and the established in Fig. 2 connections.

In Fig. 2, the architecture of the system, the semantic model and patterns of the two connected business processes associated with the authorization of users are shown.

Conclusion

In this paper, the problem of the rapid creation of effective web-applications of one class is considered. The performed analysis of the problem and existing decisions confirmed the relevance of the problem and allowed formulate it, identify the key aspects of the study.

The complex approach to the solution of the problem, based on autogenous template solutions for information systems with the possibility of integration into the process of components at different architectural levels, is proposed. The main advantages of the proposed solution are the formal basis for creating applications, which is based on templating the design and implementation processes and the ability to fine-tune the process. In addition, the adopted model for constructing template solutions simplifies the work of developers and helps automate the basic process of developing web-applications for a wide range of business information systems with web-representation.

Analysis of the problem and the existing solutions enabled the choice of appropriate formal means. The mathematical apparatus for the proposed solution includes means of semantic description of business processes and a formal logical system. The first provides a description of business processes and enables them to decompose subprocesses from the highest level of architecture to non-decomposable atomic components, indicating the input and output entity, and the characteristics at which the choice of the corresponding functional unit is made - a template for the processing of the subprocess, or creation own template by choosing the proposed methods. A formal logic system facilitates the selection and integration of components in a complete solution.

Further researches are connected with 3D-visualization of the processes of creating web-applications on the basis of the proposed theoretical model for building a comprehensive solution based on the template of the process of creating an information system with a web-representation.

References

1. S. Telenyk, G. Nowakowski, K. Yefremov and V. Khmeliuk Logics based application integration for interdisciplinary scientific investigations / 2017 9th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), Bucharest, 2017, pp. 1026-1031.

2. A. Y. Levy Logic-based techniques in data integration / Logic-based artificial intelligence. Springer, Boston, MA, 2000, pp. 575-595.

3. R. Kowalski Computational logic and human thinking: how to be artificially intelligent / Cambridge University Press, 2011.

4. Plaisted, David A. History and prospects for first-order automated deduction / International Conference on Automated Deduction. Springer, Cham, 2015.

Зміст

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Дослідження спотворень сигналів при інтерполяції у SDR передавачах з модуляцією QPSK / Ю.М. Бойко, І.С. П’ятін, О.І. Єрьоменко, І.Р.Пархомей // Міжвідомчий науково-технічний збірник «Адаптивні системи автоматичного управління». -2019.- № 1 (34).-С. 5-15

Технологія програмно-керованого радіо (SDR) дозволяє за допомогою програмного забезпечення встановлювати або змінювати робочі радіочастотні параметри: стандарт зв’язку, діапазон частот, тип модуляції, вихідну потужність, тощо. Складовою частиною передавача є інтерполятор, який підвищує частоту дискретизації модульованого сигналу. Інтерполятори будують на основі інтегральних Cascaded Integral-Comb (CIC) фільтрів, що не містять помножувачів. Фільтри CIC-Interpolation мають нерівномірну АЧХ, тому для її вирівнювання запропоновано фільтр CIC-Compensator. У статті досліджені око-діаграми сигналів з різними коефіцієнтами інтерполяції. За око-діаграмою проведено оцінювання якісті сигналу у передавачі. Інтерполяція супроводжується ефектом підсилення сигналу, зменшенням часу наростання імпульсу, зменшенням коефіцієнту якості сигналу. Джиттер у передавачі зменшується, якщо коефіцієнт інтерполяції кратний частоті дискретизації інформаційної послідовності символів. Якщо коефіцієнт якості сигналу Q>7, то коефіцієнт бітових помилок має припустиме для практики значення BER<10-9.

Ключові слова: інтерполяція, модуляція, обробка сигналів, джитер.

Бібл. 11, іл. 16

УДК 004.042

Застосування джерел подій і шаблонів CQRS в розподілених системах / Дьяков С. О., Зубрей Т. Є., Самойдюк А. С. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 16-22

Ця робота демонструє проблеми архітектури сучасних високонавантажених розподілених систем і пропонує рішення для них. Мета полягає в пошуку відповідних підходів для вирішення проблеми, зокрема, здатності відтворювати стан системи. Для досягнення поставленої мети у статті будуть розглянуті причини існуючих проблем, проведено їх порівняння з запропонованими архітектурними рішеннями, підкреслено його переваги та недоліки. Розглянутий спосіб розробки додатків заснований на двох поняттях: розділення відповідальності на команди та запити (CQRS) та джерело подій. Їх поєднання пропонується для вирішення проблем пов'язаних з продуктивністю та проектуванням, які часто виникають при розробці традиційних інформаційних систем.

Ключові слова: CRUD, CQRS, event sourcing, архітектура програмного забезпечення, шаблони проектування, моделювання даних.

Бібл. 10, іл. 4, табл. 1

УДК 004.056.55

Захист електронного документа за допомогою консолідованого підходу до застосування електронного цифрового підпису / Корнага Я.І., Гарматін В.Д., Гришко А.С., Максимюк А.В., Гасанов В.А. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». -2019.- № 1 (34).-С. 23-31

Сучасні інформаційні системи дозволяють організаціям підвищувати свою ефективність, значно знижувати свої витрати і відповідати нормативним вимогам. Хороша система управління документами часто розглядається як все, що потрібно, але додаткові заходи захисту також необхідні для забезпечення захисту даних від несанкціонованого доступу і підробки.

Метою даної статті є модифікація алгоритмів криптографічних методів захисту цілісності документа з використанням електронного цифрового підпису.

Системи управління документами зазвичай забезпечують безпеку і контроль доступу до документів в контрольованому середовищі. Однак, коли документ залишає безпечне середовище, його легко змінити. Незахищені документи не дозволяють визначити, чи є документ справжнім, хто був його творцем і стверджують або чи був він змінений з моменту його створення.

Проблема запобігання копіювання, зміни і підробки електронних документів вимагає спеціальних підходів і методів захисту для її вирішення. Одним з найбільш поширених методів такого захисту в світі є електронний цифровий підпис (ЕЦП), яка підтверджує справжність, цілісність документа і факт підписання конкретною особою документа за допомогою спеціального програмного забезпечення.

Загальні методи шифрування засновані на факторизации великих чисел (RSA, DSA, ElGamal) і дискретної логаріфмізації (ECDSA, EdDSA, ГОСТ Р 34.10-2012).

Кожна пара ключів складається з закритого ключа і відкритого ключа. Вони взаємозалежні, але можуть використовуватися окремо. Зазвичай кожна пара ключів може належати конкретному власнику ключів. Алгоритм працює таким чином, що треті сторони не можуть обчислити закритий ключ, навіть якщо вони володіють відкритим ключем.

Ключові слова: мережева інфраструктура, документ, електронний документ, електронний цифровий підпис, аутентифікація, верифікація, EdDSA, SHA-512, Argon2.

Бібл. 13, іл. 6, табл. 3

УДК 331.45

Оцінка ефективності заходів зі зниження рівня виробничого травматизму та професійної захворюваності на підприємстві / Кружилко О.Є., Майстренко В.В., Сторож Я.Б., Лях Ю.М// Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 32-36

Об’єктом дослідження є система управління охороною праці підприємства. У статті зроблено огляд існуючих принципів запобігання та покращенню умов праці в системах управління охороною праці. Основні недоліки - відсутність відповідної методики оцінки ступеня ризику та професійна і психологічну непідготованість фахівців у цій сфері.

Метою роботи є розробка методичних підходів до оцінки ефективності заходів зі зниження рівня виробничого травматизму та професійної захворюваності на підприємстві як важливої складової сучасної системи управління охороною праці. Для досягнення мети у статті проаналізовано основні причини виробничого травматизму та професійної захворюваності та запропоновано методичний підхід, який дозволяє оцінювати ефективність плану заходів підвищення безпеки виробництва з урахуванням причинно-наслідкових зв’язків між реалізацією заходів та економічними показниками діяльності підприємства. Побудована математична модель прогнозу показників виробничого травматизму та професійної захворюваності.

Ключові слова: виробничий травматизм, професійні захворювання, гігієна праці, шкідливі та небезпечні умови праці, прогнозна модель.

Бібл. 7.

УДК 331.452

Удосконалення оперативного управління гігієною та безпекою праці на основі оцінки виробничого ризику / Кружилко О.Є., Ткалич І.М., Полукаров О.І. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 37-41

Об’єктом дослідження є методи управління охороною праці на підприємствах. Схвалення Кабінетом Міністрів України «Концепції реформування системи управління охороною праці в Україні» зумовлює необхідність побудови системи управління гігієною та безпекою праці на основі ризикоорієнтованого підходу. Побудова вказаної системи потребує проведення теоретичних та експериментальних досліджень, призначених для формування методичного забезпечення процесів ідентифікації існуючих на виробництві небезпек та оцінки виробничих ризиків.

Метою роботи є обґрунтування для практичного використання підходу до оцінювання ризику настання нещасного випадку на підприємстві. Для досягнення мети проаналізовано існуючі методи та підходи до оцінювання виробничих ризиків та запропоновано підхід до оцінки виробничого ризику, який базується на використанні статистичних даних про показники виробничого травматизму з урахуванням галузевої приналежності підприємств.

Ключові слова: гігієна та безпека праці, виробничий ризик, оперативне управління, планування, інформаційна система.

Бібл. 6, іл. 1.

УДК 004.89:65.011.56

Гібридний підхід до прогнозування часового ряду електроспоживання для організаційного управління на оптовому ринку / Остапченко К.Б., Лісовиченко О. І., Борукаєв З.Х. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 42-52

Розглядається проблема підвищення ефективності вирішення комплексу задач прогнозування і планування електроспоживання регіональними компаніями постачальників електроенергії - суб'єктами системи організаційного управління оптовим ринком електроенергії. Проведено аналіз використання різних методів моделювання при вирішенні завдання вибору і побудови моделі прогнозування електроспоживання, формулюється завдання побудови гібридної прогностичної моделі, позбавленої недоліків окремих методів моделювання. Перевага надається підходу, пов'язаного з комплексним використанням математичних засобів на базі апаратів штучних нейронних сіток, генетичного алгоритму і фільтра Калмана для побудови узагальнених нелінійних багатофакторних моделей. Він дозволить підвищити ефективність процесу побудови моделей і їх подальшого використання для пошуку, як короткострокових, так і довгострокових прогнозів. Для виключення впливу випадкових складових часового ряду з нерівномірним розподілом значень показника електроспоживання на процес навчання нейронної сітки як нелінійної моделі прогнозування пропонується попередня її підготовка за допомогою застосування фільтра Калмана. Надалі здійснюється оптимізація топології нейронної сітки на базі генетичного алгоритму, який дозволяє на етапі мутації адаптивно вибирати тип перетворення структури, найбільш підходящий для заданої конфігурації сітки.

Ключові слова: гібридний підхід, прогнозування часового ряду, процеси електроспоживання, організаційне управління, оптовий ринок електроенергії.

Бібл. 24, іл. 3

УДК 004.652

Обробка інформації оптичним датчиком робота за умови неповної вхідної інформації / Пархомей І.Р., Батрак Є.О., Цьопа Н.В.,Зєнів І.О.// Міжвідомчий науково технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 53-64

Область задач, що вирішуються за допомогою властивостей класифікації та узагальнення досить широка. Однак якість вирішення задач по тим або інших причинах не завжди буває однаковою. Наприклад, якщо буде поставлена задача за допомогою візуальних спостережень розділити на два класи однакові за геометричними розмірами і за кольором предмети. Причому частина виготовлена зі сталі, а частина - з гіпсу. Для класифікації таких предметів достатньо отримати дані про вагу предметів, щоб задача класифікації перетворилася в тривіальну.

Складність в даному випадку полягає у відшуканні такого опису явищ, при якому зображення (явища) у середині кожного класу мали би визначені подібні властивості. Тому для усунення впливу завад на процес розпізнавання пропонується ввести спеціальне вирішальне правило, яке засновано на тому, що рішення про належність зображення до образу виноситься на основі аналізу зображень, що потрапили в певний близький простір, який класифікується.

За допомогою цього методу знаходять рішення, які майже нечуттєві до похибок, які виникають внаслідок впливу завад. Тому при збільшенні множини зображень це правило переходить у правило Байєса.

Ключові слова: автокореляційна функція, інваріантність, коефіцієнт подібності, розпізнавання, опис зображень, межі зображення, обробка сигналів.

Бібл. 20, іл. 3.

УДК 004.042

Алгоритм визначення електромагнітної сумісності для рішення задач частотного планування / І.Р. Пархомей, В.В. Недолужко // Міжвідомчий науково технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 65-72

Об’єкт дослідження – процес визначення електромагнітної обстановки для вирішення задач частотного планування радіоелектронних засобів рухомої служби. Предмет дослідження – дослідження та розрахунок ЕМС РЕЗ в районі планування. Мета роботи – дослідження ефективності використання та визначення напрямків удосконалення розрахуноку ЕМС РЕЗ в районі планування.

Методика припускає проведення аналізу ЕМС РЕЗ у районі планування, а у випадку використання загальної площадки для розміщення РЕЗ - ЕМС локального угруповання РЕЗ (об’єктова ЕМС).

У роботі викладено причини виникнення взаємних завад при роботі радіоелектронних засобів в ускладненій радіоелектронній обстановці, розглянуто сучасний науково-методичний апарат радіомоніторингу з визначенням в цьому місці електромагнітної обстановки для вирішення частотного планування РЕЗ .

У роботі проведено аналіз причин виникнення взаємних завад при роботі радіоелектронних засобів в ускладненій радіоелектронній обстановці, розглянуто сучасний науково-методичний апарат радіомоніторингу з визначенням в ньому електромагнітної обстановки для вирішення задач частотного планування РЕЗ рухомої служби.

Ключові слова: джерело радіовипромінення, електромагнітна обстановка, електромагнітна сумісність, пункт технічного радіоконтролю, радіовипромінюючий пристрій, радіорегламент, радіотехнології, радіочастотний ресурс.

УДК 378.147:159.95:519.816

Дослідження характеру зв’язку мотивації слухачів онлайн-курсів із успішним завершенням навчання / Пархоменко А.В., Сегол Р.І., Лісовиченко О.І. // Міжвідомчий науково технічний журнал «Адаптивні системи автоматичного управління». 2019. № 1 (34). С. 73-80

Розвиток онлайн-освіти стає рушійною силою змін у світових освітніх тенденціях. Запропонована стаття містить аналіз результатів навчання на масових відкритих онлайн-курсах «Навчаймось вчитись» та «Освітні інструменти критичного мислення» для визначення мотиваційних потреб учнів. Курс «Навчаймось вчитись» адаптований українською мовою, а «Освітні інструменти критичного мислення» створений українським автором. Курси було розміщено на платформі Prometheus у 2018 році, вони створені для різних цільових аудиторій і містять різні мотиваційні компоненти для студентів. Метою статті є розв’язання таких завдань: аналіз та дослідження результатів тестування на курсах «Навчаймось вчитись» та «Освітні інструменти критичного мислення» для мотивації учнів та подальшої розробки нових мотиваційних методик для студентів онлайн-курсу. Враховуючи наведені дані, можна зробити висновок, що головним мотивом для студентів аналізованих курсів було освоєння нових знань або поглиблення наявних для отримання нових посад, поліпшення фінансового стану або зміни професії з тією ж метою. Отже, матеріальна мотивація відіграє провідну роль. У висновках запропоновано мотиваційні методи підвищення якості навчального процесу та поліпшення співвідношення між засвоєнням теоретичного матеріалу та проходженням практичних вправ.

Ключові слова: кореляція, масовий відкритий онлайн-курс, мотиваційна техніка, мотиваційні потреби, результат навчання. Бібл. 17, іл. 5.

УДК 519.854.2

Оптимізація для одного класу комбінаторних задач в умовах невизначеності / Павлов О.А. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2019. – №1 (34) С. 81-89

Для досить загального класу задач комбінаторної оптимізації, функціонал яких містить лінійну згортку ваг і довільних числових характеристик допустимого розв’язку, формалізуються поняття невизначеності, компромісного розв’язку, компромісні критерії та умови. Наводяться алгоритми знаходження компромісних розв’язків як оригінальна реалізація відомої ідеї лінійної згортки критеріїв. Ефективність запропонованих алгоритмів однозначно визначається ефективністю розв’язання задачі комбінаторної оптимізації в детермінованій постановці. Показано, що отримані раніше ефективні ПДС-алгоритми для NP-трудних задач комбінаторної оптимізації – мінімізація сумарного зваженого запізнення виконання завдань одним приладом, мінімізація сумарного зваженого моменту закінчення виконання взаємозв’язаних завдань (довільний ациклічний орієнтований граф) одним приладом – дозволяють ефективно розв’язувати ці задачі в умовах невизначеності.

Ключові слова: Комбінаторна оптимізація, невизначеність, ймовірність, ефективний алгоритм, розв’язання невизначеності, ПДС-алгоритм, NP-трудні задачі.

Библ. 7

УДК 621.865.8(031)

Концепція синтезу крокуючих роботів довільної орієнтації / Михайло Поліщук // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2019. – №1 (34) – С. 90-102

Роботи довільної орієнтації (Climber Robot) – нова модифікація мобільних роботів. Ці роботи постачені засобами втримання робота на поверхні довільної орієнтації щодо обрію технологічного простору. Створення цього виду робототехніки перебуває на початковій стадії й продиктоване необхідністю виконання технологічних операцій моніторингу промислових об'єктів, монтажу й демонтажу будівельних конструкцій, ремонту й профілактичному обслуговуванню їх компонентів. У статті запропоновано три основні принципи синтезу крокуючих мобільних роботів: нагромадження й перетворення енергії, інтеграція приводів руху й використання генератора реактивної пневматичної тяги. Реалізація цих принципів допомагає знизити загальну потужність приводів і підвищити надійність утримання роботів на поверхні довільної орієнтації в технологічному просторі. Представлені результати математичного моделювання конструктивних і технологічних параметрів мобільних роботів.

Ключові слова: мобільні роботи, крокуючі механізми, роботи вертикального переміщення, альпіністські роботи

УДК 519.8

Математична модель виробництва електроенергії енергоблоками АЕС для вирішення завдань розвитку електроенергетики України / С.Є. Саух, А.В. Борисенко // Міжвідомчий науково технічний журнал «Адаптивні системи автоматичного управління». 2019. № 2 (35). С.

Об'єкт дослідження - виробничі процеси, що реалізуються на АЕС ДП «НАЕК« Енергоатом ». Предмет дослідження - планово-попереджувальні ремонти обладнання енергоблоків АЕС. Мета роботи - розробка математичної моделі виробничих процесів, що реалізуються на АЕС ДП «НАЕК« Енергоатом », придатної для прогнозування помісячного динаміки обсягів вироблення електроенергії енергоблоками АЕС в різних сценарних умовах розвитку атомної енергетики країни.

Модель розроблена на основі комплексного аналізу наявних даних про встановлені потужності енергоблоків, обсягах вироблення ними електроенергії, періодичності та тривалості раніше виконаних капітальних і середніх ремонтів основного устаткування АЕС.

У моделі адекватно відтворені загальні характеристики планово-попереджувальних ремонтів обладнання енергоблоків і їх вплив на помісячні обсяги вироблення електроенергії кожної АЕС в середньо- і довгостроковій перспективі.

Математична модель орієнтована на використання в складі систем моделювання електроенергетики України та забезпечує можливість обліку в таких системах різних стратегій розвитку компанії ДП «НАЕК «Енергоатом», зокрема, введення в експлуатацію нових енергоблоків з регламентованими характеристиками періодичності і тривалості виконання планово-попереджувальних ремонтів.

Ключові слова: система, модель, АЕС, довгострокове прогнозування.

УДК 681.5

Концепція управління конструкторською підготовкою виробництва електронних апаратів / Смолій В.М. // Адаптивні системи автоматичного управління. - 2019.- №1 (34) – С. 113-124

В результаті проведених досліджень розроблена нова концепція управління конструкторською підготовкою виробництва електронних апаратів, що спирається на єдиний інформаційний простір компонування електронного апарату, оперативного управління конструкторською підготовкою виробництва і системи управління ресурсами підприємства, що дозволяє підвищити ефективність управління конструкторською підготовкою виробництва електронних апаратів.

Бібл. 22, іл. - 2., табл. 0

УДК 004.042

Нейросемантичний підхід до побудови автоматизованих інформаційно-пошукових систем / Стенін О.А., Пасько В.П., Лемешко В.А. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». -2019.- №1 (34) – С. 125-129

В даний час однією з актуальних проблем при формуванні максимально інформативних моделей знань даної предметної області є створення ефективних інформаційно-пошукових систем, в першу чергу, в Інтернеті, як найбільшому сховищі інформації. Для вилучення потрібної для даної предметної області інформації з Інтернет потрібна обробка величезної кількості різнорідних документів. Це досить складне завдання, яке вимагає не тільки автоматизації процесу пошуку інформації, але і забезпечення її смислового змісту відповідно до поточної ситуації в даній галузі. Для автоматизації процесу пошуку і визначення максимально інформативного контенту моделі знань даної предметної області запропонована мультиагентна інтелектуальна система пошуку і відбирання інформації, побудована на основі нейронних мереж. У системі реалізується нейросемантичний підхід до смислової адаптації пошукової інформації до зміни поточної ситуації в даній галузі і відповідної їй еволюції моделі знань на основі генетичного алгоритму.

*Ключові слова***:** інтелектуальна мультиагентна система, нейронна мережа, генетичний алгоритм, модель знань, предметна область

УДК 681.5

Оптимальне управління автономним роботизованим підводним апаратом на основі прогнозуючих моделей / Стенін О.А., Пасько В.П., Тимошин Ю.А., Ігнатенко В.М., Стенін О.С. // Адаптивні системи автоматичного управління. – 2018. – №1 (34) - С. 130-137

Розглядаються методи оптимального управління з використанням прогнозуючої моделі,зокрема, найбільш відомий і широко розповсюджений підхід MPC (Model Predictive Control). Запропоновано структурно-функціональна схема реалізації автоматичної оптимальної стабілізації заданої траєкторії руху автономного роботизованого підводного апарату на основі оригінальних методів параметричної ідентифікації прогнозуючої моделі і модального синтезу оптимальних регуляторів на окремих горизонтах прогнозу.

Ключові слова: оптимальне управління, прогнозуюча модель, параметрична ідентифікація, горизонт прогнозування, модальний синтез.

Бібл.14,илл..3

УДК 004

Інформаційна технологія для розробки та впровадження web-застосунків / Теленик С., Новаковський Г., Жаріков Е., Вовк Є. // Міжвідомчий науково-технічний журнал «Адаптивні системи автоматичного управління». 2018.- № 1 (34) С. 138-151

Розглянуто проблему швидкого створення ефективних веб-застосунків одного класу з використанням формальних засобів. Запропоновано концептуальний підхід до її розв'язання на основі аналізу особливостей побудови веб-застосунків. Підхід базується на визначенні стандартної архітектури веб-застосунків і виборі його компонентів за допомогою формальних методів відповідно до вимог користувача. З цією метою використовується формальна логічна система, яка використовує розробку веб-застосунків як процес виведення формули, заданої відповідно до потреб користувача, що визначає схеми виконання модулів системи. Важливою особливістю підходу є можливість

3D-візуалізації процесу проектування системи, що створює умови для ефективної взаємодії між розробниками та інструментальними засобами розробки.

Ключові слова: веб-застосунки; розробка застосунків; бізнес-процеси; математична логіка. Бібл. 4, іл. 2.

УДК 621.396.96

Исследование искажений сигналов при интерполяции в SDR передатчиках с модуляцией QPSK / Ю.Н. Бойко, И. С. Пятин, А.И. Еременко, И.Р.Пархомей // Межведомственный научно-технический сборник «Адаптивные системы автоматического управления». -2019.- № 1 (34).-С. 5-15

Технология программно-управляемого радио (SDR) позволяет с помощью программного обеспечения устанавливать или изменять рабочие радиочастотные параметры стандарта связи, диапазон частот, тип модуляции, выходную мощность и тому подобное. Составной частью передатчика является интерполятор, который повышает частоту дискретизации модулированного сигнала. Интерполятор строят на основе интегральных Cascaded Integral-Comb (CIC) фильтров, не содержащих умножителей. Фильтры CIC-Interpolation имеют неравномерную АЧХ, поэтому для ее выравнивания предложено фильтр CIC-Compensator. В статье исследованы глазковые диаграммы сигналов с различными коэффициентами интерполяции. По глазковым диаграммам проведена оценка качества сигнала в передатчике. Интерполяция сопровождается эффектом усиления сигнала, уменьшением времени нарастания импульса, уменьшением коэффициента качества сигнала. Джиттер в передатчике уменьшается, если коэффициент интерполяции кратный частоте дискретизации информационной последовательности символов. Если коэффициент качества сигнала $Q > 7$, то коэффициент битовых ошибок имеет допустимое для практики значение $BER < 10^{-9}$.

Ключевые слова: интерполяция, модуляция, обработка сигналов, джиттер.

Библ. 11, ил. 16

УДК 004.042

Применение источников событий и шаблонов CQRS в распределенных системах / Дьяков С. А., Зубрей Т. Е., Самойдюк А. С. // Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 16-22

В этой работе раскрыты проблемы архитектуры современных распределенных систем с высокой нагрузкой и предложены решения для них. Цель состоит в поиске подходов для решения проблемы, в частности, возможности воссоздать состояние системы. Для достижения цели в статье будут рассмотрены причины существующих проблем, проведено сравнение с предлагаемыми архитектурными решениями, подчеркнуты его преимущества и недостатки. Рассмотренный способ разработки приложений опирается на две концепции: разделение ответственности на команды и запросы (CQRS) и источник событий. Их сочетание предлагается для решения проблем производительности и проектирования, которые часто возникают при разработке традиционных информационных систем.

Ключевые слова: CRUD, CQRS, event sourcing, архитектура программного обеспечения, шаблоны проектирования, моделирование данных.

Библ. 10, ил. 4, табл. 1

УДК 004.056.55

Защита электронного документа с помощью консолидированного подхода к применению электронной цифровой подписи / Корнага Я.І., Гарматин В.Д., Гришко А.С., Максимюк А.В., Гасанов А.В. // Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». -2019.- № 1 (34).-С. 23-31

Современные информационные системы позволяют организациям повышать свою эффективность, значительно снижать свои расходы и соответствовать нормативным требованиям. Хорошая система управления документами часто рассматривается как все, что требуется, но дополнительные меры защиты также необходимы для обеспечения защиты данных от несанкционированного доступа и подделки.

Целью данной статьи является модификация алгоритмов криптографических методов защиты целостности документа с использованием электронной цифровой подписи.

Системы управления документами обычно обеспечивают безопасность и контроль доступа к документам в контролируемой среде. Однако, когда документ покидает безопасную среду, его легко изменить. Незащищенные документы не позволяют определить, является ли документ подлинным, кто был его создателем и утверждающим или был ли он изменен с момента его создания.

Проблема предотвращения копирования, изменения и подделки электронных документов требует специальных подходов и методов защиты для ее решения. Одним из наиболее распространенных методов такой защиты в мире является электронная цифровая подпись (ЭЦП), которая подтверждает подлинность, целостность документа и факт подписания конкретным лицом документа с помощью специального программного обеспечения.

Общие методы шифрования основаны на факторизации больших чисел (RSA, DSA, ElGamal) и дискретной логарифмизации (ECDSA, EdDSA, ГОСТ Р 34.10–2012).

Каждая пара ключей состоит из закрытого ключа и открытого ключа. Они взаимозависимы, но могут использоваться отдельно. Обычно каждая пара ключей может принадлежать конкретному держателю ключей. Алгоритм работает таким образом, что третьи стороны не могут вычислить закрытый ключ, даже если они владеют открытым ключом.

Ключевые слова: сетевая инфраструктура, документ, электронный документ, электронная цифровая подпись, аутентификация, верификация, EdDSA, SHA-512, Argon2.

Библ. 13, ил. 6, табл 3

УДК 331.45

Оценка эффективности мероприятий по снижению уровня производственного травматизма и профессиональной заболеваемости на предприятии / Кружилко О.Е., Майстренко В.В., Сторож Я.Б., Лях Ю.М// Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 32-36

Объектом исследования является система управления охраной труда предприятия. В статье сделан обзор существующих принципов предотвращения и улучшению условий труда в системах управления охраной труда. Основные недостатки - отсутствие соответствующей методики оценки степени риска и профессиональная и психологическая неподготовленность специалистов в этой сфере.

Целью работы является разработка методических подходов к оценке эффективности мероприятий по снижению уровня производственного травматизма и профессиональной заболеваемости на предприятии как важнейшей составляющей современной системы управления охраной труда. Для достижения цели в статье проанализированы основные причины производственного травматизма и профессиональной заболеваемости

и предложен методический подход, который позволяет оценивать эффективность плана мероприятий по повышению безопасности производства с учетом причинно-следственных связей между реализацией мероприятий и экономическими показателями деятельности предприятия. Построена математическая модель прогноза показателей производственного травматизма и профессиональной заболеваемости.

Ключевые слова: производственный травматизм, профессиональные заболевания, гигиена труда, вредные и опасные условия труда, прогнозная модель.

Библ. 7.

УДК 331.452

Усовершенствование оперативного управления гигиеной и безопасностью труда на основе оценки производственного риска / Кружилко О.Е., Ткалич И.Н., Полукаров А.И. // Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 37-41

Объектом исследования являются методы управления охраной труда на предприятиях. Утверждение Кабинетом Министров Украины «Концепции реформирования системы управления охраной труда в Украине» предопределяет необходимость построения системы управления гигиеной и безопасностью труда на основе рискоориентированного подхода. Построение указанной системы требует проведения теоретических и экспериментальных исследований, предназначенных для формирования методического обеспечения процессов идентификации существующих на производстве опасностей и оценки производственных рисков.

Целью работы является обоснование для практического использования подхода к оценке риска наступления несчастного случая на предприятии. Для достижения цели проанализированы существующие методы и подходы к оценке производственных рисков и предложен подход к оценке производственного риска, основанный на использовании статистических данных о показателях производственного травматизма с учетом отраслевой принадлежности предприятий.

Ключевые слова: гигиена и безопасность труда, производственный риск, оперативное управление, планирование, информационная система.

Библ. 6, ил. 1.

УДК 004.89:65.011.56

Гибридный подход к прогнозированию временного ряда электропотребления для организационного управления на оптовом рынке / Остапченко К.Б., Лисовиченко О. И., Борукаєв З.Х. // Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 42-52

Рассматривается проблема повышения эффективности решения комплекса задач прогнозирования и планирования электропотребления региональными компаниями поставщиков электроэнергии - субъектами системы организационного управления оптовым рынком электроэнергии. Проведен анализ использования различных методов моделирования при решении задачи выбора и построения модели прогнозирования электропотребления, формулируется задача построения гибридной прогностической модели, лишенной недостатков отдельных методов моделирования. Предпочтение отдано подходу, связанному с комплексным использованием математических средств на базе аппаратов искусственных нейронных сетей, генетического алгоритма и фильтра Калмана для построения обобщенных нелинейных многофакторных моделей. Он позволит повысить эффективность процесса построения моделей и их последующего использования для поиска, как краткосрочных, так и долгосрочных прогнозов. Для исключения

влияния случайных составляющих временного ряда с неравномерным распределением значений показателя электропотребления на процесс обучения нейронной сети как нелинейной модели прогнозирования предлагается предварительная ее подготовка с помощью применения фильтра Калмана. В дальнейшем осуществляется оптимизация топологии нейронной сети на базе генетического алгоритма, который позволяет на этапе мутации адаптивно выбирать тип преобразования структуры, наиболее подходящий для заданной конфигурации сети.

Ключевые слова: гибридный подход, прогнозирование временного ряда, процессы электропотребления, организационное управление, оптовый рынок электроэнергии.

Библ. 24, ил. 3

УДК 004.652

Обработка информации оптическими датчиками робота при условии неполной входной информации / Пархомей И.Р., Батрак Е.О., Цёпа Н.В., Зенив И.О.// Межведомственныйнаучнотехнический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 53-64

Область задач, решаемых с помощью свойств классификации и обобщения достаточно широка. Однако качество решения задач по тем илиным причинам не всегда бывает одинаковым. Например, если будет поставлена задача, с помощью визуальных наблюдений, разделить на два класса одинаковые по геометрическим размерам и по цвіту предметы. Причем часть зготовлена из стали, а часть – из гипса. Для классификации таких предметов достаточно получить данные о весе предметов, чтобы задача классификации превратилась в тривиальную.

Сложность в данном случае заключается в отыскании такого описания явлений, при котором изображение (явления) в середине каждого класса имели бы определённые подобне свойства. Поэтому, для устранения влияния помех на процесс распознавания, предлагается ввести спеціальное решающее правило. Данное правило основывается на том, что решение про принадлежность изображения к образу, выноситься на основание анализа изображения, которое попало в определённое близкое пространство, которое классифицируется.

С помощью этого метода находять решения, которые почти не чувствительны к погрешностям, что возникают в результате воздействия помех. Поэтому при увеличении множества зображений это правило переходит в правило Байеса.

Ключевые слова: автокорреляционная функция, инвариантность, коэффициент сходства, распознавание, описание изображений, границы изображения, обработка сигналов.

Библ. 20, ил. 3.

УДК 004.042

Алгоритм определения электромагнитной совместимости для решения задач частотного планирования / И.Р. Пархома, В.В. Недолужко // Межведомственный научно технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 65-72

Объект исследования - процесс определения электромагнитной обстановки для решения задач частотного планирования радиоэлектронных средств подвижной службы. Предмет исследования - исследования и расчет ЭМС РЭС в районе планирования. Цель работы исследования эффективности использования и определение направлений совершенствования расчет ЭМС РЭС в районе планирования.

Методика предполагает проведение анализа ЭМС РЭС в районе планирования, а в случае использования общей площадки для размещения РЭС - ЭМС локального группировки РЭС (объектовая ЭМС).

В работе изложены причины возникновения взаимных помех при работе радиоэлектронных средств в осложненной радиоэлектронной обстановке, рассмотрено современное научно-методический аппарат радиомониторинга с определением в этом месте электромагнитной обстановки для решения частотного планирования РЭС.

В работе проведен анализ причин возникновения взаимных помех при работе радиоэлектронных средств в осложненной радиоэлектронной обстановке, рассмотрено современное научно-методический аппарат радиомониторинга с определением в нем электромагнитной обстановки для решения задач частотного планирования РЭС подвижной службы.

Ключевые слова: источник радиоизлучения, электромагнитная обстановка, электромагнитная совместимость, пункт технического радиоконтроля, радиоизлучающих устройство, радиорегламент, радиотехнологии, радиочастотный ресурс.

УДК 378.147:159.95:519.816

Исследование характера связи мотивации слушателей онлайн-курсов с успешным завершением обучения / Пархоменко А.В., Сегол Р.И., Лисовиченко О.И. // Межведомственный научно технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 73-80

Развитие онлайн-образования становится движущей силой изменений мировых образовательных тенденций. В статье приведен анализ результатов обучения на массовых открытых онлайн-курсах «Учимся учиться» и «Обучающие инструменты для критического мышления», чтобы выявить мотивационные потребности студентов. Курс «Учимся учиться» адаптирован на украинский язык, курс «Обучающие инструменты для критического мышления» создан украинским автором. Курсы размещены на платформе Prometheus 2018 году, они созданы для разных целевых аудиторий и включают различные мотивационные компоненты для студентов. Целью статьи является решение таких задач: анализ и исследование результатов тестирования на курсах «Учимся учиться» и «Обучающие инструменты для критического мышления» с целью мотивации учащихся и создания и разработки мотивационных техник для студентов онлайн-курса. Учитывая представленные данные, мы можем заключить, что основной мотивацией для студентов было овладение новыми знаниями или углубление существующих для получения новой должности, улучшение финансового положения или смены профессии с той же целью. Следовательно, материальная мотивация играет ведущую роль. В выводах предложены мотивационные приемы для повышения качества учебного процесса и увеличения корреляции между усвоением теоретического материала и прохождением практических занятий.

Ключевые слова: корреляция, массовый открытый онлайн-курс, мотивационная техника, мотивационные потребности, результат обучения.

Библ. 17, ил. 5.

УДК 519.854.2

Оптимизация для одного класса комбинаторных задач в условиях неопределенности / Павлов А.А. // Межведомственный научно технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 81-89

Для достаточно общего класса задач комбинаторной оптимизации, функционал которых содержит линейную свертку весов и произвольных числовых характеристик допустимого решения, формализуются понятия неопределенности, компромиссного решения, компромиссные критерии и условия. Приводятся алгоритмы нахождения компромиссных решений как оригинальная реализация известной идеи линейной сверстки критериев. Эффе-

ктивность предложенных алгоритмов однозначно определяется эффективностью решения задачи комбинаторной оптимизации в детерминированной постановке. Показано, что полученные ранее эффективные ПДС-алгоритмы для NP-трудных задач комбинаторной оптимизации – минимизация суммарного взвешенного запаздывания заданий на одном приборе, минимизация суммарного взвешенного момента окончания выполнения взаимосвязанных заданий (произвольный ацикличный ориентированный граф) одним прибором – позволяют эффективно решать эти задачи в условиях неопределенности.

Ключевые слова: Комбинаторная оптимизация, неопределенность, вероятность, эффективный алгоритм, разрешение неопределенности, ПДС-алгоритм, NP-трудные задачи.

Библ. 7

УДК 621.865.8(031)

Концепция синтеза шагающих роботов произвольной ориентации / Михаил Полищук // Межведомственный научно технический журнал «Адаптивные системы автоматического управления». 2019. № 1 (34). С. 90-102

Роботы произвольной ориентации (Climber Robot) – новая модификация мобильных роботов. Эти роботы снабжены средствами удержания робота на поверхности произвольной ориентации относительно горизонта технологического пространства. Создание этого вида робототехники находится на начальной стадии и продиктовано необходимостью выполнения технологических операций по мониторингу промышленных объектов, монтажу и демонтажу строительных конструкций, ремонту и профилактическому обслуживанию их компонентов. В статье предложены три основных принципа синтеза шагающих мобильных роботов: накопление и преобразование энергии, интеграция приводов движения и использование генератора реактивной пневматической тяги. Реализация этих принципов помогает снизить общую мощность приводов и повысить надежность удержания роботов на поверхности произвольной ориентации в технологическом пространстве. Представлены результаты математического моделирования конструктивных и технологических параметров мобильных роботов.

Ключевые слова: мобильные роботы, шагающие механизмы, роботы вертикального перемещения, альпинистские роботы

УДК 519.8

Математическая модель производства электроэнергии энергоблоками АЭС для решения задач развития электроэнергетики Украины / С.Е. Саух, А.В. Борисенко // Межведомственный научно технический журнал «Адаптивные системы автоматического управления». 2019. № 2 (35). С.

Объект исследования – производственные процессы, реализуемые на АЭС ГП «НАЭК «Энергоатом». Предмет исследования – планово-предупредительные ремонты оборудования энергоблоков АЭС. Цель работы – разработка математической модели производственных процессов, реализуемых на АЭС ГП «НАЭК «Энергоатом», пригодной для прогнозирования помесячной динамики объемов выработки электроэнергии энергоблоками АЭС в различных сценарных условиях развития атомной энергетики страны.

Модель разработана на основе комплексного анализа имеющихся данных об установленных мощностях энергоблоков, объемах выработки ими электроэнергии, периодичности и длительности ранее выполненных капитальных и средних ремонтов основного оборудования АЭС.

В модели адекватно воспроизведены общие характеристики планово-предупредительных ремонтов оборудования энергоблоков и их влияние на помесячные объемы выработки электроэнергии каждой АЭС в средне- и долгосрочной перспективе.

Математическая модель ориентирована на использование в составе систем моделирования электроэнергетики Украины и обеспечивает возможность учета в таких системах различных стратегий развития компании ГП «НАЭК «Энергоатом», в частности, ввод в эксплуатацию новых энергоблоков с регламентированными характеристиками периодичности и длительности выполнения планово-предупредительных ремонтов.

Ключевые слова: система, модель, АЭС, долгосрочное прогнозирование.

УДК 681.5

Концепция управления конструкторской подготовкой производства электронных аппаратов / Смолий В.Н. // Адаптивные системы автоматического управления. -2019.- №. 1(33).-С. 113-124

В результате проведенных исследований разработана новая концепция управления конструкторской подготовкой производства электронных аппаратов, опирающаяся на единое информационное пространство компоновки электронного аппарата, оперативного управления конструкторской подготовкой производства и системы управления ресурсами предприятия, позволяющая повысить эффективность управления конструкторской подготовкой производства электронных аппаратов.

Библ. 22, ил. -.2, табл. 0

УДК 004.042

Нейросемантический подход к построению автоматизированных информационно-поисковых систем / Стенин А.А., Пасько В.П., Лемешко В.А. // Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». -2019.- № 1 (34) С. 125-129

В настоящее время одной из актуальных проблем при формировании максимально информативных моделей знаний данной предметной области является создание эффективных информационно-поисковых систем, в первую очередь, в Интернете, как самом большом хранилище информации. Для извлечения нужной для данной предметной области информации из Интернет требуется обработка огромного количества разнородных документов. Это достаточно сложная задача, которая требует не только автоматизации процесса поиска информации, но и обеспечения ее смыслового содержания в соответствии с текущей ситуацией в данной предметной области. Для автоматизации процесса поиска и определения максимально информативного контента модели знаний данной предметной области предложена мультиагентная интеллектуальная система поиска и отбора информации, построенная на основе нейронных сетей. В системе реализуется нейросемантический подход к смысловой адаптации поисковой информации к изменению текущей ситуации в данной предметной области и соответствующей ей эволюции модели знаний на основе генетического алгоритма.

Ключевые слова: интеллектуальная мультиагентная система, нейронная сеть, генетический алгоритм, модель знаний, предметная область

УДК 681.5

Оптимальное управление автономным роботизированным подводным аппаратом на основе прогнозирующих моделей / Стенин А.А., Пасько В.П., Тимошин Ю.А., Игнатенко В.Н., Стенин А.С. // Адаптивные системы автоматического управления. – 2018.– №. 1 (34).-С. 130-137

Рассматриваются оптимальные методы управления сложными техническими объектами с использованием прогнозирующей модели. Предложена структурно-функциональная схема реализации автоматической оптимальной стабилизации заданного движения автономного роботизированного подводного на основе оригинальных

методов параметрической идентификации прогнозирующих моделей и модального синтеза оптимальных регуляторов на отдельных горизонтах прогноза.

Ключевые слова: оптимальное управление, прогнозирующая модель, параметрическая идентификация, горизонт прогнозирования, модальный синтез.

Библ. 14, ілл. 3

УДК 004

Информационная технология для разработки и внедрения web-приложений / Теленик С., Новаковский Г., Жариков Э., Вовк Е. // Межведомственный научно-технический журнал «Адаптивные системы автоматического управления». -2018.- № 1 (34). С. 138-151

Рассмотрена проблема быстрого создания эффективных веб-приложений одного класса с использованием формальных средств. Предложен концептуальный подход к ее решению на основе анализа особенностей построения веб-приложений. Подход базируется на определении стандартной архитектуры веб-приложений и выборе его компонентов с помощью формальных методов в соответствии с требованиями пользователя. С этой целью используется формальная логическая система, которая использует разработку веб-приложений как процесс вывода формулы, заданной в соответствии с потребностями пользователя, определяет схемы выполнения модулей системы. Важной особенностью подхода является возможность 3D-визуализации процесса проектирования системы, создает условия для эффективного взаимодействия между разработчиками и инструментальными средствами разработки.

Ключевые слова: веб-приложения; разработка приложений; бизнес-процессы; математическая логика. Библ. 4, ил. 2

UDC 621.396.96

Investigation of signals distortion during interpolation in SDR transmitters with QPSK modulation / Boiko J.M., Pyatin I.S., Eromenko O.I.,ParkhomeyI.R. // Interdepartmental scientific-technical journal «Adaptive systems of automatic control». - 2019. - № 1 (34).- P. 5-15

Software-defined radio (SDR) allows using software to set or modify working radio frequency parameters: communication standard, frequency range, modulation type, output power, etc. An interpolator is an integral part of the transmitter, which increases the sampling frequency of the modulated signal. Interpolators are built on the basis of integrated cascaded integral-comb (CIC) non-multiplier filters. CIC interpolation filters have uneven amplitude-frequency characteristic (AFC), so the CIC compensator filter is turned on for its alignment. The eye-diagrams of signals with different interpolation coefficients are investigated in the paper. The quality of the signal in the transmitter can be evaluated by the eye-diagram. Interpolation is accompanied by the effect of amplifying the signal, reducing the time of increase in pulse, reducing the signal quality factor. The jitter in the transmitter decreases when the interpolation factor is a multiple of the sampling rate of the information sequence of symbols. If the signal quality factor is $Q>7$, the bit error rate has a $BER<10^{-9}$ value for practice.

Keywords: interpolation, modulation, filter, signal processing, jitter.

Ref. 11, pic. 16

UDC 004.042

Application of event sourcing and CQRS patterns in distributed systems / Diakov S.O., Zubrei T. E., Samoidiuk A.S. // Interdepartmental scientific technical journal «Adaptive systems of automatic control». 2019. № 1 (34). P. 16-22

This report showcases problem in architecturing modern high load distributed systems and proposes solutions for them. The purpose is finding suitable approaches for dealing with

the issue, particularly ability to recreate system state. In order to achieve the goal, the report will overview causes of existing problems, compare conventional design to proposed architecture solutions, emphasize on its benefits and drawbacks. An examined way to design applications relies on two concepts: command query responsibility segregation (CQRS) and event sourcing. A combination of them is suggested to solve performance and design issues that often arise in conventional information systems development.

Keywords: CRUD, CQRS, event sourcing, software architecture, design patterns, data modeling.

Ref. 10, pic. 4, tabl. 1

UDC 004.056.55

Protection of an electronic document using a consolidated approach to the application of electronic digital signature / Y. Kornaga, V. Garmatin, A. Hryshko, A. Maksimyuk, V. Gasanov // Interdepartmental scientific-technical journal «Adaptive systems of automatic control».- 2019.- № 1(34).- P. 23-31

Modern information systems allow organizations to improve their efficiency, significantly reduce their costs and meet regulatory requirements. A good document management system is often regarded as all that is required, but additional protection measures are also needed to ensure that data is protected from unauthorized access and forgery.

The purpose of this article is to modify the algorithms of cryptographic methods of protecting the integrity of a document using an electronic digital signature.

Document management systems typically provide security and control access to documents in a controlled environment. However, when a document leaves a secure environment, it is easy to modify it. Unprotected documents do not allow to determine whether the document is authentic, who was the originator and the approver or has it been modified since its creation.

The problem of keeping electronic documents from being copied, modified, and forgery requires specific approaches and methods of protection for its solution. One of the most common method of such protection in the world is an electronic digital signature (EDS), which confirms the authenticity, integrity its details and the fact of signing by a specific person of the document with the help of special software.

Common encryption methods are based on factorization of large numbers (RSA, DSA, ElGamal) and discrete logarithmization (ECDSA, EdDSA, GOST R 34.10–2012).

Each pair of keys consists of a private key and a public key. They are interdependent, but can be used separately. Usually, each pair of keys may belong to a specific key holder. The algorithm works in such a way that it is impossible for third parties to calculate the private key, even if they own the public key.

Keywords: network infrastructure, document, electronic document, electronic digital signature, authentication, verification, EdDSA, SHA-512, Argon2.

Ref. 13, figure 6, table 3

UDC 331.45

Evaluating the effectiveness of measures to reduce the level of occupational injuries and occupational disease in the enterprise / Kruzhilko O., Maystrenko V., Storozh Y., Lyakh Y.// Interdepartmental scientific-technical journal «Adaptive systems of automatic control».- 2019.- № 1(34).- P. 32-36

The object of the research is the system of management of labor protection of the enterprise. The article gives an overview of the existing principles of prevention and improvement of working conditions in occupational health and safety management systems. The main disadvantages are the lack of a suitable method for assessing the risk and the professional and psychological disadvantages of specialists in this area.

The aim of the work is to develop methodological approaches to assessing the effectiveness of measures to reduce the level of occupational injuries and occupational disease in the enterprise as an important component of the modern system of management of occupational safety. In order to achieve the goal, the article analyzes the main causes of occupational injuries and occupational morbidity and proposes a methodical approach that allows assessing the effectiveness of the plan of measures to increase the safety of production, taking into account the causal relationships between the implementation of measures and economic indicators of the enterprise. A mathematical model for prediction of occupational injuries and occupational morbidity rates was constructed.

Key words: occupational injuries, occupational diseases, occupational health, harmful and dangerous working conditions, forecast model.

Ref. 7.

UDK 331.452

Improvement of operational management of hygiene and labor safety on the basis of assessment of occupational hazard / Kruzhylko O., Tkalych I., Polukarov A.// Interdepartmental scientific-technical journal «Adaptive systems of automatic control».- 2019.- № 1(34).- P. 37-41

The research object is the methods of management of labor protection at enterprises. Approval of the “Concept for Reforming the System of Labor Protection Management in Ukraine” by the Cabinet of Ministers of Ukraine necessitates the establishment of a hygiene and safety management system based on a risk-oriented approach. The construction of the specified system requires a complex of theoretical and experimental research, intended to form the methodological support for identifying processes of hazard identification and occupational hazard assessment

The purpose of the work is to provide grounds for the practical application of the approach to occupational hazard assessment. To complete the purpose, existing methods and approaches to the occupational hazard assessment have been analyzed, and an approach to the occupational hazard assessment is proposed, which is based on the use of statistics on indicators of occupational injuries with consideration of the branch affiliation of enterprises.

Keywords: hygiene and labor safety, occupational hazard, operative management, planning, information system.

Ref. 6, pic. 1

UDC 004.89:65.011.56

Hybrid approach to the forecasting of electric consumption time series for organizational management in the wholesale market / K.B. Ostapchenko, O.I. Li-sovychenko, Z.Kh. Borukaiev // Interdepartmental scientific-technical journal «Adaptive systems of automatic control».- 2019.- № 1(34).- P. 42-52

Abstract: The problem of increasing the efficiency of solving the complex of tasks of forecasting and planning electric consumption by regional companies of electricity suppliers - subjects of the organizational management system in the wholesale electricity market is considered. The analysis of the use of various modeling methods in solving the problem of choosing and building a model for forecasting electric consumption is carried out. The task of constructing a hybrid prognostic model devoid of the shortcomings of individual modeling methods is formulated. Preference is given to the approach associated with the integrated use of mathematical tools based on apparatus of artificial neural networks, a genetic algorithm and a Kalman filter for constructing generalized nonlinear multifactor models. It will increase the efficiency of the model building process and their subsequent use for searching both short-term and long-term forecasts. In order to eliminate the effect of random components of the time

series with an uneven distribution of the values of the electric consumption on the training process of the neural network as a non-linear forecasting model, we suggest its preliminary preparation using the Kalman filter. Further optimization of the neural network topology is carried out on the basis of a genetic algorithm that allows, at the mutation stage, to adaptively choose the type of structure transformation most suitable for a given network configuration.

Keywords: hybrid approach, time series forecasting, electric consumption processes, organizational management, wholesale electricity market.

Ref. 24, pic. 3

UDC 004.652

Information processing with an optical sensor when incomplete initial information / I. Parkhomey, Ye. Batrak, N. Tsopa,I. Zeniv// Interdepartmental scientific technical journal «Adaptive systems of automatic control». - 2019.- № 1(34).- P. 53-64

The range of tasks, solved by the properties of classification and generalization, is quite broad. However, the quality of solving to the problem, for one reason or another, is not always the same. Some tasks cannot be solved at once, but a detailed study of phenomenon allows us to make the necessary classification. For instance, the task is to divide the objects, with the same geometric dimensions and objects, by visual observation into two classes. Moreover, the part is made of steel, and another one - of gypsum. In principle, such task cannot be solved. To classify these subjects, a more detailed study of them is required. It is sufficiently to get data on the weight of objects, so that the task of classification has become trivial.

The difficulty is to find such a description of phenomenon, in which the image (phenomenon), within each class, would have defined similar properties. Therefore, in order to eliminate the effect of interference on the recognition process, it is proposed to introduce a special decisive rule based on the fact that the decision to attach the image to the image is made on the basis of an analysis of images that have fallen into a definite close space that is classified. Using this method, the solutions, that are almost unintelligible to the errors that arise due to the effects of interference, are found. Therefore, in incrementstheset of images, this rule passes into the Bayes’ rule.

Keywords: autocorrelation function, invariance, coefficient of similarity, recognition, description of images, image border, signal processing

Ref. 20, pic.3.

UDC 004.042

Algorithm for determination of electromagnetic compatibility for solution of frequency planning problems / I. P. Parhkhomey, V. V. Nedoluzhko // Interdepartmental scientific and technical journal "Adaptive systems of automatic control". 2019. No. 1 (34). P. 65-72

The object of the study is the process of determining the electromagnetic environment for solving the frequency scheduling problems of electronic vehicles of the mobile service. Subject of research - research and calculation of EMC RES in the planning area. The purpose of the work is to investigate the effectiveness of using and defining directions for improving the calculation of EMC REFs in the planning area.

The method involves conducting an EMC analysis of the RES in the planning area, and in case of using the general site for the RES-EMC of the local REF grouping (object EMC).

The paper presents the reasons for the occurrence of interference in the work of radio electronic devices in a complicated electronic environment, examines the modern scientific and methodical apparatus of radio monitoring with the definition in this place of the electromagnetic environment for the solution of frequency scheduling of RES.

The paper analyzes the causes of mutual interference in the work of radio electronic devices in a complicated electronic environment, examines the modern scientific and methodical

apparatus of radio monitoring with the definition of electromagnetic environment in it for solving the problems of frequency planning of mobile service reflexes.

Key words: radio emission source, electromagnetic environment, electromagnetic compatibility, point of technical radio control, radio-transmitting device, radio regulation, radio technology, radio frequency resource

UDC 378.147:159.95:519.816

Comprehensive analysis of the students’ motivation connection to the massive open online courses completion rate / Parkhomenko A.V., Segol R.I., Lisovychenko O.I. // Interdepartmental scientific technical journal «Adaptive systems of automatic control». 2019. № 1 (34). P. 73-80

The online education development will be the driving force behind changes in the world’s educational trends. The proposed article provides the analysis for the learning outcome at massive open online courses "Learning How to Learn" and "Educational Tools for Critical Thinking" to identify students’ motivational needs. "Learning How to Learn" course is adapted in Ukrainian, "Educational Tools for Critical Thinking" is developed by Ukrainian authors. Courses are distributed on the Prometheus platform in 2018, they are created for different target audiences and include different motivational components for students. The article aims to solve such problems: analysis and research the testing results at the courses "Learning How to Learn" and "Educational Tools for Critical Thinking" to motivate students and further guidelines creation for the motivational techniques’ development for online course students. Considering the presented data, we can conclude the main motivation for these students was to master new knowledge or deepen existing ones to obtain a new post, improving the financial position or changing the profession for the same purpose. Consequently, material motivation plays a leading role. Motivational techniques for improving the learning process quality and increasing the correlation between mastering the theoretical material and passing practical exercises are proposed in conclusions.

Keywords: correlation, learning outcome, massive open online course motivational technique, motivational needs.

Ref. 17, fig. 5.

UDC 519.854.2

Optimization for one class of combinatorial problems under uncertainty / Pavlov A.A. // Interdepartmental scientific technical journal «Adaptive systems of automatic control». 2019. № 1 (34). P. 81-89

We formalize uncertainty and compromise solution concepts, compromise criteria and conditions for a sufficiently common class of combinatorial optimization problems which functional contains a linear convolution of weights and of arbitrary numerical characteristics of a feasible solution. We present algorithms for compromise solutions finding as an original implementation of the well-known idea of linear convolution of criteria. Efficiency of the proposed algorithms is unambiguously determined by the efficiency of solving the combinatorial optimization problem in a deterministic formulation. We show that previously obtained efficient PSC-algorithms for NP-hard combinatorial optimization problems — the total weighted tardiness of tasks minimization on one machine, the total weighted completion time of interrelated tasks (by arbitrary acyclic oriented graph) minimization on one machine — allow to solve these problems efficiently under uncertainty conditions.

Keywords: Combinatorial optimization, uncertainty, probability, efficient algorithm, uncertainty resolution, PSC-algorithm, NP-hard problems.

Ref. 7

UDC 621.865.8(031)

The concept of synthesis of walking robots of arbitrary orientation / Mikhail Polishchuk // Interdepartmental scientific technical journal «Adaptive systems of automatic control». 2019. № 1 (34). P. 90-102

Robots of arbitrary orientation (Climber Robot) are a new modification of mobile robots. These robots are equipped with means of holding the robot on a surface of arbitrary orientation relative to the horizon of the technological space. The creation of this type of robotics is at the initial stage and is dictated by the need to perform technological operations for monitoring industrial facilities, installation and dismantling of building structures, repair and preventive maintenance of their components. The article proposed three basic principles for the synthesis of walking mobile robots: the accumulation and transformation of energy, the integration of motion drives and the use of a generator of reactive pneumatic thrust. The implementation of these principles helps to reduce the total power of the drives and to increase the reliability of the holding robots on the surface of an arbitrary orientation in the technological space. The results of mathematical modeling of constructive and technological parameters of mobile robots are described.

Keywords: mobile robots, walking mechanisms, robots of vertical movement, climbing robots

UDC 519.8

Mathematical model of NPP units power generation to solve the problems of Ukrainian power system development / S. Ye. Saukh, A.V. Borysenko // Interdepartmental scientific and technical journal "Adaptive systems of automatic control". 2019. No. 2 (35). P.

The object of the research is the production processes implemented at NPP of the SE NNEGC "Energoatom". The subject of the research is planned preventive repairs of the equipment of NPP power units. The purpose of the work is to develop a mathematical model of production processes implemented at NPPs of the SE NNEGC "Energoatom" suitable for predicting the monthly dynamics of the volumes of electricity generation by NPP units in various scenario conditions for the development of the country's nuclear power industry.

The model was developed on the basis of a comprehensive analysis of the available data on the installed capacities of power units, the volumes of electricity generation by them, the frequency and duration of previously completed major and intermediate maintenance of the main equipment of NPPs.

The model adequately reproduces the general characteristics of the PPM of the equipment of power units, and their impact on the monthly electricity production volumes of each NPP in the medium and long term.

The mathematical model is focused on the use as a part of Ukrainian power industry modeling systems and makes it possible to take into account various development strategies of the SE NNEGC "Energoatom" in such systems, in particular, the commissioning of new power units with regulated characteristics of periodicity and duration of preventive maintenance.

Keywords: system, model, NPP, long-term forecasting.

UDC 681.5

Management conception designer preproduction of electronic vehicles / Smolij V.N. // Interdepartmental scientific technical journal «Adaptive systems of automatic control». 2019. № 1 (34). P. 113-124

As a result of undertaken studies new conception of management is worked out by designer preproduction of electronic vehicles, leaning against single informative space of arrangement of electronic vehicle, operative management designer preproduction and control system by the resources of enterprise, allowing to promote management efficiency designer preproduction of electronic vehicles..

Ref. 22, pic. - 2, tabl. 0.

UDC 004.042

Neurosemantic approach to building automated information retrieval systems / Stenin A.A., Pasko V.P., Lemeshko V.A. // Interdepartmental scientific-technical journal «Adaptive systems of automatic control».- 2019. № 1 (34). P. 125-129

Currently, one of the actual problems in the formation of the most informative knowledge models of this subject area is the creation of effective information retrieval systems, primarily on the Internet, as the largest repository of information. To extract the necessary information for this subject area from the Internet, processing of a huge number of heterogeneous documents is required. This is the rather complicated task that requires not only automating the process of searching for information, but also ensuring its semantic content in accordance with the current situation in this subject area. To automate the search process and determine the most informative content of the knowledge model of this subject area, a multi-agent intelligent system for searching and selecting information based on neural networks proposed. This system implements a neurosemantic approach to the semantic adaptation of search information to changes in the current situation in this subject area and the corresponding evolution of the knowledge model based on a genetic algorithm.

Keyword: intelligent multiagent system, neural network, genetic algorithm, knowledge model, subject area

UDC 681.5

Optimal control of Autonomous Underwater Vehicles on the basis of predictive models / Stenin A.A., Pasko V.P., Timoshin Y.A., Ignatenko V.N., Stenin A.S. // Adaptive systems of automatic control. – 2018. – № 1(34).- P. 130-137

Optimal control methods are considered using the predictive model, including the most well-known and widely used MPC-approach (predictive control model). A structural-functional scheme for the implementation of the automatic optimal stabilization of a given movement based on original methods of parametric identification of predictive model and AUV modal synthesis of optimal regulators on individual forecast horizons is proposed.

Keywords: optimal control, predictive models, parametric identification. forecast horizon, modal synthesis.

Ref.14, ill.3.

UDC 004

Information technology for web-applications design and implementation / Sergii Telenyk, Grzegosz Nowakowski, Eduard Zharikov, Yevhenii Vovk // Interdepartmental scientific-technical journal «Adaptive systems of automatic control».- 2019.- № 1 (34).- P. 138-151

The problem of the rapid creation of effective web-applications of one class with using formal means are considered. The conceptual approach to its solution is offered on the basis f analysis of the peculiarities of web-applications construction. The approach is based on defining the standard web application architecture and selecting its components using formal methods in accordance with user requirements. A formal logical system is used, which uses the design of web-applications as a process of outputting the formula specified according to the needs of the user, which defines the schemes of execution of the modules of the system. An important feature of the approach is the ability to 3D-visualize the process of designing the system, which creates conditions for effective interaction between developers and machine development tools.

Keywords: web-applications; application construction; business processes; mathematical logic.

Ref. 4, pic. 2

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Наукові інтереси: хмарні обчислення, моделювання складних систем, центри обробки даних, розробка застосунків

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