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Prospects for developing digital telecommunication complexes for storing and analyzing media data

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ABSTRACT

In today's digital world, saturated with data flows, universal multifunctional systems are developing, capable of solving various problems related to optimizing the use of available computing resources. A distinctive feature of such systems is the heterogeneity of incoming flows of user requests due to the multifunctionality of modern information systems, expressed in supporting various multimedia services on a single platform. Data heterogeneity and large volumes of data create many problems related to the speed of digital systems and data storage security. The solutions can be found in artificial intelligence (AI) technologies, particularly machine learning. Therefore, development and implementation of digital telecommunication complexes for storing, processing, and forming a dynamic flow of multiformat data using AI technologies are becoming more relevant. This paper aims to identify trends and prospects for developing these complexes, and develop proposals on their perspective characteristics. The authors focused on review the experience of Russian organizations developing multi-object analytics systems and analyze the technical and functional characteristics of existing systems. The result of the review and analysis is a table with a comparison of the technical characteristics of existing complexes and proposals for characteristics that are promising for further implementation.

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1. INTRODUCTION

A problem of modern high-loaded information systems is the need for large amounts of computing resources [1]. Simultaneously, the growth of resource consumption, in contrast to changes in the available amounts, has an exponential nature [2]. To organize the operation of services in a single information space, it is necessary to solve several classes of problems, including optimization of the use of available computing resources depending on their demand under physical constraints [3], [4]. Another feature of modern information systems is the heterogeneity of incoming streams of user requests due to the multifunctionality of current information systems, expressed in supporting various multimedia services on a single platform. Simultaneously, each of these services has its requirements for the performance of computing resources and, unfortunately, affects the entire information system.

The problem of limited resources is especially relevant for the industry that supports its information systems [5]–[7]. To provide continuous access to information systems using modern means of telecommunications and communication, it is necessary to solve the problem of efficient distribution of limited resources between services [8]. Simultaneously, the flows of incoming requests have heterogeneous intensity and differentiated use of the main components. It is also important to note that monitoring systems increasingly face the need to correlate heterogeneous multiformat data to obtain the resulting service status [9], [10]. In today's market, in addition to the signal transmission path, additional factors also influence the service provision, which cannot be described straightforwardly but can be considered in status correlation [11].

The development of integrated telecommunications systems, the transition to higher-speed information flows, new methods of modulation and coding, and video playback and storage have brought forward some tasks whose successful solution requires new, unconventional methods of information processing. These methods would consider the properties, laws, and dynamics of telecommunications data transmission media, intellectualization of technical devices themselves, and their high degree of adaptation to the actual interference situation on the communication channel. Currently, there are no universal solutions capable of simultaneously distributing and balancing the load between different multimedia services under physical constraints on computing resources.

These problems can be solved by applying the modern concept of cloud computing, according to which end users have access to the virtual resources of a single system that controls, distributes, and balances the load between computing nodes and applications [12]–[14]. Here, to ensure the implementation of the limitation on the total amount of computing resources, it is necessary to use additional models and algorithms that optimize the placement of objects and data in the information system, as well as form the order of service requests according to the selected criteria [15], [16]. One of the promising innovations in this area may be artificial intelligence (AI) technologies, namely, machine learning methods, in particular, artificial neural networks. Artificial neural networks potentially provide data processing and search for specific fragments according to a given algorithm for the automated formation of the necessary dynamic flow [17]–[19]. In one of the reviewed papers, to solved the problem of predicting cloud computing system failure, among several machine learning algorithms, including artificial neural network, naive Bayes classifier, and regression, the artificial neural network was the most efficient. According to Sheik and Muniyandi [17], artificial neural networks can be used in cryptography for cloud security.

Prospects for developing digital telecommunication complexes are also due to the simultaneous control of an unlimited number of video, audio signals, and others in real-time on one or more computer monitors in multiscreen mode [20]. The main technical advantage can be considered the successful combination of universal capabilities, multichannel, multiformat, and a high degree of reliability, which will ensure the further practical implementation of such systems in the projects of the largest information operators. A unique difference and an advantage over traditional multiviewers will be not only the reception and display of video and audio signals but also a full instrumental analysis and monitoring of the parameters of each input signal. The goals of creating digital telecommunication complexes for storing, processing, and forming a dynamic stream of multiformat data using AI technologies are to create a multi-user complex that unifies the work with data, automating processes and facilitating description, data search using neural networks, which allows for improved data monetization through integration with external systems of line broadcasting and broadcasting on demand.

The efficiency of using such complexes is to provide automated round-the-clock control over the dissemination of information in broadcasting networks. This ability is used to organize the control of different types of networks and to automate processes related to control, supervisory activities and information monitoring in terms of compliance with legislation in communications. The main objectives are as follows:

- Ensuring continuous round-the-clock monitoring of broadcasting in analog and digital standards and automated identification of specified information and emergencies
- Ensuring control and supervisory activities as part of the data analysis process
- Obtaining, collecting, and structured storage of information to provide the data monitoring process
- Providing analytical information on the data flow state, grouped by place, time, and source
- The relevance of implementation and improvement of such complexes is due to
- The ability to create a holistic picture of the system state, allowing the assessment of service provision by creating universal "virtual services" and a logical graph that makes it possible to expose the dependence of the states of actual monitoring objects
- The ability to work with almost all formats used in the distributed content delivery network and to use data uploading from outside sources affects the quality of service delivery
- An innovative solution for the analysis of video fragments based on machine learning, previously not applied in similar complexes for data storing, processing, and forming

Consequently, to form the requirements for the functional characteristics of digital telecommunication complexes for storing, processing, and forming a dynamic stream of multiformat data using AI technologies. It is relevant to determine their current technical level and development trends. Which was the purpose of this work.

Literature review:

The radical changes in the information sphere at the global level that we are now observing in society are occurring through the rapid development and dissemination of new information and communication technologies [21], [22]. If earlier the development of information and communication technologies proceeded toward a well-defined specialization and differentiation, today, the primary condition for their development is the possibility of their universal use [23], [24]. Currently, information and communication technologies can be considered a leading factor in the organization of production and business processes [25], education [26], the interaction of the subjects of society (state, organizations, population), leisure activities, and obtaining knowledge, information, and services.

Infocommunications is a term that means the inseparable connection between information and telecommunication elements of information exchange [27], [28]. Infocommunication and infocommunication technologies (ICT) together form the infocommunication infrastructure of society, the degree to which development will determine how successfully Russia enters the global information society [29]. The development of the three main components of infocommunication infrastructure (user equipment, access network, base network–a set of human information exchange devices from a landline phone to a mobile computer, local telecommunications networks, and global transport backbones) depends entirely on the development of the country's economy. Information and telecommunications components are developing in a convergence process–mutual penetration. At present, large financial flows circulate in infocommunications, so infocommunications, on the one hand, are high technology, and on the other–a large economy [30], [31]. Thus, infocommunicationsareafusionoftechnologies.

The following concepts characterize the general direction of ICT development at the beginning of this century: in terms of technical means–universalization, integration, and intellectualization, and of services–globalization and personalization [32]. The rapid increase in the volume of network exchange has entailed significant changes in many aspects of communication. In particular, the insufficiency of a conventional unit (a type of atom of a digital network) called the basic digital channel (BDC) 64 kbps bandwidth will be increasingly felt, and there is a trend in strengthening. These hierarchical unit after the BDC is the primary digital channel (PDC) with a bandwidth of 2048 kbps. However, PDC is ineffective as a switched unit in circuit-switched systems because it is too large for voice information and too small for real-time video information. This fact, combined with the expected rapid growth of high-speed non-speech traffic, will lead to the gradual replacement of channel switching by packet switching and a greater need for increasing the bandwidth of transmission systems (with more efficient use of the transmission medium). The current ratio between the optical and electronic technologies will gradually change in favor of the former. This process is called the "photonization" of a telecommunications network. Table 1 shows the results of the literature review on the problems of developing multifunctional complexes using AI (see in Appendix).

2. METHOD

Despite the high rate of IT developing in the last decade, Russia has failed to reduce the gap with industrialized countries in the level of informatization of the economy and society. This situation is partly caused by general economic reasons (lack of investment, low level of material well-being of most population, and others). Simultaneously, the lack of ICT development in Russia is determined by some factors that create artificial obstacles to accelerating informatization, the widespread adoption and effective use of ICT in the government and private sectors of the economy, to the development of the domestic ICT manufacturing sector. These negative factors include insufficient attention to the level of training in both the creation and use of ICT. The ICT skills of personnel play an essential role in developing and disseminating relevant technologies.

Using infocommunication technologies also implies high-quality, high-speed access availability and working with heterogeneous data [33]. Therefore developing and improving digital telecommunication complexes to work with multi-format data is required. The input data can be: i) audio data: files in wav, mp3 formats, ii) audiovisual data: files in mp4, mov, mxf, avi formats, iii) visual data: files in mxf, mov formats, iv) graphic data: files in png, tga, bmp formats, v) descriptive data: text files in xml format encoded utf8, and vi) subtitles: files in srt and stl formats. The output data may be data provided at the user's request:

- Audiovisual works in the form of files, graphic files
- Text accompanying materials
- Reports on object state statistics: i) summary report generated manually (on request) or automatically (on schedule), displayed at the administrator's user interface, and ii) a summary report generated manually (by request) or automatically (by schedule) in *.XLS, *.XML, *.CSV, *.PDF formats.

The analysis of current world trends in the development of digital telecommunication complexes has revealed that in their operation, it is promising to use AI technologies, in particular, artificial neural networks. They demonstrate high efficiency in solving many problems (including efficient processing of multi-format data, cloud computing security ensuring, and many others). The trend of "photonization" of telecommunication networks has also been revealed, which consists of shifting the balance toward developing optical technologies. Additionally, the analysis revealed that Russia, due to several reasons of economic and social nature, is not yet among the leading countries in the level of ICT development. Therefore, analyzing the current situation in the Russian ICT market seems essential both in assessing the current industry state and forming proposals for developing promising domestic infocommunication systems corresponding to the global level. The following section will analyze the Russian experience of creating digital telecommunication complexes.

3. RESULTS AND DISCUSSION

3.1. The proposed work - analyzing domestic telecommunication complexes

At present, officially declared complexes for storing and processing multiformat data with the subsequent formation of a dynamic stream using AI technologies in the Russian market are absent. Nevertheless, several multi-object analytics systems exist, namely: i) intellect platform from ITV (ITV Group, Russia) [34], ii) Vocord complexes from Vocord telecom (Russia) [35], and iii) FindFace multi-object video analytics platform from NTechlab (Russia) [36]. Below we conduct a comparative analysis of the above mentioned systems.

3.2. “Intellect” platform

“Intellect” is an integrated software platform with a distributed architecture that allows you to combination all security systems into an integral complex [34]. Thanks to “intellect,” the complex of different security systems becomes a single information environment, which implements information processing and analysis functions using AI technologies and can respond flexibly to various events. Due to the modular architecture, the customer can precisely choose the functions needed to build an efficient security system for a particular object, thus obtaining a system with an optimal set of functions at minimal costs. The system's base distribution kit includes the kernel and modules providing main and service functions. The intellect kernel that is the foundation for a comprehensive solution built by adding functional modules, ensures information transfer and interconnection between all integrated subsystems and software components of intellect.

The main functions implemented by the system based on the intellect platform are video and audio recording. The intellect video subsystem, having all the advantages of a distributed architecture, includes powerful video analytics functions, provides high image quality, operational stability, and ergonomics, and makes it possible to connect telemetry devices to the system. The ability to record audio allows the operator to get more information about what is happening at the protected object. The main tasks of the system are: i) video and audio recording, storage, and processing of input data, ii) image and audio quality control, iii) intelligent data analytics, and iv) provision of information transfer and interconnection between integrated subsystems and software components. The intellect system structure is shown in Figure 1.

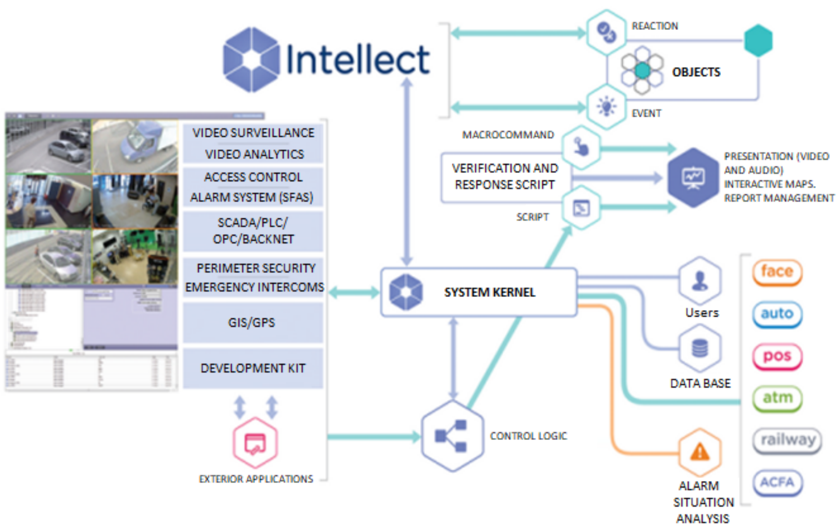

Figure 1. The intellect system structure

The system uses the Microsoft product line as the server platform and a database to store information. Scalability is provided by the distributed architecture (Figure 2) and by: i) the possibility to connect an unlimited number of data sources (video services and cameras), ii) centralized or remote monitoring and administration, and iii) transmission of multistream video from the source (separate streams can be used for display on the local monitor and remote workplaces, to record in the archive, and for video analytics). The advantages of an integrated platform include: i) combining equipment from different manufacturers and managing the equipment from a single center, ii) minimizing financial expenses for equipping the object by reducing the hardware and software, including the existing equipment in the system, iii) implementing new functions that are not available when using autonomous systems, iv) reducing the amount of information coming to the operator, the information becomes more visual, v) better analysis of the situation based on the information coming from different sources, vi) automated decision–making for typical situations, vii) significant reduction in the probability of operator's erroneous actions, and viii) increased system security from external influences. Intelligence is provided using complex algorithms of the system response to events and the execution of various complex functions. The platform provides opportunities for organizing cloud service according to the video surveillance as a service (VSAAS) scheme.

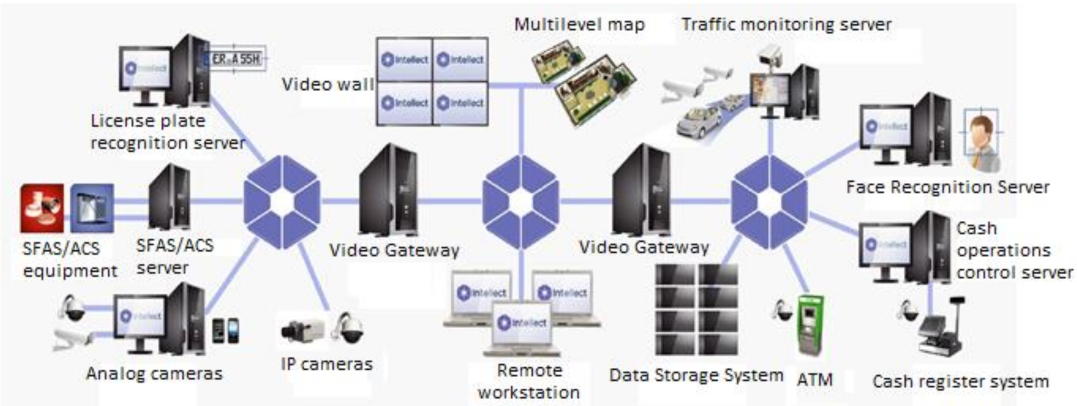

Figure 2. Distributed architecture of the intellect system

3.3. Vocord systems

Vocord is a Russian developer and manufacturer of intelligent transport systems, professional video surveillance, and video analytics systems areas [35]. The company's systems have been implemented in more than 2,000 commercial and government projects and 70 safe city projects in Russia and abroad. This company offers the following products.

- Vocord traffic system of photo-video registration of traffic violations
- Vocord tahion intelligent video surveillance and video analytics system
- The Vocord traffic system is a hardware and software complex built on a distributed architecture that provides
- Recognition of state registration plates (SRP) of vehicles (with the probability of recognition of visually distinguishable SRP not lower than 96%)
- Measurement of vehicle speed
- Determination of the time and location of the vehicle fixation
- Measurement of time and location by the signal of a satellite system
- Calculation of the vehicle's average speed on the road section
- Tracking and fixation of various traffic violations on linear road sections and intersections

This system has various configuration and control options, including the configuration of mathematical algorithms for video information processing and analysis. The settings can be controlled during the system operation ("hot" settings control). A generalized block diagram of the Vocord traffic system using integrated modules is shown in Figure 3.

The Vocord traffic system saves information about the registration number, type, speed, movement direction, and other characteristics of vehicle movement regarding the time and location of the vehicle fixation. The images of the vehicle, its license plate, and the entire control zone at the moment of passing the vehicle and violation traffic rules are also saved. In the case of using overview cameras, the system also saves overview images of the control area. Vocord traffic integrates with other Vocord systems and with external systems. When connecting external databases of registration numbers to the system, it automatically determines the data of the vehicle owner and checks it in the search databases. Digital data transmission channels can transmit the recorded information. The Vocord traffic system can broadcast the image directly in real-time and, if necessary, signal various events. Vocord traffic system exports data on traffic violations to external information systems for issuing decisions on the imposition of an administrative fine, calling for a tow truck, and others.

The Vocord Tahion system is a geographically distributed video surveillance complex for the following: i) round-the-clock video surveillance of objects and territories using multiple observation points, ii) tracking of monitored objects in manual and automatic mode, iii) automatic detection of events in the monitored area (movement, appearance, or disappearance of an object, e.g., a person, suitcase, car, and others), iv) advanced video analysis of objects and events in the surveillance area, statistical processing of the accumulated data (in the system with video analytics function), v) saving vast amounts of video surveillance data, vi) searching for events of interest using archived video recordings, vii) during operation, the system provides the following capabilities for collecting, storing, transmitting, and playing back video and audio information, viii) real-time collection of video and related audio information from multiple surveillance points, ix) automated analysis of large volumes of video information, x) long-term storage of large amounts of surveillance data, xi) display of high-quality video data on operators' monitors, from many cameras simultaneously on one monitor, xii) using a video wall system to display large amounts of real–time video data, xiii) control of video cameras from remote workplaces, xiv) detection of specified events (using sensors, motion detectors, and left/stolen objects detectors on IP cameras), xv) use of the optional video analytics module for advanced image analysis, including traffic analysis, object detection, detection of predefined situations, and statistical data collection, xvi) integration with actuators via Modbus protocol, xvii) operator notification of alarm events in the video surveillance area, xviii) operator's control of the validity of alarm event recording, xix) continuous recording of the current video and audio data into the system archive, xx) archiving under a condition (when a sensor or video detector triggers, on schedule), xxi) archiving on operator's command, xxii) archiving of video data analyzed using the video analytics module (if used), including continuous recording, by condition, on operator's command, xxiii) automatic control of Modbus executive devices on the alarm when a sensor or video detector triggers and on schedule, xxiv) archive data search for recording time, xxv) export of the archive records for a specified period, xxvi) viewing the current video and archive recordings and listening to the accompanying audio data, xxvii) supporting remote access to the system control, current surveillance, and archive materials, xxviii) warning the operator about events in the system visually, by an audio signal, short text messages (SMS), or by email, xxix) linking surveillance points to the map of the area under control and switching to the image from the required point, xxx) ensuring information security, including the use of local and domain Windows accounts, and xxxi) differentiationofaccessrights. As a part of a multi-core hierarchical system, several such complexes can be used, combining fully independent autonomous fieldwork with access to local resources and their management from a single center. A generalized block diagram of the Vocord Tahion system is shown in Figure 4.

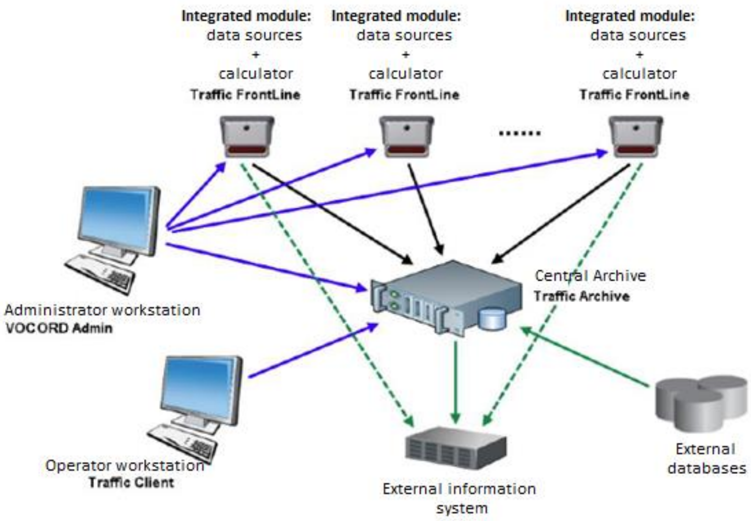

Figure 3. Generalized block diagram of the Vocord traffic system

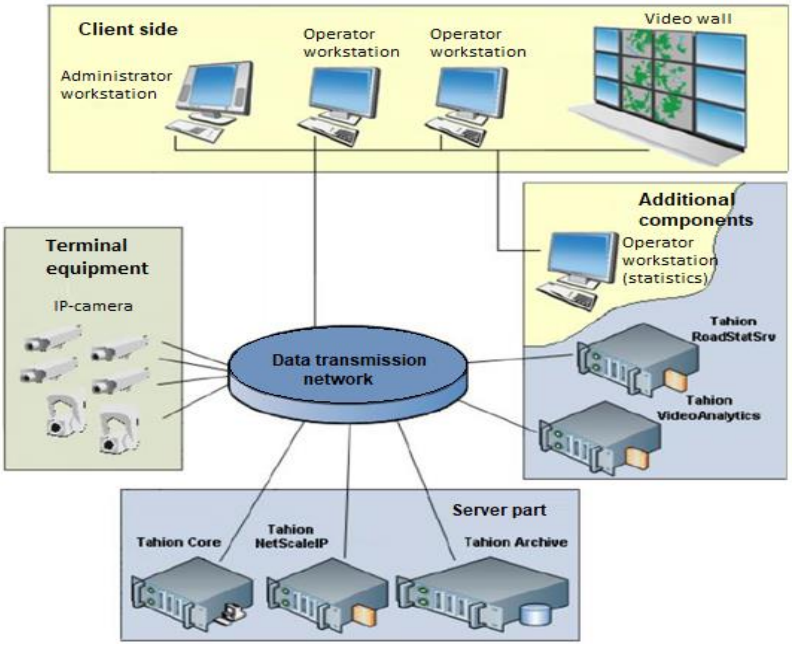

Figure 4. Generalized block diagram of the Vocord tahion system

3.4. FindFace multi-object video analytic platform from NTech lab (Russia)

Based on the described technology, the Ntechlab company presents a line of solutions for the public sector and various business sectors [36]. In 2018–2020 NtechLab facial recognition technology was implemented and used in the Moscow city video surveillance system. The basis of the NtechLab platform is the technology that provides record-breaking accuracy and high-speed face, silhouette, human action recognition, and car detection. The multi-objectivity and analytical capabilities of FindFace Multiopen up new opportunities for solving various tasks in all areas ofvideo analytics applications. The technology is used as a web service to help find people on the social network "VKontakte" by their photos. The FindFace multivideo analytics platform interface is shown in Figure 5. This system performs the following functions:

- Allows for recognizing the faces and silhouettes of people, cars, and license plates in the video stream as quickly and accurately as possible
- Searchingall types of objects (faces, silhouettes, cars, license plates) by photo sample or by characteristics, for example, by age, the color of clothes, or car model
- Distinguishing a live person from a picture. The neural network analyzes several frames simultaneously and records changes in the face. It guarantees that a live person, not a picture, is in front of the camera
- Uses databases to store information. "Object cards" allow you to create relationships between objects, perform searches, and much more
- Analyzing data and collecting statistics by various criteria (gender, age, emotions, and number of unique and returning visitors) and therefore improve customer service and offer the products and services they need
- By analyzing faces, the system makes it possible to establish a person's circle of contacts and connections between people; it allows digital investigations and tracing paths of spreading, including viral infections
- Recordings information in a database and allows you to run scripts when recognizing an event with a detailed analysis of audio and video recordings of the event
- Implementing personal data protection that does not artificially prevent solving the task set
- Implementing a module for creating reports and integrating them with external systems. The function of unloading reports will allow you to quickly analyze data in external BI systems and visualize the work results without access to the system
- The separation of access rights and logging of user actions are conveniently implemented

Maintaining a structure with many subdivisions and a complex hierarchy is easy. FindFace multi ACL implements the separation of access rights to all functional parts of the system. Alerts are flexibly configurable–they come only to those who need them. For example, security officers will not receive automatic notifications about VIP clients' visits. In this section, we reviewed three domestic multi-object analytics complexes, the closest by their characteristics to the digital telecommunication complexes of storing, processing, and forming a dynamic multiformat data stream using AI technologies. In the next section, we will focus in detail on comparing their main technical characteristics and identify the presence or absence of some essential technical solutions that make the system a full-fledged telecommunication complex for multiformat data processing.

Figure 5. FindFace multivideo analytics platform interface

3.5. Comparison of the main technical characteristics of Russian telecommunication complexes and identification of further trends in the development of promising complexes for media data storage and processing

To determine development trends and technical solutions in promising complexes for the media data storage and processing field, we conducted a comparative analysis of the domestic telecommunications complexes considered in the previous section. A comparison of technical characteristics and definition of the technical level of competing systems is given in Table 2 (see in Appendix). The algorithm for selecting promising performance of a digital telecommunication complex for processing and storing multiformat data based on the analysis of the performance of similar analogs is schematically presented in Figure 6.

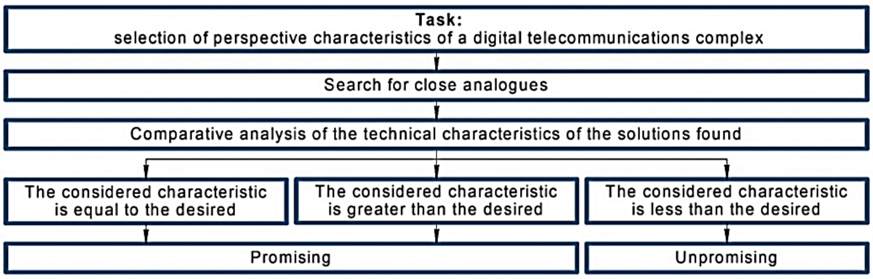

Figure 6. Algorithm for selecting promising performance of a digital telecommunication complex for processing and storing multiformat data based on the analysis of the performance of similar analogs is schematically (schematically)

Comparative analysis of domestic systems revealed that further the most effective approach is the application of some technical solutions to implement the development trends relevant to complexes of media data storage and processing using AI technologies. These solutions are the requirements to which the functionality of promising multifunctional telecommunication complexes should correspond. These requirements include:

a. Using different media: data storage formats. Storing in metadata container information about the error associated with a missing or corrupted data sample in a sequence of data samples together with the sample number associated with the data sample;
b. Improving the computational processing efficiency. Identifying an object in media data through face and voice recognition, with one of face and voice recognition performed when the other of face and voice recognition fails to identify the media object within a predetermined level of accuracy;

c. Introducing variation into the transcriptional representation of the text. The standard pre-processing of the text added the formation of transcription modeling rules and their application to the resulting ideal transcriptions to obtain possible transcription variants;
d. Increasing the speed of outline extraction of grayscale images in conditions of pulse interference. The selection of the smoothing coefficient considers the level of image noisiness, and the coefficients of smoothing cubic B-splines are calculated along each image row and column. After forming two matrices and a component of the brightness gradient, object contours are formed by transforming the brightness gradient modulus.
e. Increasing the accuracy of object detection and recognition on video include:
- Obtaining video and automatic extracting metadata and object attributes in frames and/or their sections in the video, segmenting the video based on the depicted situation and/or events by comparing the content of consecutive frames, composing segments with the same or similar situation, and analyzing one or more of them to detect one or more objects;
- Describing the structure of the accumulated entities in the data bank as a data type containing a sequence of parameters with,in each data type, marking the identifying parameters forming a key, selecting the parameters that may have different values in the vicinity of the standard value, developing software procedures where each parameter corresponds to a neural network, determining the order of action with non-identifying non-variable parameters, providing loading information into the data bank;
f. Reducing the consumption of computing resources while maintaining a high degree of recognition accuracy. They feed input data to the current layer of the trained neural network, process them to obtain the output data, and if the number of the current layer of the neural network is less than N, they move to the following network, if equal to N, they output the obtained output data;
g. Improving the overall performance of the hardware and software complex. It includes installing software computing nodes and the controller node with the ability to distribute data applications and system services to these blocks of the data storage subsystem, depending on the requirements, nature, and specifics of the applications and services;
h. Protecting of computer systems against unauthorized activity. The system has multilevel information security in cloud architecture, secret machine intelligence, logical security, and instant real-time response without database creation, memory, and perception based on critical thinking;
i. Simplifying the structures of one or more machine learning models and reducing the number of processing and computing resources, the work with hieroglyphs. A processing device obtains a hieroglyph image and feeds it as input information to the trained machine learning model. It determines the combination of components on the set of positions in the hieroglyph and hieroglyph classification as a specific language character based on a particular combination of components at multiple places in the hieroglyph image. This technique is applicable when working with symbols;
j. Expanding the functionality of data storage and processing includes:
- Complex analysis of input data on environmental objects and connections between them considering the initial data on environmental objects;
- Obtaining training data, using them to train the parameters of the full layer of neural network model connections, using the trained neural network model as an image recognition model;
k. Multi-video codec support. The perceptual video quality assessment system generates content-aware training data with the neural network trained with different datasets for different use cases;
l. Identification of a given voice among other voices. A pre-trained neural network performsrecognizing pre-identified by the network based on the previously recorded audio-visual data;
m. Automatic training on the available video. Using a multilevel system of non-linear data processing, it is possible by machine methods using model training to select specific features of objects, increasing the accuracy of their analysis and classification. Deep learning algorithms create self-training or use already trained model systems for recognizing faces or different kinds of objects.

4. CONCLUSION

In today's digital world, saturated with data flows, universal multifunctional systems evolve. They can solve many problems related to optimizing the use of available computing resources depending on their demand under physical constraints. Additionally, a distinctive feature of modern information systems is the heterogeneity of incoming flows of user requests due to the multifunctionality of advanced information systems, expressed in supporting various multimedia services on a single platform. Each of these services has its requirements for the performance of computing resources and, consequently, affects the entire information system.

We have found that there are currently no universal solutions capable of simultaneous distribution and balancing load between different multimedia services under physical constraints on computing resources. These problems can be solved by applying the modern cloud computing concept, according to which end users gain access to the virtual resources of a single system that controls, distributes, and balances the load between computing nodes and applications. Here, to enforce the limitation on the total amount of computing resources, we propose to develop additional models and algorithms that optimize the placement of objects and data in the information system and form the order of service requests according to the selected criteria.

This paper examined Russian organizations that developed several well-known multi-object analytics systems, analyzed the technical and functional characteristics of existing systems, collected the current information on work, and analyzed and compared the known systems of multi-object analytics. Based on the above, it identified trends for further industry development and technical solutions for the characteristics of digital telecommunication complexes for storing, processing, and forming a dynamic stream of multiformat data using AI technology. It is possible to distinguish different levels of novelty and uniqueness of the proposed solutions.

- Data analysis. Systems applying AI methods to analyze the obtained data, recognize pathologies in the early stages, and make further recommendations are absent. The largest IT companies have been working on such developments only since 2018/2019 and plan to launch solutions no earlier than 2022
- Data storage and processing. Close analogs exist, but all of these solutions have two serious disadvantages: non-compliance with information security standards of the Russian Federation and the presence of a "closed" operating code. Addressing these issues with upgrades to known algorithms makes solutions at this level unique
- Data collection, preprocessing, and transfer. A whole class of similar solutions for data collection and exchange exist. However, most well-known solutions are oriented to work with high-speed communication channels at high bandwidth

Conclusions on the underlying technologies:

- Most of the known systems do not meet or do not fully meet the requirements of the Russian Federation on information security and localization in the Russian market. With the development of solutions that meet these requirements, the resulting technologies will have high market potential in the Russian Federation
- The issue of increasing data processing speed and storage reliability remains topical for the Russian Federation and the entire world. The main priority in this direction will be the adaptation or modification of known algorithms for the developed solutions to improve efficiency and increase market potential.
- A separate direction related to the issue of multiformat data transfer and integration with the existing diagnostic equipment is related to the solution development

Therefore, it is possible to say that the issue of data processing and recognition in medicine using AI algorithms is relevant and that in demand sincethe market has several solutions only at the level of algorithms. The results of the study and analysis are presented in the table presented in this article with a comparison of the technical characteristics of existing complexes and proposals for characteristics that are promising for further implementation. The presented data can become a platform for further research, which will apparently develop toward the increasing use of AI technologies when working with media data.

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Appendix

Table 1. Literature review on the problems of developing multifunctional complexes using AI

Source	Results
[1]	This paper studies the problem of allocating communication and computational resources under the assumption that computational resources are sufficient, but the communication resources are limited. Due to cloud computing, the system has sufficient computational resources. However, since the system has a sub-channel, its communication resources may be limited. To solve problems in an energy-efficient way, this paper proposes a communication resource-aware cooperated with computation resources (CRACCR) scheme, which consists of two components: spectral multiplexing, considering the distribution of computing resources; and scaling correction. Additionally, to develop a user-friendly CRACCR scheme, the authors also developed a mechanism for evaluating user trust. Our simulation results prove the energy efficiency improvement achieved by the proposed scheme.

Table 1. Literature review on the problems of developing multifunctional complexes using AI (continue)

Source	Results
[3]	This study focuses on the economics of cloud computing. The authors focus on private unused computing resources owned by various organizations that want to form a network of cloud providers and sell services to cloud computing users. The authors address the problem of profit maximization in terms of game theory. This paper proves that a Nash equilibrium exists for this game problem. Experimental results have shown that the algorithm proposed by the authors can quickly converge to a stable state, and due to the calculation of appropriate strategies for requesting services (resources) and strategies for selling services for all organizations, the profit of organizations increases.
[4]	This paper considers an optimization algorithm based on learning without a duplicate removal step as "sanitized" learning-based optimization. It proposes three competitive strategies for paralleling the sanitized teaching learning-based optimization algorithm, which can take advantage of parallel computation. The proposed strategies demonstrated their efficiency on 14 benchmark problems and CEC'14 benchmarks with actual parameters. Additionally, this paper investigated the effect on computation time depending on the computational complexity of the target function and the number of resources. The proposed strategies can lead to a computational time reduction of up to 90% compared with the disintegrated learning-based optimization algorithm.
[5]	The authors in this paper used industrial information integration engineering (IIIE) principles for the design, development, and implementation processes of machine learning-enabled systems. This paper proposes an enterprise integration architecture with machine learning support for a university hospital designed and developed according to the IIIE guidelines.
[6]	This paper proposes a general reference architecture for an intelligent manufacturing information system based on a detailed study of 42 enterprises. The implementation path for this system results from the connection of integrated subsystems. This paper presents a comprehensive case study of this system in the automotive industry.
[8]	The peculiarity and complexity of the design of multilayer networks lie in the different requirements for the design and connectivity of the flows linking the solutions at different levels. The article's authors conducted a classification and state-of-the-art review of the design problems of multilayer networks. It focuses on applications in transportation and telecommunications, as well as solution methods.
[9]	The study on the relationship between telecommunications and economic development published in 20th century has been reviewed. It started in 1963 with the first publication of the Jipp curve. In the last decade of the century, subsequent research broadened the scope (the lack of an adequate telecommunication infrastructure is a serious drawback for any country), and also made a qualitative and quantitative jump forward.
[12]	Machine learning and AI techniques have proved useful in solving various complex problems, such as energy optimization, workflow planning, video games, and cloud computing. Combining machine learning and cloud computing algorithms helps achieve better results, providing improved cloud data center performance compared to the solutions currently used by various researchers. This study focuses on improving dynamic load balancing, task scheduling, energy consumption optimization, live migration, mobile cloud computing, and security in the cloud through machine learning classification. This study also highlights cloud services based on machine learning and the role of AI in various cloud computing platforms.
[13]	This article presents a detailed review of machine learning-based resource management solutions. It suggests promising directions for future research based on specific resource management problems and the disadvantages of existing approaches to solving these problems.
[14]	Cloud computing as a centralized and remote infrastructure creates significant communication delays that cannot meet the requirements of latency-sensitive applications. This paper proposes the concept of Edge Computing, in which cloud computing capabilities are moved closer to endpoints at the network edge. It presents a detailed overview of how edge and/or cloud computing can be combined to facilitate the solution of the task offloading problem.
[15]	The number of cloud users and corresponding workloads is increasing every day due to the benefits of cloud computing. However, it is becoming critical for service providers to maintain the quality of service (QoS) even under high workload conditions. To provide better computing services in the cloud, virtual machine (VM) migration techniques facilitate delivery services to the user without delay and with minimum energy consumption. Existing cloud computing services mainly rely on migration methods, but processing large VM migrations consumes more energy, directly affects VM performance that necessitates developing an effective VM migration strategy to perform the necessary migrations and avoid unnecessary migrations. This research presents a hybrid optimization algorithm for managing VM migration in a cloud environment. The cuckoo search optimization algorithm and particle swarm optimization algorithm are combined to obtain the proposed hybrid optimization model. This research mainly reduces power consumption, computation time, and migration costs and maximize resource usage.
[17]	Cloud security plays a vital role in establishing trust between cloud service providers, consumers, and many users to maintain a level of security for their data. This paper explores cloud security issues, existing authentication schemes, and storage technologies and offers a glimpse at artificial neural networks used to secure clouds.

Table 2. Comparison of the technical characteristics of different systems and recommended technical requirements for newly created

Parameters	Values of parameters			Recommended technical requirements
	Domestic and foreign objects of similar application			Forecast
	Intellect platform	Vocord complex	FindFace platform	
1. Data aggregation				
1.1 User authentication	Implemented in the main software	Implemented in the main software	Implemented in the main software	Availability
1.2 Database	No less than MS SQL Server 2008 R2	No less than MS SQL Server 2008 R2	Used	Availability
1.3 Formation of reports	Implemented	Implemented	Implemented	Availability
1.4 Context search using neural networks	Implemented with a neural network	The search was implemented using own algorithms	The search is implemented using own proprietary algorithms	Availability

Table 2. Comparison of the technical characteristics of different systems and recommended technical requirements for newly created (continue)

Parameters	Values of parameters			Recommended technical requirements
	Domestic and foreign objects of similar application			
	Intellect platform	Vocord complex	FindFace platform	Forecast
1.5 Graphical representation of data	Implemented, there are clients for Windows, Mac, Android, Apple	For the graphical representation of the data the internal WEB server is used	Implemented, there are clients for Windows, Mac, Android, Apple	Availability
1.6 Graphical user interface	An ergonomic interface for all platforms down to display data on large screens	An internal WEB server is used	Implemented, there are clients for Windows, Mac, Android, Apple	Availability
2. Data logistics				
2.1 Data and request flow control	Implemented	Implemented	Implemented	Availability
2.2 Received data analysis	Scenario mechanisms of analysis are implemented	Own data analytics algorithms are used	Proprietary algorithms are used, including those based on neural networks	Availability
2.3 Converting media content	Implemented	Implemented	Implemented	Availability
2.4 Metadata conversion	No data	No data	No data	Availability
2.5 Bringing into a single format	No data	No data	No data	Availability
3. Data processing				
3.1 Processing and analysis of audio and video series	Implemented	Implemented	Implemented	Availability
3.2 Image processing	Implemented	Implemented	Implemented	Availability
3.3 Generation of additional metadata	Implemented	Implemented	Implemented	Availability
4. Integration with external systems	Provided	Data on traffic violations of road traffic regulations are exported to external information systems (CARTO, DPC, etc.)	Implemented	Availability
5. Input data				
5.1 Audio data	G.711, G.726, AAC, PCM, MPEG2, LAYER2 (MP2L2), IMA ADPCM	No data about the input format in the documentation. A list of recommended equipment for obtaining audio data is provided	No data about the input format in the documentation. A list of recommended equipment for obtaining audio data is provided	Availability
5.2 Audiovisual data	All supported by MS Windows	All supported by MS Windows	No data	Availability
5.3 Visual data	MJPEG, Motion Wavelet, MPEG, H.264, MxPeg	All supported by MS Windows	No data	Availability
5.4 Descriptive data	No data	No data	No data	Availability
5.5 Subtitles	No data	No data	No data	Availability
6. Output data				
6.1 Reports at the user interface	WEB reporting is provided	WEB reporting is provided	A wide range of analytics is provided	Availability
6.2 Unloading reports	*.XLS, *.XML, *.CSV, *.PDF, TXT,	*.XLS, *.XML, *.CSV, *.PDF, TXT,	*.XLS, *.XML, *.CSV, *.PDF, TXT,	Availability
7. Mode of operation	24/7	24/7	24/7	Availability
8. Scaling	By extending the architecture based on standard software and hardware	By extending the architecture based on standard software and hardware	By extending the architecture based on standard software and hardware	Availability
9. Reliability				
9.1 Recovery time after a system crash	No data	No data	No data	Availability
9.2 Recovery time after a power failure or non-fatal OS failure	No data	No data	No data	Availability
9.3 Recovery time after a fatal hardware or OS crash	No data	No data	No data	Availability
9.4 MTBF (before system reboot)	No data	No data	No data	Availability
9.5 Probability of failure-free operation	No data	No data	No data	Availability
9.6 Complex recovery time	No data	No data	No data	Availability

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