Digital Transformation Legacy Social Service Information System

S B Popov¹², P V Khripunov²

¹Image Processing Systems Institute of RAS - Branch of the FSRC "Crystallography and Photonics" RAS, Molodogvardejskaya street 151, Samara, Russia, 443001
²Samara National Research University, Moskovskoe Shosse 34A, Samara, Russia, 443086

e-mail: s.b.popov@gmail.com

Abstract. The article considers the methodological aspects of the digital transformation of legacy social service information systems. The result of this transformation is the social service digital platform that ensure the use of new innovative technologies for processing and analysing big data, machine learning and artificial intelligence. The base of this transformation is cloud computing; big data technology; microservice architecture with container-based software development technology. We propose a person digital profile as a basis of data management in the social service digital platform. The proposed one is based on a new abstraction level of software stack – dataware. The implementation uses a microservice architecture and a container-based software development technology in according to the Data-as-a-Service concept.

1. Introduction

The improvement of social services is currently associated with the implementation of the “Government-as-a-Platform” concept [1], the most important part of this concept is the digital transformation of interaction between the government and municipal authorities and the citizens.

The public sector does not face the competitive pressure that forces the commercial companies to transform their business processes; therefore, the degree of digitalization of government bodies and the level of development of digital platforms differ significantly in various countries. However, having gained the experience of accessing a wide range of services in various areas through business platforms, the citizens expect the government as well to provide basic social services online in the most user-friendly digital format.

Currently, the social services are provided to the general public in electronic form through the internet portals of the federal and regional level, and through the information systems of various government agencies and departments. The flagship service of the kind is the Unified Portal of Public and Municipal Services and Functions, which constantly expands the range of federal and regional services provided, enlarges the user base, improves the ways of interaction with the citizens through the mobile applications of the Public Services Portal [2].
2. Basic information system architectures in the area of social services to the public

The existing solutions in the area of information systems of various government departments and authorities, which are often collectively referred to as the e-government, represent an intermediate step towards creating a target architecture for the “Government-as-a-Platform”. The global experience of creating such systems shows that, in one form or another, the e-government includes the following elements:

- Information system for the provision of public services. As a rule, it is implemented in the form of a unified portal of public services or as a system of portals of various government departments and authorities with a uniform design (user interface and appearance).
- Technological infrastructure of electronic interaction of state bodies and other state agencies or the system of interdepartmental electronic document management system.
- Identification and authentication system.

These three components were implemented differently in different countries, in different periods of time.

At the initial stage, the basic components of digital government were created in the form of an enterprise-level information system (broadly speaking) in the form of a separate application with remote user access via LAN or Internet. Information systems served the internal needs of government departments and other state authorities. The technological infrastructure of electronic interaction between the state authorities was also implemented in the form of information systems based on typical databases, which functioned as the points of information exchange between other participants of electronic document management. Currently, such systems function as an internal layer of government information systems and they do not interact directly with the external consumers of public services: individual citizens, organizations, enterprises, associations, etc.

The emergence of the concept of e-government has led to the necessity to ensure that the consumers of public services can access the information systems of state authorities. At the same time, the integrated architecture of e-government applications was focused on portals, and the portal applications were the extensions of some internal information systems of government departments.

The development of technologies for the design of complex large-scale IT-systems [3] and the introduction of methodologies based on the concept of service-oriented architecture [4] led to the development of a separate layer of e-government based on a software-defined service bus for applications and services that coordinates and integrates not only the services developed specifically for this layer, but the inherited applications as well.

At this stage of the development of e-government, the greatest impetus was given to the technological infrastructure of electronic interaction which was implemented as a service bus for applications and a set of specialized services. Elements of the identification and authentication system were also designed in the form of the services.

At the present stage, the existing applications are being upgraded gradually, monolithic applications are being transformed into distributed software systems based on data processing services and technologies, thus creating an architecture for the transition phase applications.

As soon as all the applications which used to be monolithic are transformed into processes and services, the e-government architecture is formed as a cloud of public services. The e-government applications are transformed into simple connectors to this cloud. The above architecture is a good basis for the transformation of e-government into a digital platform. At this stage, all the e-government elements, including the technological infrastructure of e-interaction, are available in the form of services, which is illustrated by the example of the X-tee platform (X-Road until 2018) in Estonia.

Australia is implementing cloud.gov.au cloud platform into the e-government, which facilitates greatly the deployment and maintenance of digital services. The cloud.gov.au platform provides a fast, secure, and standard way to modify web applications transparently for the users. This makes it easier for the government to release, monitor and expand custom digital services, and together with the Digital Marketplace online platform, the Australian government completely transforms the state procurement of digital services and simplifies access to state contracts for businesses of any size.
The development of e-government towards a truly electronic social system will turn the e-government architecture into a social cloud interacting with the cloud of public services. The latter serves as a platform for social, professional, private, voluntary and other services that should be integrated into the electronic social system.

The part of e-government that interacts with the partners is a collective extranet that is similar to popular social network tools (Facebook, LinkedIn, etc.) and e-banking. Its main functionality includes the following components:

- secure storage of short messages, documents and videos;
- specialized (including role) information and functionality;
- various services in the form of small modular applications connected as needed;
- direct channel to governmental business processes;
- uniform design (user interface and appearance) of central, regional and local authorities.

The governmental part of e-government (set of applications) is an integration and coordination resource necessary to meet the needs of partners. It is important to separate the e-government layer from the layer of the existing state information environment. This separation means operational and evolutionary independence.

3. Architectural solutions and technologies of modern digital platforms

In the conditions of digital transformation, digital platforms should ensure that the base organization uses the innovative technologies for processing and analyzing big data, machine learning and artificial intelligence, support for the Internet of things.

Conventional or legacy systems with the architecture was developed in the late 1980s, simply cannot support these technologies in an effective way, if they are able to work with such technologies at all.

The modern update of the information technology infrastructure is primarily associated with the following innovative technologies:

- cloud technologies [5];
- big data technologies for distributed fault-tolerant storage, processing and analytics [6];
- container-based technologies of software development in accordance with the microservice architecture.

3.1. Cloud technologies

The key to the emergence of cloud computing and its deployment platforms is the concept of virtualization, in which computing resources are separated from their original equipment and united into a “virtual” pool of resources. This makes it much easier for cloud providers to use software to automate the preparation and configuration of systems that traditionally require hardware-level configuration.

The initial idea of virtualizing enterprise IT resources or acquiring these resources from public cloud providers evolves and forms a more complex picture with multiple details and concepts like containers, microservices, serverless application architectures, and other types of resource management software.

Among all the variety of cloud service models, attention should be paid to the following important variations of the Platform-as-a-Service model in the view of digital platforms development:

- Integration Platform-as-a-Service (iPaaS);
- Containers-as-a-Service (CaaS).

The integration Platform as a Service (iPaaS) is a set of cloud services that provide development, implementation, and management of integration workflows that connect any combinations of local and cloud processes, services, applications, and data within one or several organizations. iPaaS can be interpreted as a system for metaprogramming of software workflows, which forms a software network of independent services by way of interconnecting them, and coordinating their interfaces with specialized connectors.
IPaaS platforms provide a centralized console for control, managing and integrating cloud applications. These tools work by connecting cloud applications/services and managing integration workflows (data transfer between services). They can accelerate product development by integrating the existing tools and expanding data through the use of external sources. Companies use these tools to scale performance, add product functionality, and structure the applications integrated. Services or data can be added or removed quickly, thus reducing failover, downtime, and development time.

There are certain intersections between the ESB (Enterprise Service Bus) and the iPaaS solutions, but they are used for different systems. iPaaS integrates cloud applications, while ESB tools are commonly used as part of enterprise information systems [7].

Containers-as-a-Service (CaaS) is a set of container-based workload management services. CaaS offers a platform for deploying and managing clusters of applications and containers by providing users with the means to run containers, the services for their orchestration and basic resources. Container management platforms facilitate the organization and virtualization of software containers, which is sometimes called operating system-level virtualization. Developers use containers to run, test, and protect applications in resource-independent environments. Containers encapsulate application components, libraries they need, or interactive program modules. Management platforms help users allocate resources to optimize performance and balance system workloads. Containers provide a flexible, portable platform for organizing, automating, and distributing applications. Companies use container management platforms to simplify container delivery to avoid the complexity of interdependent system architectures. These tools are scalable and can improve the performance of distributed applications significantly.

3.2. Big Data Technologies

The term “Big Data” can be viewed as a characteristic of extra-large data sets and as a characteristic of innovative technologies for collecting, organizing and processing data in order to extract knowledge about the phenomena and objects associated with these data sets.

A common approach in the first case is the use of the Gartner’s triad, which determines the data of extra-large volume as a combination of 3V characteristics: Volume, Velocity, Variety. Despite the fact that the original work [8] dealt with the problems of data processing technologies, and the term “Big Data” was not mentioned, a trend was set to go beyond the traditional brute force approach to data management, and a request was defined to use various new architectural solutions, which will affect significantly the set of applications and data processing strategies used by the business.

Actually, the second version of the definition shows that big data technologies are data processing technologies that are used when traditional data processing technologies based on relational databases are not applicable to solving the particular tasks.

Since then, numerous suggestions from other authors have defined the 5V of big data - two more aspects have been added: Veracity and Value.

The multiple meanings of latter aspect (Value) led to the remarkable brief Forrester’s definition which explains that Big Data encompasses "techniques and technologies that make capturing value from data at an extreme scale economical".

Summarizing the numerous discussions in this area, the following definition can be given: “Big Data technologies are the technologies for converting information into knowledge”. It should be noted that knowledge is not just information, but the information with dependencies, context, revision history (over time), model (of its receipt and use). The main difference between knowledge and data is the structure and activity: when the new facts appear in the database or the new dependencies are established, it may lead to the formation of new knowledge, and, consequently, to the changes in decision-making. Decision-making requires knowledge, not information.

Why did traditional technologies based on relational databases fail to work in the field of processing extra-large data?

Because they do not create knowledge. Traditional technologies rely on the existing knowledge provide the basis for the accumulation and interpretation of information within the existing knowledge. The traditional approach assumes that we know in advance how to use all the data stored in the data warehouse and the technology for their processing is already defined in the majority of
cases, some variations are possible, but within the framework of pre-designed procedures. Going beyond this framework is impossible or causes significant software modifications, high time costs for data conversion or reformatting. The main problem is the stage of data structuring when the data is entered into the database, the need to form a recording format in advance, according to which the information will be stored. In the case of big data, the heterogeneity of this information can be so great that the it is practically impossible to create a single storage pattern, and the number of formats for recording a single portion of information is comparable to the number of these portions.

The concept of Big Data took shape at the moment when it became clear that a huge layer of data generated by an organization, as well as its machines, people and other various sources of information related to it [9] is not recorded at all or is stored unconsciously (and remains unused) on users' computers and the company servers. Moreover, at the moment it is impossible to predict what kind of information, with what dependencies and timestamps can be claimed later, what methods will be used in its integration, processing and analysis.

Therefore, at the initial stage of the development of big data technologies, it was necessary to save all data for whatever it may be worth, to understand the existing data sources, to save all the data (probably, unstructured, “as is”) into some kind of single “large” storage.

Since the information is not structured, in accordance with the concept it is stored with all the associated links, time and space tags. However, without proper processing methods, such unstructured information is dead. The concept of Big Data actually appeared in connection with the creation of new tools for storing, processing and analyzing such information in the form of a bundle of several information technologies - distributed Google File System (GFS), scalable distributed data processing MapReduce paradigm and the distributed non-relational Bigtable database. These technologies have been developed by Google and were presented in the form of reports at several conferences [10-12].

Creation of Hadoop framework implemented as an open source Java-based project led the rapid development of big data technologies. Using the ideas of Google researchers, the Hadoop developers have created a software platform that provides distributed storage and parallel processing of unstructured data on cluster computing systems.

Until recently, the Apache Hadoop project contained four basic components:

- Hadoop Common is a set of basic modules that provide software support for other components and frameworks of the entire Hadoop infrastructure.
- Hadoop Distributed File System (HDFS) is a distributed file system that provides high-throughput access to data from a distributed application running on the Hadoop platform.
- Hadoop YARN is a framework for job scheduling and computing cluster resource management.
- Hadoop MapReduce is a system for parallel processing of large data sets using the YARN framework.

In October 2018, the Apache Hadoop Ozone project was included in the base modules. Apache Hadoop Ozone provides object storage semantics for Hadoop and uses the Hadoop Distributed Data Storage (HDDS) for the data storage level. HDDS is another new Apache Hadoop subproject.

Apache Hadoop can be viewed both as a data processing system with MapReduce as a default processing software mechanism, and as an infrastructure (ecosystem) for a range of big data processing technologies. The frameworks used within the Hadoop infrastructure are interchangeable and / or can be used together. For example, Apache Spark, a batch and stream [13-15] data processing framework, can be connected to Hadoop to replace MapReduce. A variety of processing platforms and software processing components are integrated into Hadoop to use HDFS and YARN resource manager. This inter-component interoperability is one of the reasons why Apache Hadoop is currently the base platform for big data processing.

Working with big data is not like a standard business intelligence process, where the simple addition of known values is performed: for example, the addition of data on paid invoices results in annual sales. When working with big data, the result is obtained in the process of data cleaning by sequential modeling: first a hypothesis (or even a set of hypotheses) is advanced, then a statistical, visual or semantic model (set of models) is built, it is used to check the correctness of the hypothesis
suggested, and then (but rather simultaneously) the next hypothesis is advanced (or analyzed). This process requires the researcher either to interpret the visual values [16-17] or to compile interactive requests based on knowledge, or to develop adaptive machine learning algorithms that can provide the desired result.

Traditional approaches to research involve the initial formation of a certain model, then data gathering and processing, followed by the assessment of parameters of such a pre-formed model. In the process of forming new knowledge the big data technologies integrate modeling, computational experiment and information technologies [18]. In the research process, in accordance with the big data methodology, the problem of finding a model that matches certain experimental data most closely is solved [16-17]. Moreover, this methodology is aimed at finding the most interesting (i.e., unexpected, effective) and robust (predicting future behavior) models [19].

At the present stage of development of big data technologies, there is a tendency to move away from the concept of storing all the data. More attention is paid to the aspects of Veracity and Value. The concept of data lifecycle is developed, within its framework the data management processes are developed, an understanding is formed of the way the data appeared, who is responsible for the data, and who is interested in it, what contribution the data provides to the formation of the target product - knowledge.

Data management processes acquire independent value, they produce reliable data, maintain its reliability (Veracity) [9], control the relevance of specific data, evaluate its contribution to the creation of surplus value (Value), predict the appropriateness of subsequent storage of particular data.

3.3. Microservice architecture and containers

Microservice architecture [20] is an architectural approach that focuses on the decomposition of applications into interacting, functionally simple, loosely coupled services, which ensures the delivery and support of complex software systems with the speed and quality required for modern digital business. Microservices can be used to break a large monolithic application into smaller and simpler services. Each microservice implements one function, and works fine, so “micro” in microservice refers to the scope of service functionality, and not to the number of lines of code.

Microservices are independent of the programming language, platform and operational system. Currently, the main tool for this independence is the container technology [21].

The microservice approach is often inefficient at creating simple applications and is better suited to complex applications that are developed over a period of time, with large code bases and commands. Microservices are ideal for many business functions, with each microservice focusing on implementing one business function or sub-function. Teams can independently upgrade the code to suit their own plan.

The key factors driving this style of architecture are the ability to quickly update an application and the significant reduction of time required to prepare a new release.

The concept of microservices is similar to service-oriented architecture (SOA). When comparing the concepts of SOA (service-oriented architecture) and microservice architecture, we should note that the microservice architecture is a divide-by-minimum-parts-possible architecture pattern that emphasizes the concept of context delineation, whereas SOA is a divide-by-maximum-parts-possible architectural pattern, which emphasizes the reusability of abstractions and business functions.

4. Methodological aspects of information systems transformation into digital platforms

The modernization of an information system is a complex and long process. Its starting point is often the decision not to rewrite the existing systems, but to transform them. Such a decision is usually made due to the fact that the organization accumulates a huge number of previous developments, many of which are written on obsolete languages and hardly allow further development and support.

The existing information systems based on service-oriented architecture (the most common case nowadays) can be transferred efficiently into cloud-based tool platforms that will provide the necessary level of scalability and adaptability according to the IaaS model. The presence of a service model allows to use the modules of existing information systems and implement the expanded
functionality of the digital platform either through direct use of the existing software interface of the modules or through the development of specialized adapters to them.

Further direction of modernization is associated with a decrease in system coupling due to the division of functional modules of an information system into separate independent services developed and integrated into a single environment on a selected platform that provides services on the PaaS model or on the CaaS model in the case of transition to the micro-service software architecture.

Reorganization of the existing database layer of systems is usually not required or is minor. However, this does not mean that the mechanisms of data storage and data access arrangement do not change during the transition to the digital platform model. On the contrary, the creation of a digital platform assumes that the newest technologies of big data analysis and distributed storage will be used, which will provide a high level of scaling, transparent use of modern data analysis methods, and decision making using the elements of artificial intelligence [19, 22-23].

At the same time, the existing databases can be used as one of the sources in the formation of a common data lake of target platform. In the process of the target platform development, there may be a need to create replicas of the existing databases, split them into the required domains, or use complex scaling schemes to fulfil a wider range of needs for all components of the platform. As a rule, further scenarios of inherited databases integration involve the transfer of all data to data warehouses based on the modern distributed data processing platforms.

4.1. Dataware layer

At present, an understanding is being formed that it is necessary to introduce a new layer into the enterprise software stack — dataware.

The dataware is a level of abstraction that allows to manage data as the most important corporate resource, separated from any other dependencies. The introduction of a new software layer ensures much lower total cost of ownership when managing data in different storages and applying a wide range of data processing technologies and tools and, more importantly, it allows to extract quicker competitive knowledge from data [7].

Previous generations of data management systems were the point-based products or tools aimed at solving a specific problem. As a concept, this is similar to network devices or services considered as a manageable resource. The dataware handles efficiently various types of data, data access methods and system tools necessary to manage data as an enterprise resource, regardless of the basic infrastructure and location.

The dataware provides enterprises with a consistent approach to managing and protecting data. A set of standard APIs allows data to be used by a wide range of applications and tools. The variety and large amount of data can be handled due to the possibility of processing data in different places using both local and cloud hardware infrastructure, as well as containers.

The dataware optimizes the entire data lifecycle — from acquisition to processing — in order to support applications that require real-time analytics, machine learning, and artificial intelligence at the same time [17, 20-21]. The dataware provides complete flexibility when using the basic infrastructure (local, cloud or container infrastructure) and deployment patterns (hybrid or multi-cloud).

Thus, legacy monolithic information systems require a fundamental transformation in order to integrate their elements into the target digital platform. More modern information systems based on service-oriented architecture can first be slightly upgraded by deploying them in a cloud infrastructure (IaaS), followed by adaptation allowing to use most of their individual components on a platform architecture (PaaS).

Databases used in information systems are connected to target platforms as one of the data sources serving for the initial filling of the basic information layer of the platform, but as the platform functions and develops, the data from the legacy databases will gradually move to the distributed data processing target platform.
5. Design solutions for implementing a digital profile of a person on the social services platform

Transformation of informational systems into digital platforms for providing social services to the public based on the introduction of a new dataware layer and the use of microservices forms a new approach to organizing data management based on the concept of a person’s digital profile.

It is the digital profile of a citizen that is reasonable to choose as a basic accounting unit when establishing Government-as-a-Platform [1].

The authors suggest to use the concept of Data-as-a-Service to implement this approach [24]. In this case, the major design decisions develop and adapt the principles of Big Data technology in relation to the tasks of information support of the provision of social services to the public: (1) all components of the data management system are implemented as services hosted in a cloud computing environment; (2) the integration solution uses the service federation, i.e. a decentralized combination of equal services interacting with each other; (3) the basic structural storage unit in the system is a digital profile of a person, which is available to the user as a separate storage service with its unique name in the service federation; (4) digital profile services use the principle of in-memory data processing and storing; (5) services are registered in a distributed repository, which provides a grouping of all services by the type they declare; (6) the person’s digital profile processing uses a data-oriented approach, in which we move the code to the data and perform the processing at where the data is stored; (7) during the processing, the data of the digital profile of a person does not change, but a new entity is added to its dependencies, which is verified using a separate data processing process launched independently in the background, providing the user with the data and the functions required (most often, visualization) immediately after they are created / updated.

The service of the person’s digital profile ensures independently the formation of reliable data for third-party data processing services, maintains its reliability, controls the relevance of particular profile entities, and manages the life cycle of storage of its data components. The digital profile of a person forms a graph of informational connections, describing all the digital traces left by the person when interacting with the digital environment [25]. The service of the digital profile of a specific person provides a secure, isolated connection with identification, data protection and information disclosure systems. This concept is fully compatible with the system of biometric identification based on face and voice recognition that is planned for implementation in public services [26-28]. Further development of the Internet of Things will enhance the digital traceability of data associated with a particular person, will help shape the medical component of the person’s profile, predict the person's product preferences, social behavior, personalize and predict the person’s life routes.

The digital profile-as-a-service will enable the transition from the provision of single digital services to the proactive provision of services using the technologies and tools to form the processes of interaction between the person and the state to provide the full range of interrelated services in a particular life situation.

In this case, the formation of workflow processes is performed within the framework of an integration platform (iPaaS), which integrates digital profile services and processing services into a program flow using metaprogramming based on specialized templates that describe the process of provision of services in accordance with the necessary regulations.

For social digital platforms the proposed approach provides a transparent use of innovative technologies for processing and analyzing big data in real time, machine learning and artificial intelligence, support of the Internet of Things technologies.

6. References

[1] Shklyaruk M 2019 State as a platform: People and technologies (Russian Presidential Academy of National Economy and Public Administration) p 111
[2] The results of work of the Unified portal of public services in 2018 Ministry of Digital Development, Communications and Mass Media of the Russian Federation URL: https://digital.gov.ru/ru/events/38738/ (03.03.2019)
[3] Kazanskiy N L and Popov S B 2012 The distributed vision system of the registration of the railway train Computer Optics 36(3) 419-428
[4] Volotovsky S G, Kazanskiy N L, Popov S B and Serafimovich P G 2010 Evaluation of the performance of applications in parallel image processing Computer Optics 34(4) 567-572
[5] Kazanskiy N L and Serafimovich P G 2013 Cloud computing for nanophotonic simulations Lecture Notes in Computer Science 7715 54-67 DOI: 10.1007/978-3-642-38250-5_7
[6] Kazanskiy N L and Popov S B 2012 Distributed storage and parallel processing for large-size optical images Proceedings of SPIE 8410 841001 DOI: 10.1117/12.928441
[7] Surnin O L, Sitnikov P V, Ivaschenko A V, Ilyasova N and Popov S B 2017 Big data incorporation based on open services provider for distributed enterprises CEUR Workshop Proceedings 1903 42-47
[8] Laney D 2001 3D Data Management: Controlling Data Volume, Velocity and Variety Application Delivery Strategies 949 URL: http://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf.
[9] Evsutin O O, Kokurina A S and Meshcheryakov R V 2019 A review of the methods of embedding information in digital objects for security in the Internet of things Computer Optics 43(1) 137-154 DOI: 10.18287/2412-6179-2019-43-1-137-154
[10] Ghemawat S, Gobioff H and Leung S-T 2003 The Google file system Proceedings of the 19th ACM Symposium on Operating Systems Principles 29-43
[11] Dean J and Ghemawat S 2004 MapReduce: Simplified Data Processing on Large Clusters Proceedings of the Sixth Symposium on Operating System Design and Implementation 137-150
[12] Chang F, Dean J, Ghemawat S, Hsieh W C, Wallach D A, Burrows M, Chandra T, Fikes A and Gruber R E 2006 Bigtable: A Distributed Storage System for Structured Data Proceedings of the 7th Symposium on Operating Systems Design and Implementation 205-218
[13] Protsenko V I, Serafimovich P G, Popov S B and Kazanskiy N L 2016 Software and hardware infrastructure for data stream processing CEUR Workshop Proceedings 1638 782-787 DOI: 10.18287/1613-0073-2016-1638-782-787
[14] Kazanskiy N L, Protsenko V I and Serafimovich P G 2014 Comparison of performance of streaming data analysis systems as applied to the problem of image processing with a sliding window method Computer Optics 38(4) 804-810
[15] Protsenko V I, Kazanskiy N L and Serafimovich P G 2015 Real-time analysis of parameters of multiple object detection systems Computer Optics 39(4) 582-591 DOI: 10.18287/0134-2452-2015-39-4-582-591
[16] Smelkina N A, Kosarev R N, Nikonorov A V, Bairikov I M, Ryabov K N, Avdeev A V and Kazanskiy N L 2017 Reconstruction of anatomical structures using statistical shape modeling Computer Optics 41(6) 897-904 DOI: 10.18287/2412-6179-2017-41-6-897-904
[17] Nikonorov A V, Petrov M V, Bibikov S A, Kutikova V V, Morozov A A and Kazanskiy N L 2017 Image restoration in diffractive optical systems using deep learning and deconvolution Computer Optics 41(6) 875-887 DOI: 10.18287/2412-6179-2017-41-6-875-887
[18] Popov S B 2015 The Big Data methodology in computer vision systems CEUR Workshop Proceedings 1490 420-425 DOI: 10.18287/1613-0073-2015-1490-420-425
[19] Kropotov Y A, Proskuryakov A Y and Belov A A 2018 Method for forecasting changes in time series parameters in digital information management systems Computer Optics 42(6) 1093-1100 DOI: 10.18287/2412-6179-2018-42-6-1093-1100
[20] Lewis J and Fowler M 2014 Microservices URL: https://martinfowler.com/articles/microservices.html (03.03.2019)
[21] Kane S and Matthias K 2018 Docker: Up and Running: Shipping Reliable Containers in Production (O’Reilly Media Inc.) p 352
[22] Kazanskiy N L and Popov S B 2010 Machine vision system for singularity detection in monitoring the long process Optical Memory and Neural Networks (Information Optics) 19(1) 23-30 DOI: 10.3103/S1060992X10010042
[23] Shatalin R A, Fidelman V R and Ovchinnikov P E 2017 Abnormal behavior detection based on dense trajectories Computer Optics 41(1) 37-45 DOI: 10.18287/2412-6179-2017-41-1-37-45
[24] Popov S 2017 Software threads of distributed image processing based on microservices CEUR Workshop Proceedings 1989 215-220
[25] Rytsarev I A, Kirsh D V and Kupriyanov A V 2018 Clustering of media content from social networks using bigdata technology Computer Optics 42(5) 921-927 DOI: 10.18287/2412-6179-2018-42-5-921-927
[26] Kalinovskii I A and Spitsyn V G 2016 Review and testing of frontal face detectors Computer Optics 40(1) 99-111 DOI: 10.18287/2412-6179-2016-40-1-99-111
[27] Nikitin M Y, Konushin V S and Konushin A S 2017 Neural network model for video-based face recognition with frames quality assessment Computer Optics 41(5) 732-742 DOI: 10.18287/2412-6179-2017-41-5-732-742
[28] Sorokin V N, Vyugin V V and Tananykin A A 2012 Voice identification: analytical review Information Processes 12(1) 1-30

Acknowledgements
This work has been supported by the Ministry of Science and Higher Education of the Russian Federation as part of the works on the State Task of the Federal Research Center for Crystallography and Photonics of the Russian Academy of Sciences - Agreement No. 007-GZ/Ch3363/26. This article contains the results of a project carried out as part of the implementation of the Program of the Center for Competence of the National Technology Initiative "Center for Storage and Analysis of Big Data", supported by the Ministry of Science and Higher Education of the Russian Federation under the Treaty of Moscow State University with the Fund for Support of Projects of the National Technology Initiative No. 13/1251/2018 dated December 11, 2017.