Microservices-based architecture for biomedical image processing software*

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Abstract

At the stage of diagnosis, cytological, histological, immunohistochemical images are actively used. A feature of this type of processing is the need for a large amount of processed data and the complexity of calculations. Currently, the image classification process is actively used not only by using computer vision algorithms, but also by means of deep machine learning. To develop high-quality software that combines conventional data processing algorithms and deep learning approaches, it is necessary to develop an improved version of monolithic architecture, namely microservice architecture, which is characterized by an increased level of reliability. In this work, a microservice architecture is proposed for performing the tasks of image processing by means of computer vision and using convolutional neural networks for classification and U-net networks for automatic segmentation.

Keywords

Microservices, biomedical images, deep learning, software architecture, image processing, neural networks.

1. Introduction

In modern processing of biomedical images based on the calculation of quantitative characteristics and deep learning, it is especially important to ensure high performance, flexibility and scalability of systems. Traditional typical monolithic architectures in most cases cannot meet the needs of real-time, efficient processing of large volumes of data and rapid adaptation. Microservice architecture is a powerful tool that allows you to divide a system into independent services, each of which performs specific tasks and can be deployed, scaled, and updated separately.

Biomedical images, in particular cytological, histological, immunohistochemical, are used to diagnose cancer by analyzing the characteristics of micro-objects (cell nuclei). The difficulty lies in the automatic selection of cell data and image classification by means of artificial intelligence to facilitate diagnosis and improve the quality of work of doctors.

To carry out the analysis of biomedical images, it is necessary to analyze both the quantitative characteristics of the studied objects and the graphic images as a whole. Quantitative characteristics are developed by segmenting images and extracting cell nuclei. At the next stage, the quantitative characteristics of the cores are calculated, such as the area, the brightness level, the average value of the RGB channels.

Deep learning tools are used for the tasks of image classification using convolutional neural networks or the task of image segmentation using U-net networks for further selection of the studied cell nuclei and calculation of their characteristics (area, brightness, etc.).

The advantages of microservice architecture for biomedical image processing systems based on deep learning are its ability to efficiently work with large volumes of data, provide high availability and flexibility, and facilitate the integration of new algorithms and technologies. The main aspects of microservice architecture include:

- division into small services;

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- facilitation of failure management;
- decentralized data management;
- horizontal scaling;
- communication via API.

The purpose of this work is to design a software system to perform the tasks of calculating the quantitative characteristics of objects and classifying, segmenting images using deep learning tools based on microservice architecture in order to improve the reliability and quality of the complex system.

The scientific novelty consists in the development of a microservice architecture for a biomedical image processing system with elements of computer vision and deep learning algorithms to perform classification and segmentation tasks.

The practical value lies in the software implementation of microservice architecture based on Laravel, vue.js, Java, OpenCV, Tensorflow, keras technologies.

2. Literature review

Scientists pay considerable attention to approaches to the development of software with elements of artificial intelligence, since such software systems require a significant amount of resources and are often executed in cloud environments. In addition, software developers and researchers have faced the problem of low reliability of traditional monolithic approaches to designing software systems. In [1], the author analyzes microservice architectures and evaluates their advantages. In the work [2], the authors pay considerable attention to the use of Docker and, in general, the problem of containerization for the implementation of microservice architecture of various levels of complexity. The authors in [3] analyze the microservice architecture in terms of the use of cloud technologies for the implementation of complex systems with high load. A generalized approach to the analysis of modern approaches to the analysis and development of software is considered in [4]. The principles of using cloud technologies are discussed in works [5-7]. The use of blockchain technology for the design and development of microservice architecture is considered in [8]. Examples of designing and developing software systems for the task of processing immunohistochemical, cytological, and histological images are given in works [9-11]. A feature of these works is the use of deep learning tools to solve the problem of classification and segmentation. The use of cloud technologies in image processing tasks using Docker technology is given in [12], the features of using cloud technologies for the task of segmentation are considered in [13]. Features of segmentation of biomedical images in cloud services are discussed in [14]. A significant role in calculations is played by the process of vaporization and the use of graphics processors to speed up calculations [15,16]. The use of cloud services as a means of classifying histological images is considered in [17].

3. Problem statement

Combining a large number of software modules to ensure the operation of a software system leads to an increase in its complexity and a decrease in reliability. In this study, a microservice architecture is proposed. For its implementation, the following tasks must be completed:

- analyze the existing biomedical image processing systems;
- specify the requirements for the developed software;
- develop the architecture of the software system based on the microservice approach;
- to conduct a comparative analysis of the obtained results.

4. Architecture of a microservice image processing system

The design of hardware and software systems based on microservice architecture is currently gaining particular popularity. The difference of the microservice architecture compared to the monolithic one is in increasing the reliability of the system and at the same time decomposition and increasing the complexity of the development.

A feature of processing biomedical images is the need to pay attention to pre-processing of data, selection of quantitative and qualitative characteristics in the image and direct processing of the images themselves. To calculate the quantitative characteristics, it is necessary to implement the stages of image processing, selection of features for research, calculation of their characteristics, storage in the database and further processing.

The use of deep learning elements in the image processing system requires significant computing resources and the need to use specialized libraries. This necessity contrasts with the requirements for the development of typical systems for data processing in medicine.

4.1. The architecture of the developed system based on the microservice approach

Microservice architecture has significant advantages compared to monolithic ones, especially when developing systems that use specialized libraries and development tools. To implement the task, it is necessary to design a complex architecture and take into account many key points that will allow to develop a safe and reliable system with specialized distribution of functionality among system users.

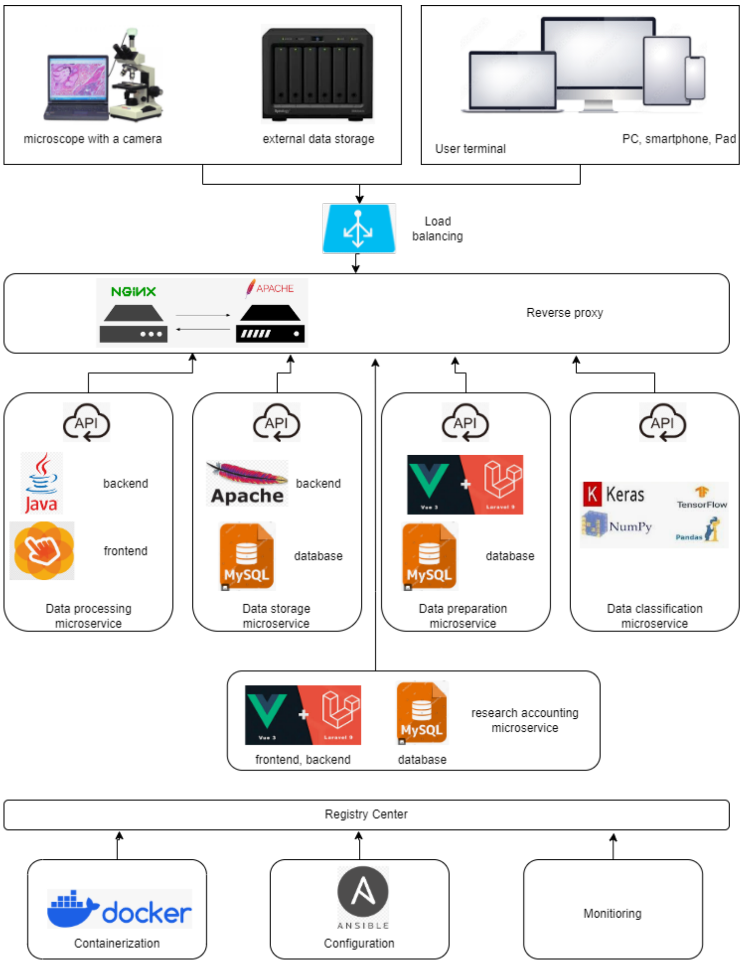

Figure 1: Architecture of the developed system with elements of microservices

For example, users working with research records do not need to configure the convolutional neural network module and vice versa. The possibility of using a microservice approach significantly increases the isolation and reliability of software modules connected to each other through an API interface.

In the microservice architecture, the API (Application Programming Interface) plays a key role, providing interaction between different microservices, as well as their communication with external systems. Since each microservice is an independent component with its own logic and often a database, an API acts as an interface through which these components exchange data and interact.

4.2. Data processing

Data processing is one of the determining factors in this system, since this module is responsible for selecting objects in the image (cell nuclei) and calculating their quantitative characteristics. The backend part is implemented in the Java programming language and using the OpenCV library. UML - a class diagram for implementing the functionality of selecting input image parameters for further processing is shown in Figure 2.

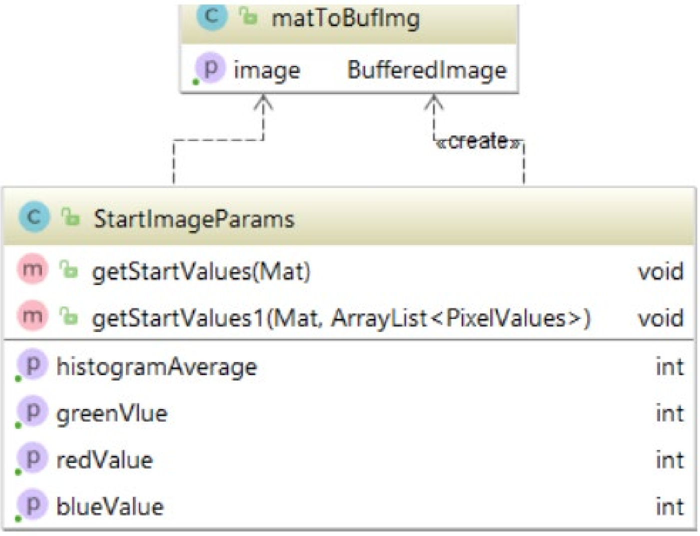

Figure 2: UML – diagram "StartImageParams"

The JavaFX framework was chosen as the front-end part, which allows you to develop a convenient and functional modern interface. JavaFX enables the creation of modern user interfaces with rich graphical capabilities. It supports extensive customization of components, as well as animations, graphics, and multimedia, allowing developers to create visually appealing and interactive applications.

4.3. Data storage

There are two main approaches to data storage:

- use of the mysql database to store records in the relational database. This database contains research records and results of calculation of input image parameters and results of processing cell nuclei. Algorithms and algorithm input parameters are also stored in the database.
- images are stored on disk space with a specific name in an encrypted form. It is assumed that the data sets will be stored in the cloud storage and will be divided into training, test and validation samples.

4.4. Data preparation

Pre-processing of data involves the presence of a module for preparing data for processing by computer vision algorithms, in particular using filtering algorithms, adjusting the level of brightness, contrast, and segmentation algorithms. In addition, this module provides functionality for preparing images for training using neural networks. In particular, the selection of width, height, type of images, color gamut, proportion of distribution between test, training and validation sample for conducting a specific study. To implement the task, Laravel frameworks were used as the backend and vue.js for the development of the graphical interface.

4.5. Data classification

The classification module is one of the most important and resource-intensive in this system, as it involves the use of deep learning algorithms, such as convolutional neural networks and U-net - networks for image segmentation. Keras, tensorflow, and other additional libraries are used for processing and visualization of research results.

4.6. REST API

The REST API mechanism was used to implement interaction between microservices. It is also possible to protect information transmitted through communication channels. A modern mechanism based on JWT tokens is used to ensure interaction between the web system and the application program.

To work with the web system, you must be a registered user. The user needs to generate his own token. An example of a simple query to store trial and patient information is shown in Figure 3.

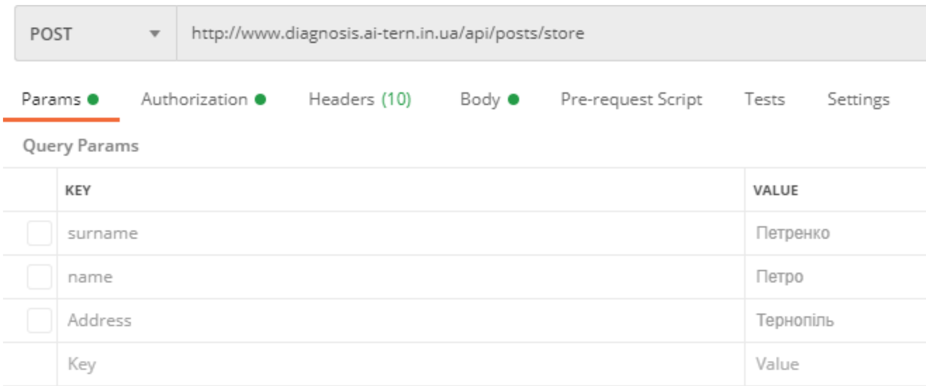

Figure 3: An example of a simple query to store information about a trial and a patient

The format of the request depends on the task, for example, image parameters and results of studies that have been carried out locally can be transferred. Using the REST API, it is possible to transfer data to the server for further storage in the database.

5. Computer experiments

An example of the graphical interface is shown in Figure 4. This page is intended for storing research results. Research information is completed via a web interface or by transferring data through a dedicated API.

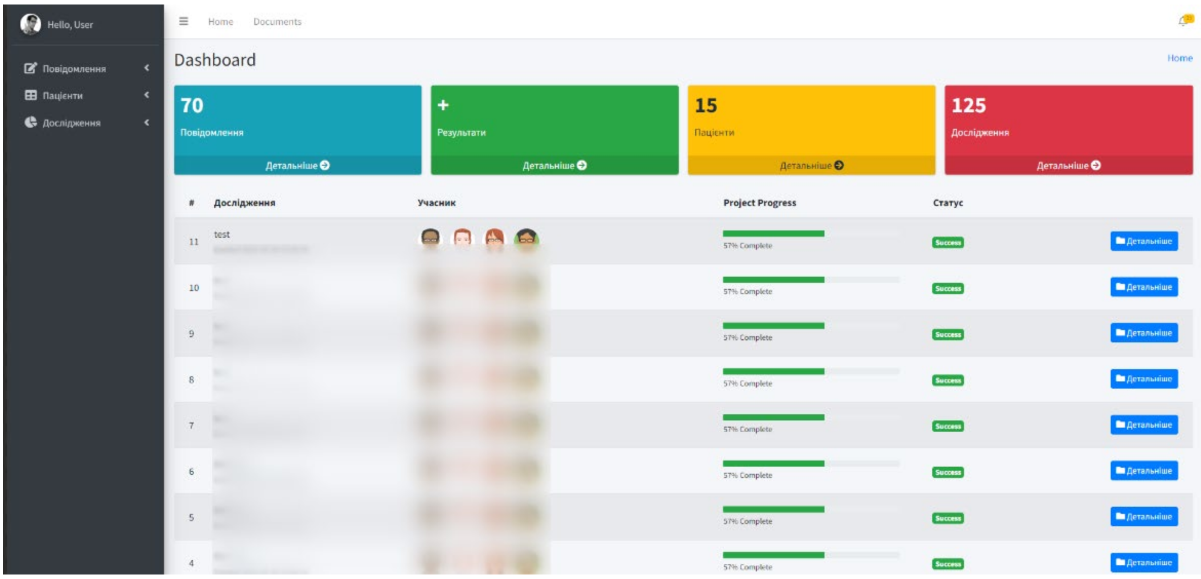

Figure 4: Home page for viewing research

The web interface is a convenient mechanism for viewing and managing information, in addition, the data is stored in a common database. In this way, changes are made locally - they are transferred to a shared server, which increases convenience and reliability. Examples of immunohistochemical images are shown in Figure 5.

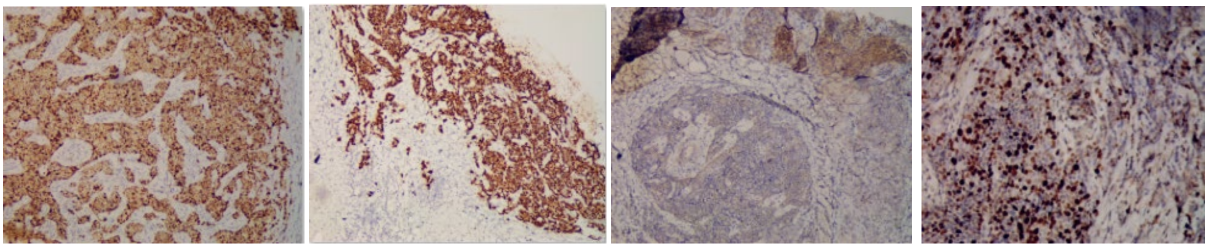

Figure 5: Examples of immunohistochemical images

A comparative analysis of modern systems used for diagnosis using immunohistochemical studies is given in Table 1.

Table 1
Comparative analysis of modern systems used for diagnosis

Software	Image Preprocessing algorithm	Segmentation algorithm	KI-67	HER2/n	API for interaction with third-party services	GUI
Leicabiosystems	+	+	-	-	+/-	+
epredia	+	+	-	-	+/-	+
ImageJ	+	+	+/-	+/-	-	+/-
HIAMS	+	+	+/-	+/-	-	+
Developed software	+	+	+	+	+	+

Based on the results of the research, it can be concluded that the developed system has a larger set of functionality, and is also implemented in the form of a microservice architecture for the distribution of functionality and increasing the reliability of the system.

6. Conclusions

In this work, a microservice architecture is proposed for performing the tasks of processing biomedical images.

- existing biomedical image processing systems were analyzed, which made it possible to highlight their functional advantages and disadvantages; to develop own microservice architecture;
- the architecture of the software system for processing biomedical images was developed using elements of computer vision and deep learning based on a microservice approach, which made it possible to increase the reliability of the system by isolating individual modules;
- the conducted comparative analysis demonstrated the advantage of the proposed system in comparison with analogues, in particular the presence of an API interface for communication between modules.

Declaration on Generative AI

The author(s) have not employed any Generative AI tools

References

[1] Kruisz, Manuel. "Evaluation of microservice implementation approaches for image processing." PhD diss., Wien, 2020.

[2] Brogi, Antonio, Davide Neri, and Jacopo Soldani. "A microservice-based architecture for (customisable) analyses of Docker images." Software: Practice and experience 48, no. 8 (2018): 1461-1474. https://doi.org/10.1002/spe.2583

[3] J. Lotz, A. Vogelsang, O. Benderius and C. Berger, "Microservice Architectures for Advanced Driver Assistance Systems: A Case-Study," 2019 IEEE International Conference on Software Architecture Companion (ICSA-C), Hamburg, Germany, 2019, pp. 45-52, doi: 10.1109/ICSA-C.2019.00016.

[4] Liu, Xiaobin, Weijia Liu, Siyuan Yi, and Jinyang Li. "Research on Software Development Automation Based on Microservice Architecture." In Proceedings of the 2020 International Conference on Aviation Safety and Information Technology, pp. 670-677. 2020. https://doi.org/10.1145/3434581.3434711

[5] V. Singh and S. K. Peddoju, "Container-based microservice architecture for cloud applications," 2017 International Conference on Computing, Communication and Automation (ICCCA), Greater Noida, India, 2017, pp. 847-852, doi: 10.1109/CCAA.2017.8229914.

[6] Sergi, Ilaria, Marco Leo, Pierluigi Carcagnì, Marco La Franca, Cosimo Distante i Luigi Patrono. "A Microservices Architecture based on a Deep-learning Approach for an Innovative Fruition of Art and Cultural Heritage." Journal of Communications Software and Systems 18, br. 2 (2022): 184-194. https://doi.org/10.24138/jcomss-2022-0001

[7] T. Cerny, A. S. Abdelfattah, V. Bushong, A. Al Maruf and D. Taibi, "Microservice Architecture Reconstruction and Visualization Techniques: A Review," 2022 IEEE International Conference on Service-Oriented System Engineering (SOSE), Newark, CA, USA, 2022, pp. 39-48, doi: 10.1109/SOSE55356.2022.00011.

[8] D. Nagothu, R. Xu, S. Y. Nikouei and Y. Chen, "A Microservice-enabled Architecture for Smart Surveillance using Blockchain Technology," 2018 IEEE International Smart Cities Conference (ISC2), Kansas City, MO, USA, 2018, pp. 1-4, doi: 10.1109/ISC2.2018.8656968.

[9] Berezsky, O., Pitsun, O., Datsko, T., Tsmots, I. , Teslyuk, V. Specified diagnosis of breast cancer on the basis of immunogistochemical images analysis. CEUR Workshop Proceedings, 2020, 2753, pp. 129–135 https://ceur-ws.org/Vol-2753/short5.pdf

[10] Berezsky, Oleh, Oleh Pitsun, Grygoriy Melnyk, Tamara Datsko, Ivan Izonin, and Bohdan Derysh. 2023. "An Approach toward Automatic Specifics Diagnosis of Breast Cancer Based on an Immunohistochemical Image" Journal of Imaging 9, no. 1: 12. https://doi.org/10.3390/jimaging9010012

[11] Berezsky, O. , Pitsun, O. , Melnyk, G. , Derysh, B. , Liashchynskyi, P. Application Of MLOps Practices For Biomedical Image Classification. CEUR Workshop Proceedings, 2022, 3302, pp. 69–77 https://ceur-ws.org/Vol-3302/short3.pdf
[12] González, Germán, and Conor L. Evans. "Biomedical Image Processing with Containers and Deep Learning: An Automated Analysis Pipeline: Data architecture, artificial intelligence, automated processing, containerization, and clusters orchestration ease the transition from data acquisition to insights in medium-to-large datasets." BioEssays 41, no. 6 (2019): 1900004.
[13] Rajput, Amitesh Singh, Vishesh Kumar Tanwar, and Balasubramanian Raman. "-Score-Based Secure Biomedical Model for Effective Skin Lesion Segmentation Over eHealth Cloud." ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM) 17, no. 2s (2021): 1-19. https://doi.org/10.1145/3430806
[14] Navale, Vivek, and Philip E. Bourne. "Cloud computing applications for biomedical science: A perspective." PLoS computational biology 14, no. 6 (2018): e1006144. https://doi.org/10.1371/journal.pcbi.1006144
[15] O. Berezsky, O. Pitsun, B. Derish, K. Berezska, G. Melnyk and Y. Batko, "Adaptive Immunohistochemical Image Pre-processing Method," 2020 10th International Conference on Advanced Computer Information Technologies (ACIT), Deggendorf, Germany, 2020, pp. 820-823, doi: 10.1109/ACIT49673.2020.9208920.
[16] Berezsky, O. , Pitsun, O. , Batryn, N. , ... Berezska, K. , L.Dubchak, Modern automated microscopy systems in oncology. CEUR Workshop Proceedings, 2018, 2255, pp. 311–325 https://ceur-ws.org/Vol-2255/paper28.pdf
[17] Abhinav Kumar, Sanjay Kumar Singh, K Lakshmanan, Sonal Saxena, and Sameer Shrivastava. 2021. A Novel Cloud-Assisted Secure Deep Feature Classification Framework for Cancer Histopathology Images. ACM Trans. Internet Technol. 21, 2, Article 52 (June 2021), 22 pages. https://doi.org/10.1145/3424221