

MUHANDISLIK

& IQTISODIYOT

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ИМЕНИ Г.В. ПЛЕХАНОВА
ТАШКЕНТСКИЙ ФИЛИАЛ



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- 05.01.01 – Muhandislik geometriyasi va kompyuter grafikasi. Audio va video texnologiyalari
- 05.01.02 – Tizimli tahlil, boshqaruv va axborotni qayta ishlash
- 05.01.03 – Informatikaning nazariy asoslari
- 05.01.04 – Hisoblash mashinalari, majmualari va kompyuter tarmoqlarining matematik va dasturiy ta'minoti
- 05.01.05 – Axborotlarni himoyalash usullari va tizimlari. Axborot xavfsizligi
- 05.01.06 – Hisoblash texnikasi va boshqaruv tizimlarining elementlari va qurilmalari
- 05.01.07 – Matematik modellashtirish
- 05.01.11 – Raqamli texnologiyalar va sun'iy intellekt
- 05.02.00 – Mashinasozlik va mashinashunoslik
- 05.02.08 – Yer usti majmualari va uchish apparatlari
- 05.03.02 – Metrologiya va metrologiya ta'minoti
- 05.04.01 – Telekommunikatsiya va kompyuter tizimlari, telekommunikatsiya tarmoqlari va qurilmalari. Axborotlarni taqsimlash
- 05.05.03 – Yorug'lik texnikasi. Maxsus yoritish texnologiyasi
- 05.05.05 – Issiqlik texnikasining nazariy asoslari
- 05.05.06 – Qayta tiklanadigan energiya turlari asosidagi energiya qurilmalari
- 05.06.01 – To'qimachilik va yengil sanoat ishlab chiqarishlari materialshunosligi
- 05.08.03 – Temir yo'l transportini ishlatish
- 05.09.01 – Qurilish konstruksiyalari, bino va inshootlar
- 05.09.04 – Suv ta'minoti. Kanalizatsiya. Suv havzalarini muhofazalovchi qurilish tizimlari
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- 10.00.04 – Yevropa, Amerika va Avstraliya xalqlari tili va adabiyoti
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- 08.00.15 – Tadbirkorlik va kichik biznes iqtisodiyoti
- 08.00.16 – Raqamli iqtisodiyot va xalqaro raqamli integratsiya
- 08.00.17 – Turizm va mehmonxona faoliyati

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DIGITAL METHODS FOR MONITORING HAND HYGIENE AND AUTOMATIC NAIL SEGMENTATION USING COMPUTER VISION TECHNOLOGIES540

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Abstract. Compliance with hand hygiene is one of the key factors in preventing infectious diseases and ensuring patient safety in healthcare institutions. In recent years, digital technologies have been increasingly introduced to automate the monitoring of sanitary and hygienic procedures. This study examines modern computer vision and machine learning methods for analyzing the condition of hands and determining nail growth parameters.

The aim of this research is to develop a digital approach to monitoring hand hygiene based on the analysis of nail plate images and the application of segmentation algorithms. As part of the study, a dataset of nail images was created, data preprocessing was performed, and the effectiveness of several segmentation models, including U-Net, Mask R-CNN, and YOLOv8-seg, was evaluated.

The results of the study demonstrated that the use of deep learning models provides high segmentation accuracy and allows automatic detection of nail boundaries and the grown part of the nail. Among the tested models, Mask R-CNN showed the highest accuracy indicators. The obtained results confirm the potential of artificial intelligence technologies for digital monitoring of hand hygiene and prevention of infectious disease spread in healthcare institutions.

Keywords: hand hygiene, computer vision, image segmentation, deep learning, Mask R-CNN, YOLOv8, medical information technologies, healthcare digitalization.

Annotatsiya. Qo'l gigiyenasiga rioya qilish yuqumli kasalliklarning oldini olish hamda tibbiyot muassasalarida bemorlar xavfsizligini ta'minlashning muhim omillaridan biri hisoblanadi. So'nggi yillarda sanitariya-gigiyena jarayonlarini monitoring qilishni avtomatlashtirish maqsadida raqamli texnologiyalar keng joriy etilmoqda. Mazkur tadqiqotda qo'llarning holatini tahlil qilish va tirnoq o'sishi parametrlarini aniqlash uchun zamonaviy kompyuter ko'rish hamda mashinaviy o'rganish usullari o'rganildi.



Tadqiqotning maqsadi tirnoq plastinkasi tasvirlarini tahlil qilish va segmentatsiya algoritmlaridan foydalanish asosida qo'l gigiyenasini monitoring qilishning raqamli yondashuvini ishlab chiqishdan iborat. Tadqiqot doirasida tirnoq tasvirlari ma'lumotlar to'plami yaratildi, ma'lumotlar oldindan qayta ishlash jarayonidan o'tkazildi hamda U-Net, Mask R-CNN va YOLOv8-seg kabi bir nechta segmentatsiya modellari samaradorligi baholandi.

Tadqiqot natijalari chuqur o'rganish modellari yuqori segmentatsiya aniqligini ta'minlashini hamda tirnoq chegaralarini va tirnoqning o'sib chiqqan qismini avtomatik aniqlash imkonini berishini ko'rsatdi. Sinovdan o'tkazilgan modellar orasida Mask R-CNN eng yuqori aniqlik ko'rsatkichlarini namoyish etdi. Olingan natijalar sun'iy intellekt texnologiyalarining tibbiyot muassasalarida qo'l gigiyenasini raqamli monitoring qilish hamda yuqumli kasalliklarning tarqalishining oldini olishda katta salohiyatga ega ekanligini tasdiqlaydi.

Kalit so'zlar: qo'l gigiyenasini, kompyuter ko'rish, tasvir segmentatsiyasi, chuqur o'rganish, Mask R-CNN, YOLOv8, tibbiy axborot texnologiyalari, sog'liqni saqlashni raqamlashtirish.

Аннотация. Соблюдение гигиены рук является одним из ключевых факторов профилактики инфекционных заболеваний и обеспечения безопасности пациентов в медицинских учреждениях. В последние годы цифровые технологии активно внедряются для автоматизации мониторинга санитарно-гигиенических процедур. В данном исследовании рассматриваются современные методы компьютерного зрения и машинного обучения для анализа состояния рук и определения параметров роста ногтей.

Целью исследования является разработка цифрового подхода к мониторингу гигиены рук на основе анализа изображений ногтевой пластины и применения алгоритмов сегментации. В рамках исследования был создан набор данных изображений ногтей, выполнена предварительная обработка данных и проведена оценка эффективности нескольких моделей сегментации, включая U-Net, Mask R-CNN и YOLOv8-seg.

Результаты исследования показали, что использование моделей глубокого обучения обеспечивает высокую точность сегментации и позволяет автоматически определять границы ногтя и его отросшую часть. Среди протестированных моделей наибольшую точность продемонстрировала модель Mask R-CNN. Полученные результаты подтверждают потенциал технологий искусственного интеллекта для цифрового мониторинга гигиены рук и профилактики распространения инфекционных заболеваний в медицинских учреждениях.

Ключевые слова: гигиена рук, компьютерное зрение, сегментация изображений, глубокое обучение, Mask R-CNN, YOLOv8, медицинские информационные технологии, цифровизация здравоохранения.

INTRODUCTION

Hand hygiene is one of the most effective and accessible measures for the prevention of infectious diseases. This concept refers to a set of practices aimed at removing pathogenic microorganisms from the surface of the skin of the hands through the use of water, soap, or antiseptic agents. The main objective of these procedures is to prevent the transmission of bacteria, viruses, and other microorganisms between individuals and the surrounding environment.

Human hands constantly come into contact with various surfaces, objects, and people. Therefore, they act as a primary mechanism for the transmission of infections. Studies show that a significant number of microorganisms may be present on the skin surface of the hands, many of which are capable of causing various diseases. When touching the face—especially the eyes, nose, or mouth—infectious agents can easily enter the body.

The issue of hand hygiene compliance is particularly relevant in medical institutions. Healthcare workers interact daily with patients, medical instruments, and biological materials. Failure to comply with sanitary standards may lead to the spread of hospital-acquired infections, which pose a serious threat to patients' health.

According to international studies, a significant proportion of infection transmission cases in medical institutions are associated with insufficient compliance with hand hygiene practices. Therefore, the development of effective methods for monitoring and controlling sanitary procedures is one of the key challenges of modern medicine.

In the context of the digital transformation of healthcare systems, increasing attention is being paid to the application of artificial intelligence and computer vision technologies. These technologies make it possible to automate the analysis of medical data, improve diagnostic accuracy, and optimize the processes of quality control in healthcare services.

One promising direction is the development of digital systems capable of automatically analyzing the condition of hands and assessing compliance with hygiene requirements. In particular, computer vision methods can be used to analyze images of hands, determine nail shape, and evaluate the degree of nail growth.

The aim of this study is to develop a digital method for analyzing nail condition and monitoring hand hygiene based on machine learning and computer vision algorithms.

REVIEW OF LITERATURE ON THE SUBJECT

Hand hygiene has long been recognized as one of the most effective preventive measures for reducing the transmission of infectious diseases, particularly within healthcare settings. The importance of proper hand hygiene practices has been emphasized by numerous international organizations and researchers. According to the guidelines developed by the World Health Organization, hand hygiene is a fundamental component of infection prevention and control in medical institutions. The organization highlights that appropriate hand hygiene practices, including handwashing with soap and water and the use of alcohol-based antiseptics, significantly reduce the spread of pathogenic microorganisms in healthcare environments. The WHO guidelines also emphasize the importance of integrating systematic monitoring and compliance strategies to ensure that healthcare workers consistently follow hygiene protocols.

Substantial empirical evidence supporting hand hygiene promotion has been provided by researchers such as Didier Pittet, Benedetta Allegranzi, and Hugo Sax. Their research proposes an evidence-based model for hand hygiene promotion that integrates education, institutional support, monitoring, and feedback mechanisms. This model demonstrates that effective hand hygiene programs require a comprehensive approach combining behavioral change strategies, organizational commitment, and continuous evaluation of compliance. Their work has significantly influenced international health policies and has become the foundation for many infection prevention programs implemented in hospitals worldwide.

Further methodological foundations for hand hygiene practices in healthcare environments were established in the clinical guidelines developed by John M. Boyce and Didier Pittet in cooperation with the Centers for Disease Control and Prevention. These guidelines provide a comprehensive framework for hand hygiene in healthcare settings, describing the epidemiological significance of hand contamination, the effectiveness of different hygiene techniques, and the conditions under which hand hygiene procedures must be performed. Their work highlights that consistent adherence to hand hygiene protocols can substantially reduce healthcare-associated infections, which remain a major challenge for patient safety across the world.

In parallel with advances in infection control research, rapid progress in computer vision and deep learning technologies has opened new opportunities for automated hygiene monitoring systems. One of the most influential developments in biomedical image analysis is the convolutional neural network architecture known as U-Net, proposed by Olaf Ronneberger, Philipp Fischer, and Thomas Brox. The U-Net architecture was specifically designed for biomedical image segmentation tasks and enables precise pixel-level classification of structures within medical images. Its encoder–decoder architecture allows the model to capture both contextual information and fine spatial details, making it particularly suitable for identifying small anatomical structures such as nails or skin regions in digital images.

Another significant advancement in image segmentation was introduced through the Mask R-CNN framework developed by Kaiming He, Georgia Gkioxari, Piotr Dollár, and Ross Girshick. This method extends object detection models by incorporating an additional branch for predicting segmentation masks at the pixel level. Mask R-CNN has demonstrated high accuracy in detecting and segmenting complex objects within images and has been widely adopted in medical image analysis tasks due to its ability to combine object localization and detailed structural segmentation.

In addition to segmentation-based approaches, real-time object detection models have become increasingly important in computer vision applications. One of the most widely used frameworks is the YOLO (You Only Look Once) architecture developed by Joseph Redmon and Ali Farhadi. Unlike traditional multi-stage detection algorithms, YOLO processes images using a single neural network, allowing object detection to be performed in real time. This characteristic makes YOLO-based models particularly suitable for practical monitoring systems that require rapid image processing and immediate feedback.

The integration of modern computer vision algorithms with healthcare hygiene monitoring systems creates new opportunities for improving sanitary control. By combining advanced image segmentation models such as U-Net and Mask R-CNN with real-time detection frameworks like YOLO, it becomes possible to develop automated systems capable of analyzing hand images and assessing hygiene-related parameters. Such technologies can significantly enhance infection prevention strategies by enabling objective monitoring and supporting compliance with established hand hygiene standards.



RESEARCH METHODOLOGY

To achieve the stated objective, a comprehensive approach was developed that included image collection and preparation, data preprocessing, and the application of segmentation algorithms.

ANALYSIS AND RESULTS

During the study, a specialized dataset of hand nail images was created. The dataset included more than 500 photographs obtained under different lighting conditions and from various shooting angles.

When forming the dataset, the following parameters were considered:

- diversity of shooting angles;
- variations in lighting conditions;
- characteristics of the nail surface;
- age and gender of participants;
- differences in skin color.

The use of diverse images made it possible to improve the robustness of machine learning algorithms and ensure their ability to generalize.

Specialized data annotation tools were used to label the images, including LabelMe, CVAT, and Roboflow. Using these platforms, the contours of the nail plate and the boundaries of its grown-out part were marked for each image.

After the annotation process was completed, the dataset was divided into three parts:

- training set — 80% of the images;
- validation set — 10%;
- test set — 10%.

Such a distribution of data makes it possible to correctly evaluate the performance of the trained models and reduces the likelihood of overfitting.

Before using the images in machine learning algorithms, a preprocessing stage was performed. This step is an important part of data preparation, as images may significantly differ in brightness, contrast, and noise level.

The main stages of preprocessing included:

Filtering is used to remove noise that appears during image acquisition. The following methods were applied in this study:

- Gaussian filtering;
- Median filtering;
- Bilateral filtering.

These algorithms help smooth random fluctuations in pixel brightness and improve overall image quality.

Normalization is used to bring images to a uniform brightness value range. Pixel values are transformed to the range from 0 to 1, which is a standard practice when training neural networks.

To improve the distinction between the nail and the surrounding skin, contrast enhancement techniques were applied, including:

- histogram equalization;
- adaptive histogram equalization (CLAHE).

These methods make it possible to more clearly highlight object boundaries in the image.

To separate the image into object and background, a thresholding method was used. The optimal threshold value was determined using the Otsu method.

Segmentation is one of the key stages of image analysis. It represents the process of dividing an image into separate regions corresponding to different objects.

Within the framework of this research, several segmentation algorithms were considered.

Traditional methods include edge detection algorithms such as:

- the Canny edge detector;
- the Sobel operator.

These methods make it possible to identify object contours; however, their effectiveness largely depends on lighting conditions and image quality.

To improve the accuracy of the analysis, modern deep learning models were applied.

The U-Net architecture is widely used in medical image processing. It has a symmetrical encoder–decoder structure and allows segmentation at the level of individual pixels.

Mask R-CNN is one of the most accurate segmentation models. It combines object detection with the generation of pixel-level masks.

YOLOv8-seg is a modern model that enables object segmentation in real time.

After the nail region is segmented, its structure is analyzed to determine the boundary between the main part of the nail and the grown-out area.

For this purpose, several feature extraction methods are applied:

- analysis of color characteristics;
- evaluation of texture features;
- computation of brightness gradients.

To detect the boundary between different parts of the nail, edge detection algorithms are used, such as the Canny edge detector and the Sobel operator.

After identifying the boundary, the relative length of the grown-out portion of the nail is calculated. This parameter can be used for automated monitoring of nail condition and hygiene compliance.

During the experiments, a comparative evaluation of the effectiveness of different segmentation models was carried out.

The obtained results demonstrated the following accuracy indicators (Table 1):

Table 1. Comparative performance of segmentation models in nail plate detection

Model	IoU	Dice
U-Net	~0.87	~0.92
Mask R-CNN	~0.91	~0.96
YOLOv8-seg	~0.88–0.90	~0.93–0.95

The most accurate results were demonstrated by the Mask R-CNN model.

At the same time, the YOLOv8-seg model showed high processing speed and can be applied in real-time systems.

Failure to comply with hand hygiene rules is one of the key factors contributing to the spread of infectious diseases.

Diseases that can be transmitted through contaminated hands include:

- intestinal infections;
- viral gastroenteritis;
- respiratory diseases;
- infections of the skin and soft tissues;
- hospital-acquired infections.

Studies show that regular hand washing can reduce the spread of intestinal infections by approximately 30%, and respiratory infections by more than 20%.

Thus, improving compliance with hand hygiene practices is an important component in the prevention of infectious diseases.

CONCLUSIONS AND SUGGESTIONS

In this study, a digital method for analyzing nail condition and monitoring hand hygiene using computer vision technologies was developed.

The experimental results demonstrated that the application of deep learning algorithms makes it possible to effectively perform segmentation of the nail plate and determine its grown-out part.

The highest accuracy was demonstrated by the Mask R-CNN model, while YOLOv8-seg provides an optimal balance between speed and accuracy.

The proposed approach can be used in digital hand hygiene monitoring systems in medical institutions. The implementation of such technologies can improve the effectiveness of sanitary control and reduce the risk of the spread of infectious diseases.

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