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APPLICATION OF ARTIFICIAL INTELLIGENCE IN MEDICAL IMAGE RECOGNITION

Abstract. *The article is devoted to the study of image recognition in medicine using deep learning. The use of deep learning allows automating image processing and analysis, which significantly reduces the human factor and increases the accuracy of diagnoses. Artificial intelligence, in particular deep learning, is actively used to recognize abnormalities in X-rays, ultrasound images, MRI, and CT scans, so this technology is actively developing in the areas of oncology and cardiology. The algorithms can learn from large amounts of data, which allows them to identify patterns that may be unnoticed or unclear to human observation, which is made possible by convolutional layers that use filters to detect local features in images.*

The purpose of the publication *is to study the current state of the art of medical image recognition and summarize the latest research in this area.*

Methodology. *The article reviews and analyzes the literature on the use of deep learning, its advantages, disadvantages and limitations relative to traditional methods in image recognition, considers the necessary steps for building image recognition systems, and proves the importance of convolutional neural networks (CNNs).*

Conclusions. *Although medical image recognition is not the most popular area of application of convolutional neural networks today, it is very important for providing more effective treatment to the population. The most researched and relevant areas in medicine are lungs, heart, breast, liver, histology, and eyes. Modern publications of scientists have proven the high accuracy of convolutional neural networks in diagnosing diseases. However, some indicators can still be significantly improved, which gives room for further research. Convolutional neural networks have demonstrated high accuracy in recognizing patterns in medical images, which can contribute to early diagnosis of diseases in the above-mentioned medical fields. In addition, the use of CNNs will help automate processes, which will reduce the workload of medical staff for more complex cases; increase the efficiency of processing large amounts of data; and reduce the number of erroneous image interpretations. Today, convolutional neural networks can be called an assistant for medical staff, but a lot of research and investment is still needed for their widespread use by doctors, but if these conditions are met, their potential is worth further research.*

Key words: *artificial intelligence, convolutional neural networks, diagnostic systems, generative adversarial networks, image recognition.*

Сергій КОЛОМОЄЦЬ. ЗАСТОСУВАННЯ ШТУЧНОГО ІНТЕЛЕКТУ В РОЗПІЗНАВАННІ МЕДИЧНИХ ЗОБРАЖЕНЬ

Анотація. *Стаття присвячена дослідженню розпізнавання зображень в медицині за допомогою глибокого навчання. Застосування глибокого навчання дозволяє автоматизувати процеси обробки та аналізу зображень, що значно зменшує людський фактор і підвищує точність діагнозів. Штучний інтелект, зокрема глибоке навчання, активно використовується для розпізнавання аномалій на рентгенівських знімках, ультразвукових зображень, МРТ та КТ, тому дана технологія активно розвивається в напрямках онкології та кардіології. Алгоритми можуть навчатися на великих обсягах даних, що дозволяє їм ідентифікувати закономірності, які можуть бути непоміченими або незрозумілими для людського спостереження, це є можливим завдяки згортковим шарам, які використовують фільтри для виявлення локальних ознак у зображеннях.*

Метою публікації *є дослідження сучасного стану питання розпізнавань медичних зображень та узагальнення новітніх досліджень у цій сфері.*

Методологія. *У статті проведений огляд та аналіз літератури щодо застосування глибокого навчання, його переваг, недоліків та обмежень відносно традиційних методів в розпізнаванні зображень, розглянуті необхідні кроки для побудови систем розпізнавання зображень, доведено важливість згорткових нейронних мереж (ЗНМ).*

Висновки. *Хоча розпізнавання медичних зображень не є найпопулярнішою сферою застосування згорткових нейронних мереж сьогодні, вона дуже важлива для забезпечення більш ефективного лікування населення. Найбільш дослідженими та актуальними областями в медицині є легені, серце, молочна залоза, печінка, гістологія та очі. Сучасні публікації вчених довели високу точність згорткових нейронних мереж у діагностиці захворювань. Однак деякі показники ще можна значно покращити, що дає простір для подальших досліджень. Згорткові нейронні мережі продемонстрували високу точність розпізнавання патернів на медичних зображеннях, що може сприяти ранній діагностиці захворювань у вищезгаданих галузях медицини. Крім того, використання CNN допоможе автоматизувати процеси, що зменшить навантаження на медичний персонал для більш складних випадків; підвищить ефективність обробки великих обсягів даних; зменшить кількість помилкових інтерпретацій зображень. На сьогоднішній день згорткові нейронні мережі можна назвати помічником для медичного персоналу, але для їх широкого використання лікарями потрібно ще багато досліджень та інвестицій, але якщо ці умови будуть виконані, то їх потенціал вартий подальших досліджень.*

Ключові слова: *штучний інтелект, згорткові нейронні мережі, діагностичні системи, генеративні змагальні мережі, розпізнавання зображень.*

Introduction. Today, the task of image recognition, image creation, reconstruction, and enhancement is becoming increasingly popular in the world. Recognizing the faces of people who have committed an offense, recognizing cars that have exceeded the speed limit, analyzing medical images for diagnosing diseases, generating DALL-E images from OpenAI, and enhancing old photos in digital quality – all of this has become possible thanks to artificial intelligence, deep learning, convolutional neural networks, and generative adversarial networks.

The task of pattern recognition is to distribute the initial data into a certain class that characterizes this data by essential features from the total mass of less essential features, and it is one of the main issues of the theory of intelligent systems [1]. Intelligent information systems are a type of automated information systems; they support human activity in the search for information in the mode of extended natural language dialogue [4]. The main task of intelligent systems is to provide answers given rules and data, which is the opposite of machine learning (it has to give rules given data and knowing the answers). Deep learning is a subset of machine learning, which in turn is a subset of artificial intelligence (Figure 1).

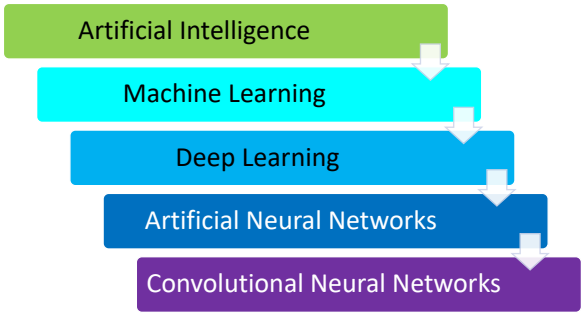

Fig. 1. Artificial intelligence hierarchy

Convolutional neural networks (CNN) get their name from the process of edge detection, from smaller local image features to more general ones, and are mathematically described by the formula (1) (convolution operation in two-dimensional space) [2].

$$f[x,y]*g[x,y]=\sum_{n_1=-\infty}^{\infty}\sum_{n_2=-\infty}^{\infty} f[n_1,n_2]*g[x-n_1,y-n_2] \quad (1)$$

Types of convolutional neural networks [13]:

– Conventional – consist of a series of convolutional and sub-sampling layers followed by one or more fully connected layers. Each convolutional layer in such a network performs convolutions using learning filters to extract features from the input image.

– Recurrent Neural Networks (RNNs) can process sequential data based on the context of previous values. Unlike conventional neural networks, which process data in a fixed order, RNNs can work with variable length inputs and draw conclusions that depend on previous inputs.

– Fully Convolutional Networks (FCN) – widely used in computer vision tasks such as image segmentation, object detection, and image classification. They are trained from start to finish using the backpropagation method to categorize or segment images.

– Spatial Transformer Network (STN) – used in computer vision tasks to improve the ability of a neural network to recognize objects or patterns in an image regardless of location, orientation, or scale.

There are 3 types of CNNs depending on the types of tasks they solve [2]:

1. 1D – used for signal processing when it is necessary to detect changes in the signal;
2. 2D

– Image classification – identifies key features of images and determines their class;

– Image recognition;

– Image segmentation (allows you to determine which segment each pixel belongs to);

3. 3D – video classification.

In order to recognize an image, there is a certain algorithm – it is necessary to select the most important initial data for a certain class that characterize them [3]:

1. Image perception – obtaining values of the characteristic properties of the object;
2. Pre-processing – removing noise, presenting the image in black and white, cropping unnecessary parts of the image;
3. Characteristic extraction (indexing) – characteristic properties of the object are measured;
4. Classification – decision making.

Consider the advantages and disadvantages of convolutional neural networks [15].

The advantages are as follows:

– fewer parameters to be adjusted;
– higher resistance to changes in the position of the image being processed;
– are good at solving image classification and recognition tasks;
– availability of ready-made settings for popular tasks.

The disadvantages are as follows:

– neuron activation functions;
– network training speed;
– the dimension of the convolutional matrix;
– number of convolutional layers.

Problem statement

Despite the fact that today's trends in the use of convolutional neural networks are focused on image and video generation, this article will consider their application in medicine due to the importance of this field and the large number of challenges it faces.

According to recent literature reviews, the most researches and publications on image recognition in various medical fields are in the areas shown in Figure 2 [10].

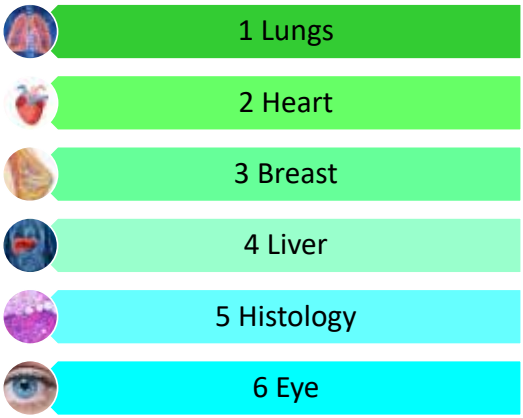

Fig. 2. Amount of publications by medical fields in image recognition

Consider in more detail each of the CNN application areas.

Lungs. As a result of the COVD-19 pandemic, the lungs have attracted the most attention, due to the large number of computed tomography (CT) data sets and the urgency due to the high prevalence of the disease (Figure 3). The lungs also attract considerable attention because of the poor diagnosis of lung cancer, which is usually diagnosed in the last stages, leading to high mortality from this disease [7, 8]. Due to the accurate segmentation of lung fields, it is possible to detect the disease in time before the onset of irreversible processes [12].

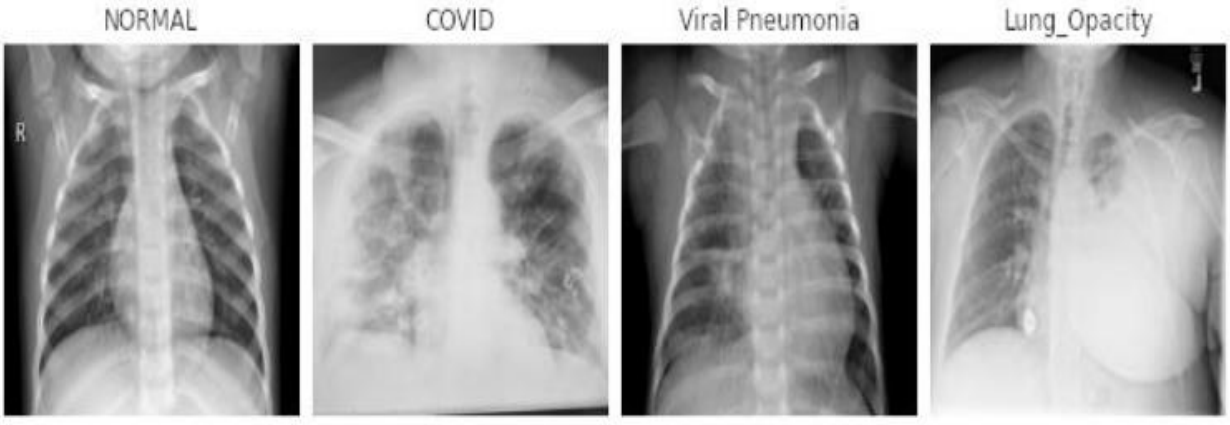

Fig. 3. An example of CNN recognition of CT images

Cardiovascular diseases. Arrhythmia classification, detection of abnormalities in ECG images, prediction of heart disease based on image classification, early detection of cardiovascular diseases in patients are the main issues that can be solved by convolutional neural networks in cardiology [5].

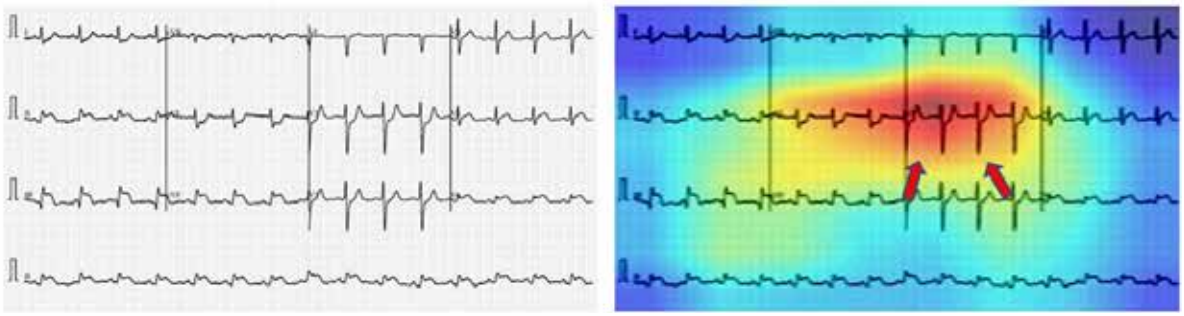

Fig. 4. An example of detecting myocardial infarction using convolutional neural networks on an ECG

Breast. Breast cancer is the second most common type of cancer, so diagnosing it at an early stage or detecting the likelihood of the disease is very important. Single-slice digital breast tomosynthesis (SSCT) classification and deep learning improve breast cancer screening by eliminating the limitations of traditional mammography, such as tissue overlap, which allows for higher diagnostic accuracy and a reduction in false-positive/negative results [6]. Analyzing the morphological shape and thickness of the skin to detect asymmetry in mammography images indicates potential breast cancer by assessing the similarity between a patient's two breasts by analyzing the distances from the breast image centroid to its perimeter, taking into account possible geometric distortions, and identifying skin-related asymmetries by expanding the set of skin pixels based on similarity in intensity and depth. This makes it possible to detect breast cancer at early stages and sometimes prevent the disease.

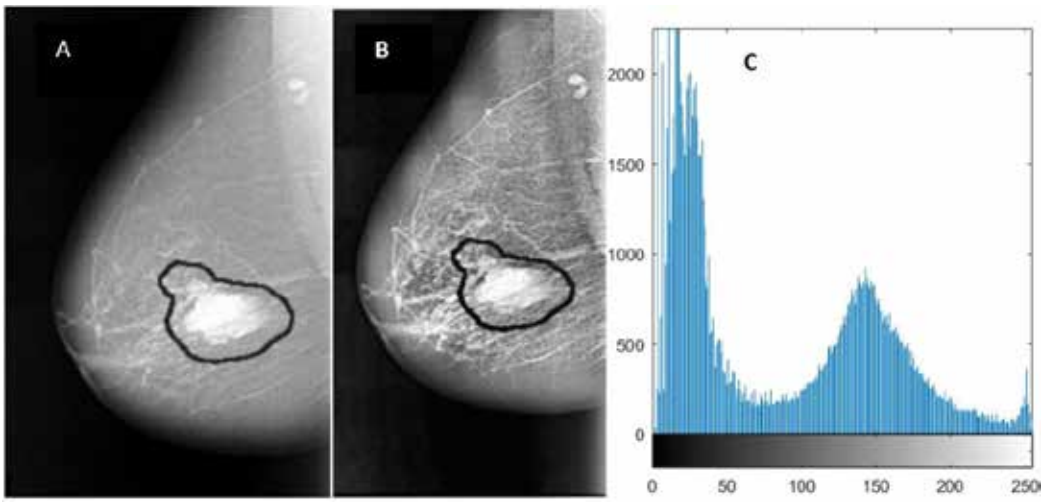

Fig. 5. An example of breast cancer detection using convolutional neural networks

Liver. Liver cancer, non-alcoholic fatty liver disease, and cirrhosis are a significant problem because the disease is often asymptomatic, making screening and early detection critical for a good prognosis. Convolutional neural networks can be used to segment liver lesions in CT images. Today, machine learning is actively used to accelerate repetitive tasks (segmentation, obtaining information about the volume of the lesion, tumor, improving image quality, reducing scanning time and optimizing image acquisition) [11].

Eye. Early detection and intervention can help to analyze the retina to diagnose diabetic retinopathy, which is the leading cause of blindness in the world, and can also detect age-related molecular degeneration and glaucoma [14].

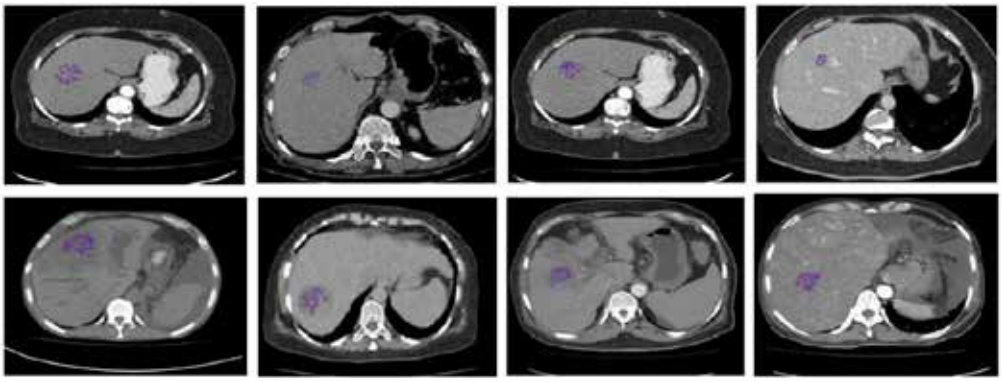

Fig. 6. An example of liver cirrhosis detection using convolutional neural networks

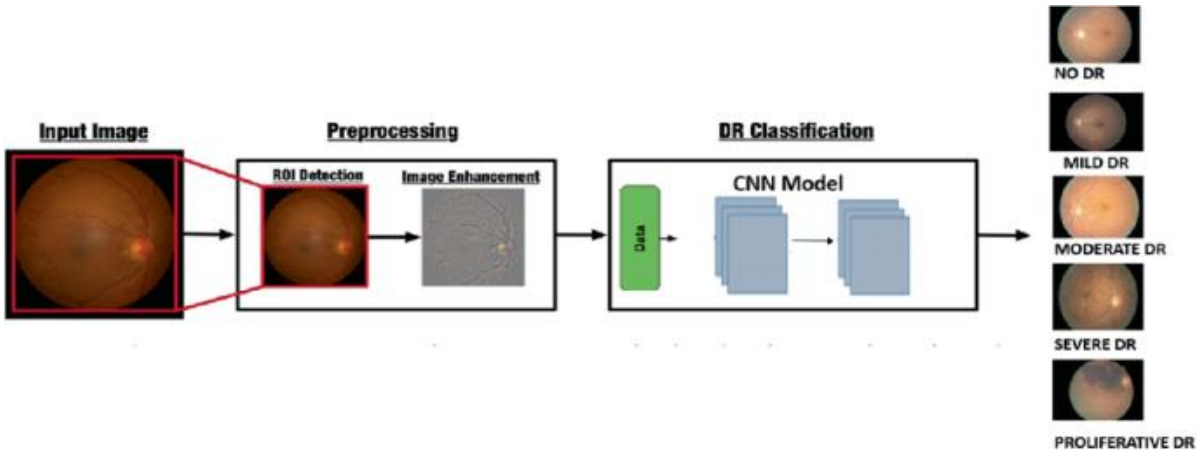

Fig. 7. An example of diabetic eye disease detection using convolutional neural networks

Table 1

Accuracy of convolutional neural networks depending on the disease

№	Localization of the disease in the organ	Diagnostic method	Accuracy (%)
1	Breast	Digital breast tomosynthesis	≈ 93
2	Brest	MRI	≈ 65
3	Brain	CTA	≈ 74
4	Brain	MRI	≈ 90
5	Eye	Retinal camera	100
6	Liver	MRI	≈ 85
7	Liver	CTI	≈ 76

Source: based on [9]

Conclusions

Although medical image recognition is not the most popular use case for convolutional neural networks today, it is very important for providing more effective treatment to the population.

The most researched and relevant areas in medicine are lungs, heart, breast, liver, histology, and eyes. Modern publications by scientists have proven the high accuracy of convolutional neural networks in diagnosing diseases. However, some indicators can still be significantly improved, which gives room for further research.

Convolutional neural networks have demonstrated high accuracy in recognizing patterns in medical images, which can contribute to the early diagnosis of diseases in the above-mentioned areas of medicine. In addition, the use of CNNs will help automate processes, which will reduce the burden on medical staff for more complex cases; improve efficiency in processing large amounts of data; and reduce the number of misinterpretations of images.

As of today, convolutional neural networks can be called an assistant for medical staff, but a lot of research and investment is still needed to make it widely used by doctors, but if these conditions are met, their potential is worth further research.

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