ADVANCES IN CYBER-PHYSICAL SYSTEMS

Vol. 8 No. 2, 2023

COVID-19 DIAGNOSIS USING DEEP LEARNING FROM X-RAY AND CT IMAGES – OVERVIEW

Magdalena Michalska-Ciekańska[1], Oksana Boyko[2]

[1]*Institute of Electronics and Information Technology, Lublin University of Technology, 38D, Nadbystrzycka Str, Lublin, 20-618, Poland*

[2]*Department of Medical Informatics, Danylo Halytsky Lviv National Medical University, 69, Pekarska Str, Lviv, 79000, Ukraine*

Authors' e-mails*: magdalena.michalska@pollub.edu.pl, oxana_bojko@ukr.net*

https://doi.org/10.23939/acps2023.02.126

Submitted on 1.06.2023

***Abstract*: Since the outbreak of the pandemic in 2019, Covid-19 has become one of the most important topics in the field of medicine. This disease, caused by the SARS-CoV-2 virus, can lead to serious respiratory diseases and other complications. They can even lead to death. In recent years, the number of Covid-19 cases around the world has increased significantly, resulting in the need for rapid and effective diagnosis of the disease. Currently, the use of deep learning in medical diagnostics is becoming more and more common. It provides the high diagnostic efficacy that scientists, doctors and patients care about. During the Covid-19 diagnostic procedure, most clinicians order images from X-ray and CT to be taken from patients. It is the analysis of these images that gives a full diagnosis. In this article, we will discuss the use of deep neural networks in the diagnosis of Covid-19, especially using chest images taken from X-ray and CT.**

***Index Terms*: deep learning, convolutional neural networks, Covid-19 diagnostics, CT scans, chest X-ray**

I. INTRODUCTION

Since the outbreak of the pandemic in 2019, Covid-19 has become one of the most important topics in the field of medicine. This disease, caused by the SARS-CoV-2 virus, can lead to serious respiratory diseases and other complications that can even lead to death [1, 2]. In recent years, the number of Covid-19 cases worldwide has increased significantly, resulting in the need for rapid and effective diagnosis of the disease [3]. In this article, we will discuss the use of deep neural networks in the diagnosis of Covid-19, especially related to lung images from X-ray and CT.

Covid-19 was first identified in December 2019 in Wuhan, China. This disease quickly spread beyond China's borders and became a pandemic. In recent years, the number of Covid-19 cases worldwide has increased significantly, exceeding 250 million infections and causing more than 5 million deaths [4].

Diagnosis of Covid-19 is crucial for the rapid and effective treatment of the disease and for preventing the further spread of the pandemic. Scientists have begun experimenting with the use of deep neural networks in the diagnosis of Covid-19, especially related to lung images from X-ray [5] and CT [6]. Deep neural networks are a type of artificial intelligence that can learn to recognize patterns in input data and predict outcomes based on those patterns. They can be used to analyze medical images and diagnose diseases.

X-ray and CT lung images are commonly used in the diagnosis of Covid-19. Researchers used deep neural networks to analyze these images and develop diagnostic tools that allow for rapid and effective diagnosis of Covid-19. One of the most important applications of Covid-19 diagnostics from lung images from X-ray and CT scan is the ability to quickly detect the disease in patients.

II. DEEP NEURAL NETWORKS IN DIAGNOSTICS

Deep neural networks are a type of artificial intelligence that can learn to recognize patterns in input data and predict outcomes based on those patterns. Owing to this, they can be used to analyze medical images and diagnose diseases.

III. BUILDING A DEEP NEURAL NETWORK

ANNs (artificial neural networks) are systems created to process information. Their structure and principle of operation refers to the human brain and the functioning of the biological nervous system, especially in the context of communication between neurons.

Neural networks are a branch of machine learning, they have a key ability to learn from given examples, and they also have the ability to generalize the acquired knowledge [7]. A simplified neural network diagram is shown in Figure 1A., the individual circles represent artificial neurons, and the arrows indicate the direction of the information

Convolutional neural network (CNN) is a special type of neural network. In networks of this type, at least one layer carries out the so-called mathematical convolution operation, which will be discussed in the following sections.

In addition, these networks are based on the architecture of sharing the weights of convolutional nuclei or

filters, which is used to construct feature maps [9]. Due to these solutions, these networks are ideal for image analysis [10]. The diagram of a typical convolutional network is shown in Figure 1B. [11]. According to Figure 1C., the convolutional neural network at the input accepts data in the form of an image. This image is then processed by a sequence of layers [12]. Feature maps are created by convolutional layers, which repeatedly perform operations of the so-called discrete plexus – this procedure is used primarily for filtration. Next, the filtered images go to the activation layer, where a nonlinear activation function processes every single pixel [13].

IV. INTEGRATED DIAGNOSTIC SYSTEMS REALIZED BY DEEP NEURAL NETWORKS

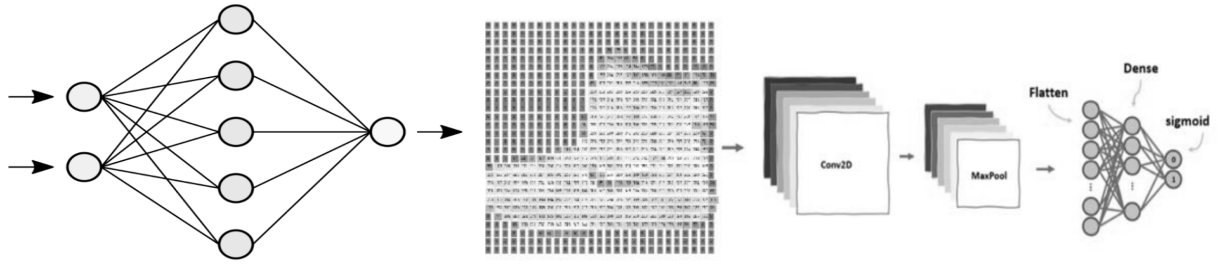
Scientists are working on entire integrated systems for diagnosing various diseases using deep neural networks. There have been many works of full diagnostics of skin lesions from dermatoscopic images [12, 13, 14, 15]. The vision of precise segmentation of anatomical structures using deep learning resulted in the development of unique architectures based on convolutional neural networks [16, 17].

Another example of the use of deep learning is the segmentation of the image of the left ventricle of the heart from cardiac magnetic resonance imaging [18]. In [19], a fully automated method of segmentation of brain tumors was presented. It is possible to obtain information on the volume of the chamber and the ejection fraction. The results obtained for parameters such as validation metric, percentage of good contours, bone measure and mean perpendicular distance proved to be significantly better than with other known methods.

A large number of publications also concerned the application of deep learning to classify image data. One popular example in which satisfactory results have been achieved is the diagnosis of skin cancer – the most common malignant tumor in humans [20].

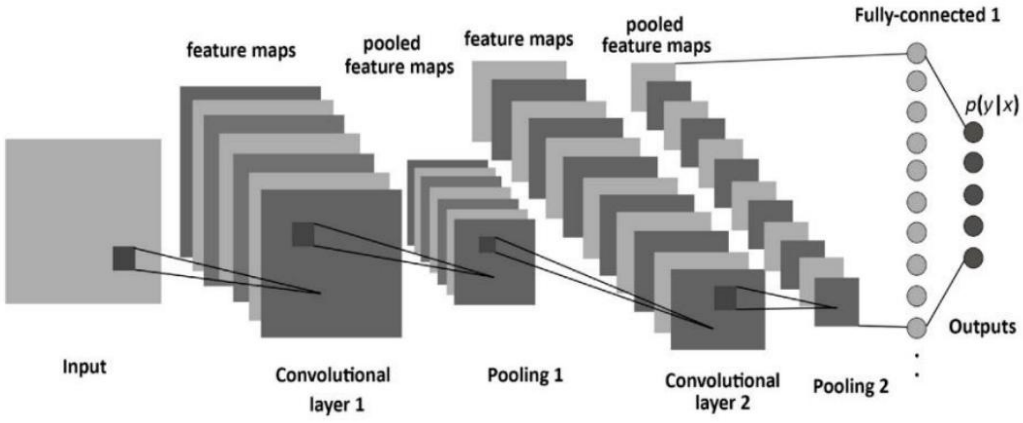
Also, the diagnosis of Covid-19 is crucial for the rapid and effective treatment of the disease and for preventing the further spread of the pandemic. Scientists have begun experimenting with the use of deep neural networks in the diagnosis of Covid-19, especially related to lung images from X-rays and CTs.

Entire diagnostic and treatment systems based on machine learning and deep learning are being developed (Figure 2C.). [21] provides a detailed overview of existing state-of-the-art ML and DL methodologies for the wider community. Scientists believe that the data collected can improve the diagnosis of COVID-19 and avoid many illnesses.



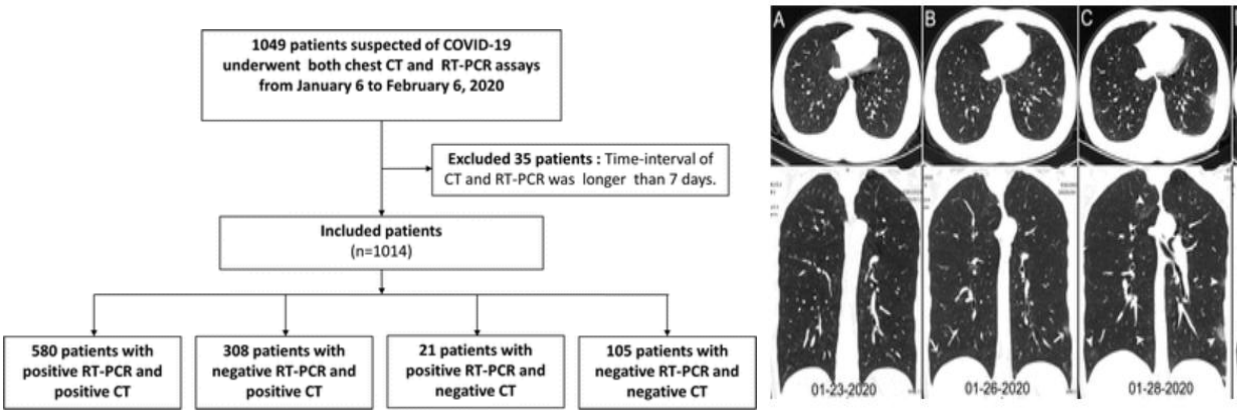
a

b

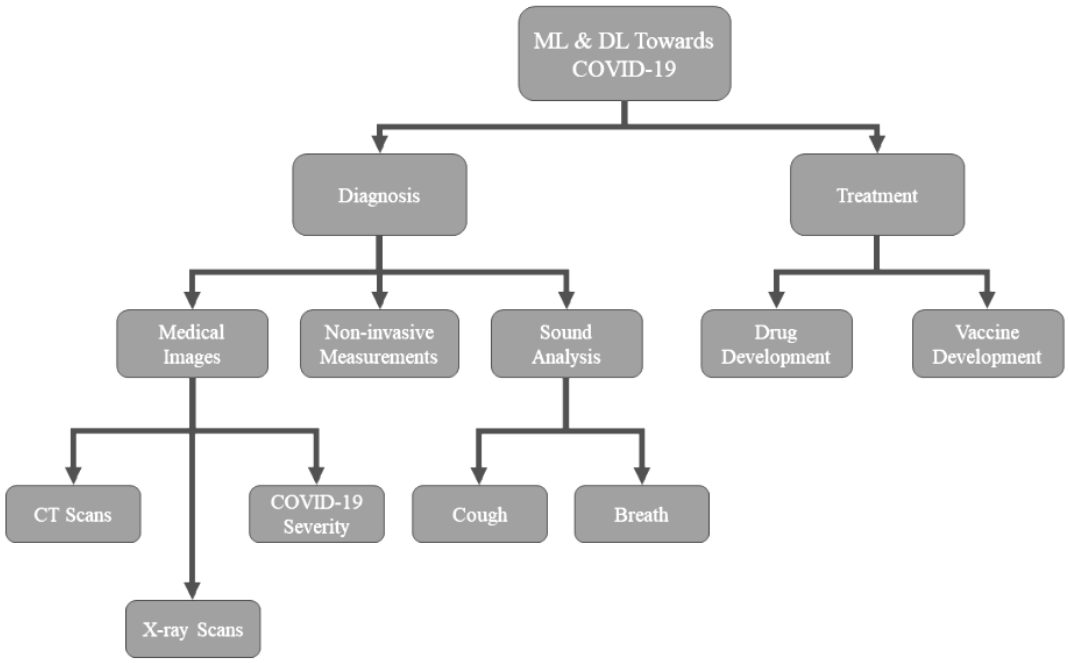


c

Fig. 1A. - Simplified scheme of one-way neural network [8]; B. - Simplified scheme of convolutional neural network [11]; C. - Diagram of a convolutional neural network using images as input [12]



a *b*



c

Fig. 2.A. - Diagram of samples used in the tests, RT-PCR = reverse-transcription polymerase chain reaction; B. - Axial (top) and coronal (bottom) chest CT images [6]; C. - Scheme of Covid-19 diagnosis and treatment system based on machine learning (ML) and deep learning (DL) [21]

V. DIAGNOSIS OF COVID-19 USING X-RAY AND CT IMAGES OF THE LUNGS

X-ray and CT lung images are commonly used in the diagnosis of Covid-19. Researchers used deep neural networks to analyze these images and develop diagnostic tools that allow for rapid and effective diagnosis of Covid-19.

One of the most important applications of Covid-19 diagnostics from lung images from X-ray and CT scan is the ability to quickly detect the disease in patients. Many studies have shown that deep neural networks are able to recognize images of the lungs from X-ray and CT with high accuracy, which can help in the rapid detection of the disease. In one of such studies there was a scientist who used deep neural networks to diagnose Covid-19 based on X-ray images of the chests. The study performed that deep neural networks can recognize Covid-19 with 90.8% accuracy, which is higher than other diagnostic methods such as PCR tests.

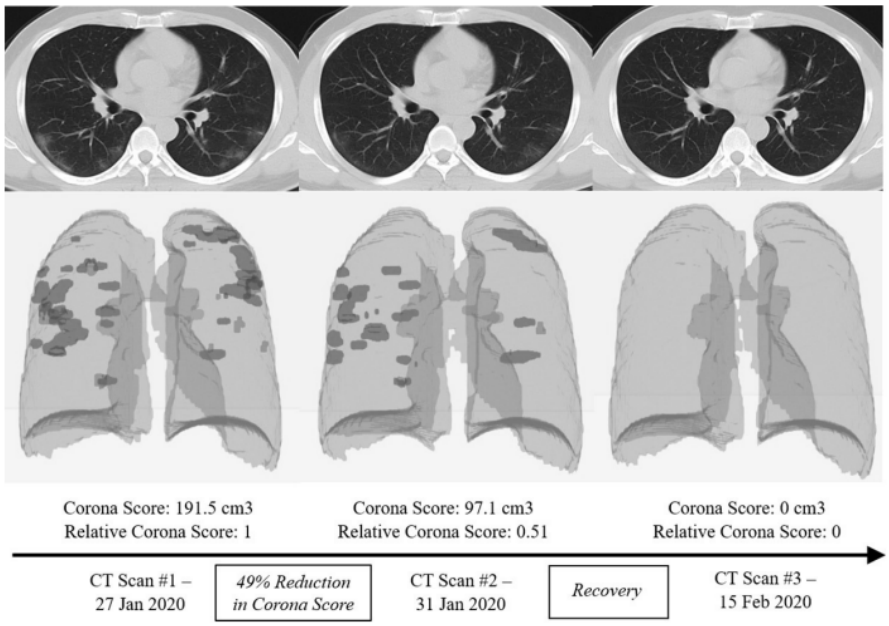
Another application of Covid-19 diagnostics from lung images X-ray and CT scan is to assess the stage of the disease in patients. Deep neural networks can help determine whether the disease is in its early stages or if it has already progressed to a worse state. According to a study by researchers at the University of Toronto, deep neural networks were able to identify whether a patient had a severe form of Covid-19 based on CT images of the chests.

VI. A. SAMPLING

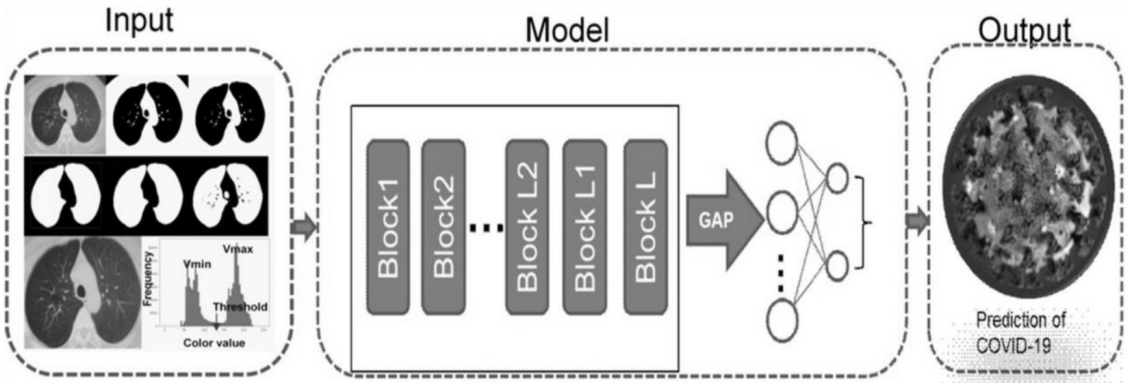
The key aspect in the analysis of diagnostic systems is, of course, obtaining the right number of samples. Of course, collecting sensitive medical data is not an easy task [22]. Obtaining a sufficiently large set of imaging data or information about the result of a covid test requires a lot of work of medical staff.

In [6] a significant number of samples were collected to carry out the necessary research. Figure 3A shows the breakdown of the sets of samples obtained. Figure 3B shows examples of three CT images of one of the patients.

However, the researchers accepted some limitations in the research. They used RT-PCR assays with a relatively low positive rate as the reference standard, chest CT sensitivity to COVID-19 may be overestimated and specificity underestimated. In the population studied by the researchers [6], negative RT-PCR results and positive CT features may still strongly suggest COVID-19. The obtained results show how important is the process of preparing samples accordingly, on the basis of which conclusions are developed.



a



b

Fig. 3A. - CT scans from a COVID-19 patient along with a simulation of recovery [23]; B. -Scheme of obtaining ROI using deep learning [24]

VII. B. DIAGNOSTICS WITH CT SCAN

Each of the computer diagnostic processes consists of three main elements. These include the process of preprocessing medical images. Another important element is the emergence of region of interest (ROI) from the image, which is shown in Figure 3B. The last element is the classification itself made by classification models.

In [24] a neural network with Inception blocks was built. The resulting images from ROI were used after the network pre-training process. They based on CT scans of COVID-19 patients. An overall accuracy of more than 89% was achieved with a specificity of 0.88 and a

sensitivity of 0.87 successful screening for COVID-19. In [23], a simulation of recovery was performed using the RADLogics algorithm, the results are presented in Figure 3A.

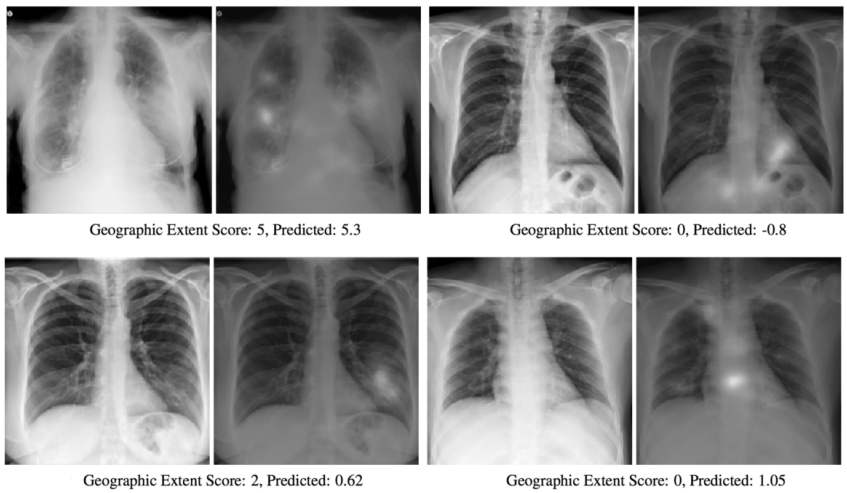
VIII.C.DIAGNOSTICS WITH CHEST X-RAY

Many researchers are even undertaking to classify the severity of COVID-19 based on chest X-rays using deep learning. Support for artificial intelligence allows to better understand the process of automatic computer diagnostics. Chest X-ray (CXR) is a non-invasive method of monitoring the development of the disease.

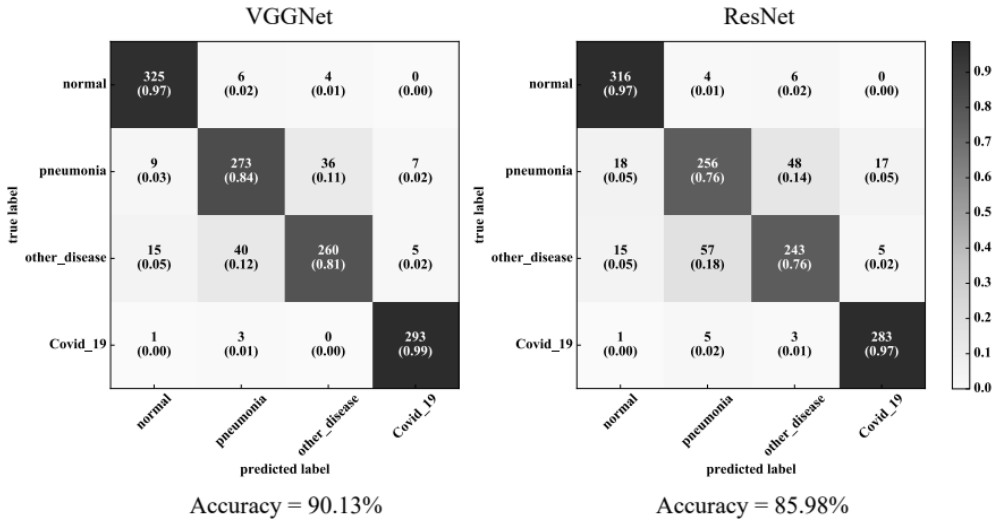
In [25], a predictive model of Covid-19 diagnostics was made from X-rays on the front of the chest. The model analyzes the expansion of the disease in the lungs based on the images provided. They include cases of Covid-19, as well as other lung diseases or healthy patients. The DenseNet model turned out to be the most effective. Figure 4A shows Chest X-ray (CX) of patients along with the diagnosis – predicted value and geographic extent score. Similar studies were done in [26].

In [27], more than 1400 X-ray scans were used for the diagnostic process. A VGG-16 network model was pre-trained on this set to divide and categorize. Chest X-ray scans were also used in [28], and transfer learning method was also used to detect COVID-19. Often, scientists do not focus only on binary classification, dividing the data into two groups as Covid-19 patient and healthy. They make a multi-class classification, obtaining up to 4 different classes as healthy, another disease, pneumonia, and Covid-19 patient. Confusion matrices for VGGNet and ResNet are shown at figure 4B.

Deep learning has been used in many works to diagnose Covid-19. Deep neural networks were used in [28, 29, 30]. Figure 3B presents the results of the work [27] in the form of Confusion matrices for VGGNet and ResNet. These two models are characterized by high efficiency.



a



b

Fig. 4A. - Chest X-ray from COVID-19 patients with simulation of the severity of recovery when using DenseNet model [25]; B. - Confusion matrices for VGGNet and ResNet [28]

IX. CONCLUSION

In recent years, the number of Covid-19 cases around the world has increased significantly, resulting in the need for rapid and effective diagnosis of the disease. Deep neural networks are increasingly used in the diagnosis of Covid-19 from lung X-ray and CT images, as they allow for a quick and effective diagnosis of the disease. However, to get the most out of these diagnostic tools, more research and testing is needed.

Studies have shown that deep neural networks are able to recognize X-ray and CT images of the lungs with high accuracy, which can help in the rapid detection of the disease. Deep neural networks are also used to assess the stage of disease in patients. However, in order to take full advantage of these diagnostic tools, ethical aspects related to their use, such as protecting patient privacy and the appropriate use of medical data, must be considered.

Although this technology has the potential to help combat the Covid-19 pandemic, other important issues such as social distancing and wearing protective masks should not be overlooked. Increasing the number of tests and following hygiene rules are also crucial steps that can help prevent the spread of the disease.

In conclusion, the diagnosis of Covid-19 from X-ray and CT images of the lungs using deep neural networks is one of the tools that help in the rapid and effective diagnosis of the disease. However, in order to take full advantage of these diagnostic tools, further research and testing are required, as well as consideration of the ethical aspects involved in their use. With the ongoing Covid-19 pandemic, it is important that we continue to adhere to hygiene and social distancing rules to help prevent the spread of the disease.

REFERENCES

[1] N. Chen, M. Zhou, X. Dong et al., "Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study," The Lancet, 395 (10223), 2020, pp. 507–513. DOI: 10.1016/S0140-6736(20)30211-7

[2] C. M. A. De O. Lima, "Information about the new coronavirus disease (COVID-19)," Radiologia Brasileira 53 (2), 2020. DOI: 10.1590/0100-3984.2020.53.2e1

[3] T. Struyf, J. J. Deeks, J. Dinnes et al., "Signs and symptoms to determine if a patient presenting in primary care or hospital outpatient settings has COVID-19 disease," Cochrane Database of Systematic Reviews 7 (7), 2020.

[4] Organization, W. H., WHO Coronavirus Disease (COVID-19) Dashboard, World Health Organization, Geneva, Switzerland, 2020, http://Https://Covid19.%20Who.%20Int/

[5] L. Wang, Z. Lin, and A. Wang, "COVID-net: a tailored deep convolutional neural network design for detection of COVID-19 cases from chest X-ray images," Scientific Reports 10, Article ID 19549, 2020.

[6] T. Ai, Z. Yang, H. Hou et al., "Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases," Radiology, 296 (2), Article ID 200642, 2020. DOI: 10.1148/radiol.2020200642

[7] R. Tadeusiewicz, M. Szaleniec: "Leksykon sieci neuronowych", Wydawnictwo Fundacji Projekt Nauka, Wrocław, 2015.

[8] Sieć neuronowa. https://pl.wikipedia.org/wiki/Sie%C4%87_neuronowa [accessed on 30.03.2022]

[9] W. Zhang, "Shift–invariant pattern recognition neural network and its optical architecture", Proceedings of Annual Conference of the Japan Society of Applied Physics, 1998.

[10] F. Chollet, "Deep Learning. Praca z językiem Python i biblioteką Keras", Helion, 2019

[11] M. Mamczur, "Jak działają konwolucyjne sieci neuronowe", https://miroslawmamczur.pl/jak–dzialaja–konwolucyjne–sieci–neuronowe–cnn/[accessed on 17.05.2022]

[12] R. Dzierżak, "Zastosowanie deep learningu w analizie obrazów medycznych" in Prace doktorantów Wydziału Elektrotechniki i Informatyki Politechniki Lubelskiej, 2018, 59–70

[13] X. Lu, Y. Firoozeh Abolhasani Zadeh, "Deep learning-based classification for melanoma detection using XceptionNet", Journal of Healthcare Engineering 2022, 2196096. DOI:10.1155/2022/2196096

[14] X. Lu, Y. Firoozeh Abolhasani Zadeh, "Deep learning-based classification for melanoma detection using XceptionNet", Journal of Healthcare Engineering 2022, 2196096. DOI: 10.1155/2022/2196096

[15] S. Chaturvedi, J. Tembhurne, T, Diwan, "A multi-class skin cancer classification using deep convolutional neural networks". Multimedia Tools and Applications 2020, 79. DOI:10.1007/s11042-020-09388-2

[16] S. Dinggang, W. Guorong., S. Heung-Il, "Deep Learning in Medical Image Analysis", The Annual Review of Biomedical Engineering, 2017, 9, pp. 221–248. https://doi.org/10.1146/annurev-bioeng-071516-044442

[17] G. Litjens, T. Kooi, B. Bejnordi, A. Setio, F. Ciompi, M. Ghafoorian., J. van der Laak, B. Ginneken B., C. Sánchez, "A survey on deep learning in medical image analysis", Medical Image Analysis 2017, 42, pp. 60–88. DOI: 10.1016/j.media.2017.07.005

[18] M. Avendi, A. Kheradvar, H. Jafarkhani, "A combined deep-learning and deformable-model approach to fully automatic segmentation of the left ventricle in cardiac MRI", Medical Image Analysis 2016, 30, pp.108–119. DOI: 10.1016/j.media.2016.01.005

[19] A. Krizhevsky, I. Sutskever, G. Hinton, "Imagenet classification with deep con- volutional neural networks", Proceedings of the Advances in Neural Information Processing Systems, 2012, pp. 1097–1105. DOI:10.1145/3065386

[20] R. Siegel, D. Naishadham, A. Jemal, "Cancer statistics", CA Cancer J Clin., 2013, 63(1), pp. 11–30. DOI: 10.3322/caac.21166

[21] T. Alafif, A. Tehame, S. Bajaba, A. Barnawi, S. Zia, "Machine and Deep Learning towards COVID-19 Diagnosis and Treatment: Survey, Challenges, and Future Directions", Int. J. Environ. Res. Public Health 2021, 18, 1117. DOI: 10.3390/ijerph18031117

[22] Y. LeCun, Y. Bengio, and G. Hinton, "Deep learning," Nature, 521 (7553),2015, pp. 436–444. https://doi.org/10.1038/nature14539.

[23] M. Scudellari, Hospitals Deploy AI Tools to Detect COVID-19 on Chest Scans, 2020. Available online: https://spectrum.ieee.org/the-human-os/biomedical/imaging/hospitals-deploy-ai-tools-detect-covid19-chest-scans (accessed on 10 September 2020).

[24] S. Wang, B. Kang, J. Ma, X. Zeng, M. Xiao, J. Guo, M. Cai, J. Yang, Y. Li, X. Meng, et al. "A deep learning algorithm using CT images to screen for Corona Virus Disease

(COVID-19)", medRxiv 2020. DOI: 10.1007/s00330-021-07715-1

[25] J. Cohen, L. Dao, P. Morrison, K. Roth, Y. Bengio, B. Shen, A. Abbasi, M. Hoshmand-Kochi, M. Ghassemi, H. Li, et al. "Predicting covid-19 pneumonia severity on chest X-ray with deep learning", arXiv 2020, arXiv:2005.11856. https://doi.org/10.48550/arXiv.2005.11856

[26] BBVA. Artificial Intelligence to detect COVID-19 in Less than a Second Using X-rays. 2019. Available online: https://www.bbva.com/en/artificial-intelligence-to-detect-covid-19-in-less-than-a-second-using-x-rays/ (accessed on 6 September 2020).

[27] M. Pandit, S. Banday, "SARS n-CoV2-19 detection from chest X-ray images using deep neural networks", Int. J. Pervasive Comput. Commun. 2020, 16, pp.419–427. DOI:10.1108/ijpcc-06-2020-0060

[28] S, Basu, S. Mitra, "Deep Learning for Screening COVID-19 using Chest X-ray Images", arXiv 2020, arXiv:2004.10507 https://doi.org/10.48550/arXiv.2004.10507

[29] L. Wang and A. Wong, "COVID-Net: A tailored deep convolutional neural network design for detection of COVID-19 cases from chest radiography images," arXiv preprint arXiv:2003.09871, 2020. DOI: 10.1038/s41598-020-76550-z

[30] S. Basu and S. Mitra, "Deep Learning for Screening COVID-19 using Chest X-Ray Images," arXiv preprint arXiv:2004.10507, 2020. DOI: 10.1038/s41598-020-76550-z

M.Sc. Magdalena Michalska-Ciekańska, Ph.D. student at Institute of Electronics and Information Technology, Lublin University of Technology. She received the B.S. degree in Biomedical engineering in 2014 and the M.S. degree in Electronics from Warsaw University of Technology, Faculty of Electronics and Information Technology in 2016. Her research interests include medical image processing, optoelectronics and deep learning. ORCID ID: 0000-0002-0874-3285

Professor Oksana Boyko, Ph. D., graduated from Lviv Polytechnic State University, Faculty of Applied Mathematics. Since 2011 she has been the Head of the Medical Informatics Department of Danylo Halytsky Lviv National Medical University.

Her research interests include mathematical modelling, biomedical sensors and embedded systems, medical information systems. She is the author of over 200 scientific and methodological works. ORCID ID: 0000-0002-8810-8969