International Journal of Allied Medical Sciences and Clinical Research (IJAMSCR)

ISSN:2347-6567

IJAMSCR |Volume 10 | Issue 3 | July - Sept - 2022
www.ijamscr.com

Research article ***Medical research***

Automatic Detection of COVID-19 in Digital Thorax Image with Convolutional Neural Network

Andi Nur Intan Wulandari*[1], Donny Kristanto Mulyantoro[1] and Dwi Rochmayanti[1]

[1]*Postgraduate Program in Applied Diagnostic Imaging Health, Poltekkes Kemenkes Semarang*

***Corresponding Author: Andi Nur Intan Wulandari**

ABSTRACT

COVID-19 is an infectious disease caused by the corona virus. Gold standard diagnosis of COVID-19 is RT-PCR. Alternative chest radiography for the diagnosis of COVID-19 plays a role in initial screening. The weakness of chest radiography is the lack of sensitivity in detecting COVID-19. Deep learning CNN AI technology has the ability to represent features to make predictions of the same diagnosis as radiologist through pattern recognition in digital images. Deep learning CNN that is able to classify the results of thorax radiographs automatically. Type research was analytic observational cross-sectional approach. Building a CNN deep learning architecture through the matlab R2018b program. Data is collected from CNN testing by measuring deep learning and ROC performance. Data analysis using diagnostic test with STATA statistical program. Research with 76 samples obtained by deep learning CNN is feasible and highly detects COVID-19 with an AUC value of 0.9232. Deep learning CNN is effective in detecting both COVID-19 and normal thorax images provided that the diagnosis decision still refers to the justification verification of a radiologist.

Keywords: COVID-19, thorax radiograph, deep learning CNN, automatic detection.

INTRODUCTION

Coronavirus disease (COVID-19) is an infectious disease caused by the newly discovered coronavirus. Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. Older people and those with underlying medical problems such as cardiovascular disease, diabetes, chronic respiratory disease and cancer may be at greater risk [1].

The indicated prevalence of COVID-19 cases based on a large study from China reported that the mean age of cases was 47 years (interquartile range 35-58 years), 87% of cases were aged 30-79 years and 3% were aged 80 years. , and the number of female patients was 41.9% [2]. This suggests that older men are more susceptible to SARS-CoV-2 compared to other groups, and this virus is more likely to affect older men with underlying chronic diseases (e.g. diabetes, hypertension, heart disease, etc.) [3].

The current Gold Standard for COVID-19 diagnostic testing must be confirmed by Reverse Transcription Polymerase Chain Reaction (RT-PCR) or gene sequencing for respiratory or blood specimens, as the main indicator for isolation [4][5]. In addition, according to the China National Health Commission in The Novel Coronavirus Pneumonia Diagnosis and Treatment Plan (5th trial version), viral nucleic acid detection is the standard for non-invasive diagnosis of COVID-19. However, the detection of SARS-CoV-2 nucleic acid has high specificity and low sensitivity, so there may be false negative results and the testing time can be relatively long [6].

Based on WHO guidelines in technical handling of Coronavirus (COVID-19), radiological examination is one of the recommended supports in assisting the diagnosis of COVID-19. The recommended standard radiological imaging modalities are chest radiography, computed tomography, and ultrasound. It considers various levels of disease severity, from asymptomatic individuals to critically ill patients and

calculates the variation in benefits and harms in different situations, this statement is addressed to patients so that the examination recommendations provided are of benefit to the patient [7].

Chest radiography as an alternative method in handling Covid-19 plays an important role in the initial diagnosis or screening process as a consideration is the action taken in the form of non-invasive measures through lung imaging because it refers to the symptoms caused, namely shortness of breath as a result of acute pneumonia. Chest radiography imaging is considered capable of describing the condition of the lungs in Covid-19 patients and can be a clinical diagnostic tool. In addition, chest radiography does not require costs and expensive device settings and does not require large resources if applied for screening in a large population when compared to CT-Scan imaging techniques [8].

The relatively rapid increase in the Covid-19 epidemic requires expertise in the field of radiology. This has increased interest in developing automated detection systems based on deep learning methods in Artificial Intelligence (AI) technology. In this pandemic condition requires a fast and precise diagnosis, but on the one hand, the limited availability of radiologists will actually hinder the diagnosis process. Therefore, deep learning models on simple, accurate, and fast AI technology are expected to help overcome these problems and provide timely assistance to patients. Although radiologists play an important role because of their extensive experience in this field, AI technology can help to get an accurate diagnosis [9] [10]. This shows that one of the most important weaknesses of the thorax radiographic analysis is the inadequate level of sensitivity in the detection of Covid-19, especially the Ground Glass Opacity (GGO) points [11]. Therefore, an accurate diagnosis method is needed by analyzing a well-trained deep learning model that can focus on points such as diffuse or patchy asymmetric opacities such as pneumonia which are commonly found in Covid-19 patients so that chest radiographs can optimally diagnose Covid-19 [9].

Deep Learning is an artificial intelligence method that is formed on the basis of computational science in carrying out digital image processing using pattern recognition techniques. The deep learning method is able to recognize patterns in digital images and make expert diagnosis predictions using one of the deep learning models, namely Convolutional Neural Network (CNN). This can support doctors to more easily interpret the findings of medical images and reduce the time in interpreting an image. Some of these algorithms have been used for breast cancer detection, segmenting brain tumors with Magnetic Resonance Imaging (MRI) modalities, detecting polyps using virtual colonoscopy or CT in colon cancer [12].

Convolutional Neural Network (CNN) is one of the deep learning models that is widely used for image analysis purposes such as patterns in digital images [13]. CNN is a system formed by an artificial neural network that includes several layers on the connection of a computing system, one of which is neurons with step-by-step processing that has made significant progress in research in the field of computing. The CNN algorithm includes convolutional, ReLu, pooling layers and fully connected layers. The convolutional layer has the main purpose of detecting edges, lines and visual elements, such as localized areas. The special filter operator parameter is called convolution [14]. CNN has the advantage of being able to analyze feature representations automatically from training data (exercise). CNN has several layers that aim to operate data in the form of images with various abstractions that allow the tool to navigate and explore large data sets and find complex patterns and structures that can be used to make predictions [15]. The application of the CNN algorithm method can be maximized through the use of digital-based radiology modalities, namely digital images generated from the Computer Radiography (CR) and Digital Radiography (DR) modalities [16]. which allow to carry out processing such as image processing, image analysis, image understanding and computer vision [17].

Chest radiography has recently become the attention of researchers to be used as an alternative in analyzing Covid-19. The study [9] diagnosed Covid-19 with an end-to-end architectural model without using any feature extraction method on chest radiography images.

Based on the above background, the researcher will examine the performance results of the deep learning algorithm model in diagnosing Covid-19. The formulation of the research problem is how the CNN deep learning model performs in detecting Covid-19 in radiographic images.

The purpose of the study was to analyze the performance of the CNN deep learning model in detecting Covid-19 in radiographic images automatically. The benefits of research can be used as input for hospitals in improving radiology services by utilizing deep learning and ensuring the handling of Covid-19 patients.

METHODS

This research is an analytic observational study with a cross sectional approach. The data used includes all digital thorax images with Covid-19, while the sample size used is 76 digital thorax images from each test group (normal) and test group (covid-19). Data was obtained from secondary data in two hospitals, the data collection process began in the period May 2020 - November 2020.

This research begins with the creation of a software program using the Matlab R2018b application to build a CNN deep learning architecture, radiographic images are trained to recognize patterns or features from normal thorax digital images and digital thorax images with Covid-19. The method used to extract features automatically is Convolutional Neural Network (CNN).

Analysis of deep learning performance assessment data is assessed based on the results of the classification, which is carried out by diagnostic tests on STATA to measure the accuracy, sensitivity, specificity, precision and negative predictive value of the model [18]. In addition, it is assessed based on Receiver Operating Characteristics (ROC).

RESULT

The study used 296 digital thorax image data which was divided into 220 training data sets consisting of 110 COVID-19 thorax and 110 normal thorax, while for the Covid-19 confirmed test data set there were 43 data and 33 normal thorax so that the total sample used is 76 samples. Samples that confirmed Covid-19 were based on the results of the RT-PCR test and validation by a radiology specialist, then normal samples were validated by a radiology specialist.

The results of the study were obtained by running the CNN deep learning model through the matlab program as shown in Fig 1.

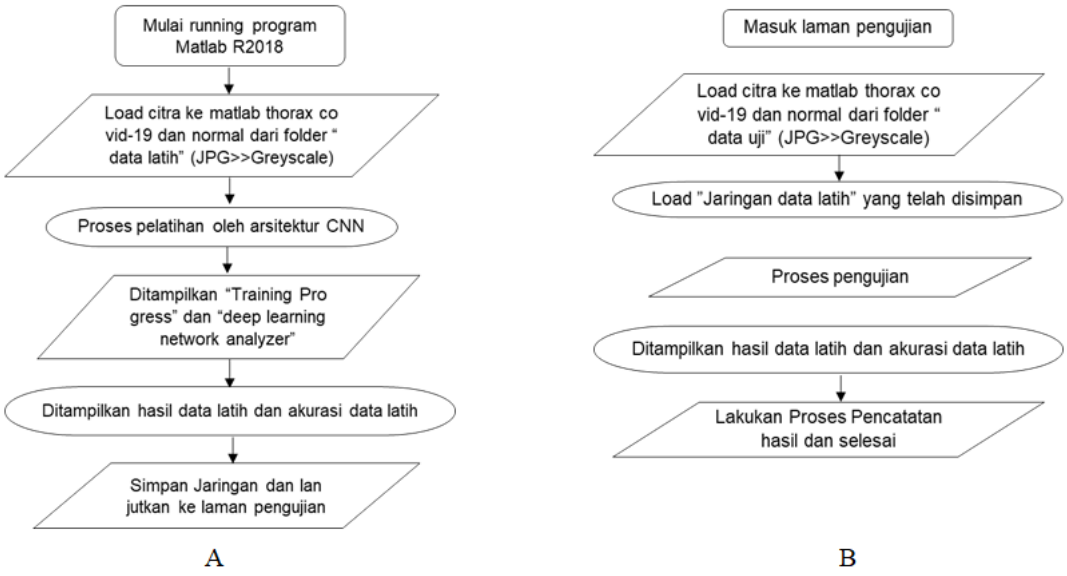

Fig 1: A. CNN Training Flowchart, B. CNN Testing Flowchart

This study went through several stages, starting with the collection of digital thorax images obtained in accordance with medical image standards, namely the DICOM format. In this process, the thorax images in DICOM form have different collimation areas. Therefore, a cropping stage is needed to uniform the lung field area on the thorax image. The image cropping process is carried out using the Image-J application. After that, the conversion process is carried out to JPG format. This is done to ease the deep learning model in processing the input image both during the training and testing process. The size of the thorax image matrix is standardized to 50 x 50. After that, the converted images are labeled according to their respective types and then grouped into different files, consisting of Covid-19 and normal.

In addition, before performing the image input process in the deep learning model, a conversion process is required once again so that the JPG image can be read in the deep learning model, the JPG image is converted to a greyscale image. This process is carried out after the deep learning algorithm is ready to use and before carrying out the training and testing process. After image preprocessing is done, then the CNN deep learning model is made. The CNN deep learning model was built using the MATLAB programming language version R2018b. CNN's deep learning model uses the Convnet architecture. The thorax image is fully related to the first layer. The image output results are in the form of a classification between Covid-19 and normal with a level of similarity presentation to radiologists.

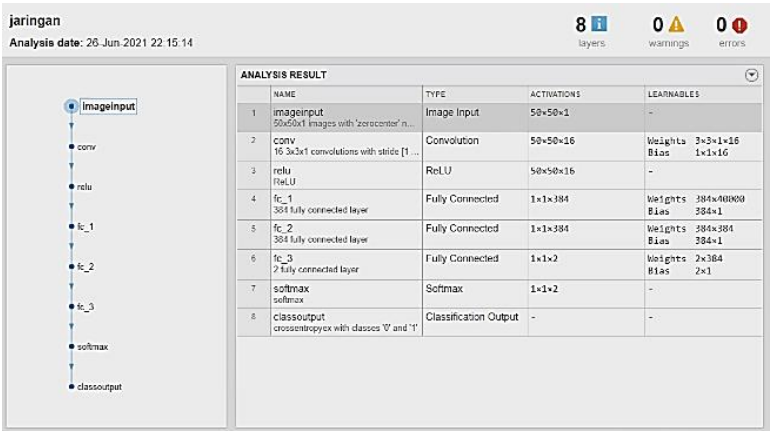

Fig 2: Summary of CNN deep learning model architecture

Based on Figure 2, which is a summary of the architectural structure used in the Covid-19 detection research, the image above shows the results table which contains the architectural structure of the CNN deep learning model. The deep learning architecture summary is called "deep learning network analyzer", this summary table will appear after the training process on the training image is carried out, it is used to display information that the architecture in each layer is valid and there are no error layers.

The purpose of classification in Covid-19 detection research is using softmax layers, in this process the detection similarity assessment is set between 0 and 1, which means that if the image value is close to 1, the training image similarity value will be even greater. The classification output that appears in the deep learning model is the largest value. Then the higher the similarity value of the test data to the training data, the greater the accuracy of the deep learning model in detecting an image.

The final step is to analyze the performance of the deep learning model through the classification results of the CNN deep learning model and the assessment of the performance of the CNN deep learning model. In the Covid-19 data classification test process with the CNN deep learning model, 95.1% of the classification results were obtained according to the test data label. 39 Covid-19 classification test data were detected which read as Covid-19 and 4 Covid-19 classification test data read as normal. Then the total prediction error in the classification of Covid-19 test data is 4.9%. In the normal data classification test process with the CNN deep learning model, 88.6% classification results were obtained according to the test data label. It was detected that 31 normal classification test data read as normal and 2 normal classification test data read as Covid-19. Then the total prediction error in the normal test data classification is 11.4%.

Classification Accuracy

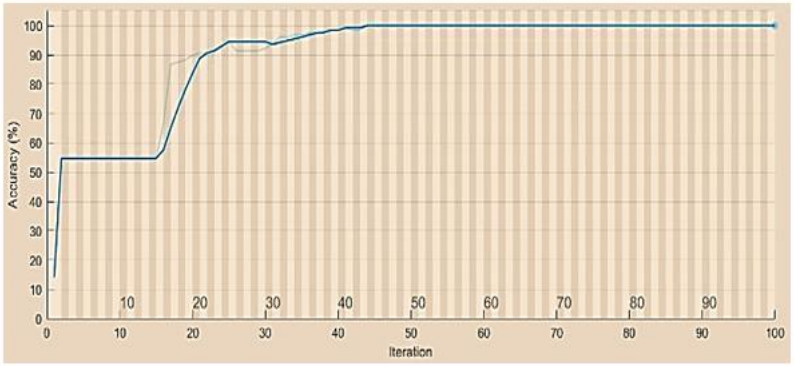

Fig 3: Graph of CNN deep learning model validation accuracy

Based on Figure 3, the validation results obtained that the accuracy level to see the best performance of the CNN deep learning model on training data based on cross validation accuracy is 97.72%. The purpose of doing cross validation is to obtain a deep learning model with the best performance on training data. Figure 3 accuracy (blue) represents ability a deep learning model to classify digital thorax images as training data, both Covid-19 thorax images and normal thorax images.

Cross Entropy Loss

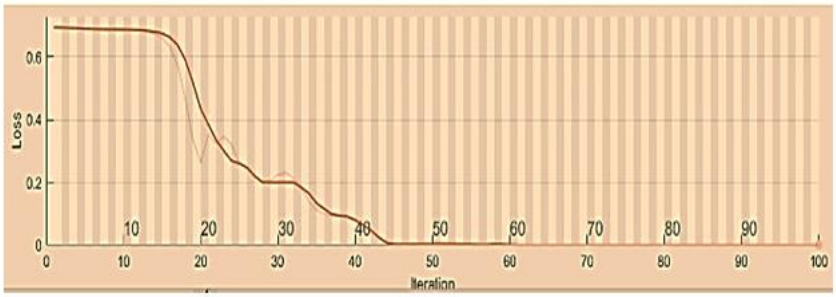

Fig 4: Graph of the cross entropy loss of CNN's deep learning model

The figure 4 error rate (yellow) is the level of prediction error of the training data on average. Another performance measurement is the Cross Entropy Loss which shows the level of prediction error from the CNN deep learning model. The amount of loss = 1 – 0.9772, which is 0.0228 (2.28%).

Based on the evaluation of the validation results with cross validation, the CNN deep learning model was obtained with an accuracy rate of 97.72% for the training data and the validation results based on the loss cross entropy of 2.28% which in principle the accuracy level of the CNN deep learning model does not always reach an accuracy of 100 % either use any algorithm.

Based on table 1 shows the classification results of the CNN deep learning model against the gold standard, so to obtain the results of the CNN deep learning model performance based on the values of accuracy, sensitivity, specificity, precision and negative predictive value (NPV), a diagnostic test was carried out using the STATA/MP statistical program. 16.0 to perform diagnostic tests automatically. The following are the results of the deep learning classification in the 2x2 diagnostic test table:

Table 1: CNN deep learning diagnostic test table

Classification Result	Test results RT-PCR		Total
	Positive	Negative	
Positive	39	2	41
Negative	4	31	35
Total	43	33	76

Based on table 1 in table 2 x 2, calculations are carried out on the performance classification of the CNN deep learning model with the values obtained as follows:

Table 2: CNN deep learning performance table

Performance	Value	CNN (%)
Accuracy	0,921	92,1%
Sensitivity	0,907	90,7%
Spesifisity	0,939	93,9%
Positive Predictive Value **(PPV)**	0,951	95.1%
Negative Predictive value **(NPV)**	0,886	88,6%

The results of the classification of the performance of the deep learning model in table 2 show that the level of accuracy, sensitivity, specificity and precision is above the range of 0.90-1.00 which means that the deep learning model is "very good" used. The negative predictive value shows results in the range of 0.80-0.90 which means the ability of the deep learning model to detect a normal thorax and classify it as normal is still in the "good" category.

The ROC curve is an effective performance measurement tool for machine learning. The table of ROC calculation results is shown by the acquisition of the AUC value as follows:

Table 3: Area Under The Curve (AUC) CNN model against gold standard

AUC Area	Std.Error	Asymp. 95% Confidence Interval	
		Lower Bound	*Upper Bound*
0,9232	0,0308	0,862	0,983

DISCUSSION

Based on the diagnostic test using the ROC value measurement method, it is shown that the AUC value obtained is above the range of 0.90-1.00, which means that the CNN deep learning model shows performance in the "very good" category. So based on the ROC measurement standard, the CNN deep learning model is feasible and very well used to detect Covid-19 and normal digital thorax images.

The CNN deep learning model is built using the Convnet architecture. In the process of programming the deep learning model, parameters are used to control the functioning of the deep learning model in order to generate classification predictions correctly. The process of compiling the architecture is carried out per layer until the last layer. The use of convnet architecture in this study is very useful in the image preprocessing process, because it does not require a long preprocessing time because convnet architecture has the ability to study filters or characteristics that are introduced automatically. In addition, the convnet architecture uses the connectivity patterns of neurons in the human brain originating from the visual cortex so that individual neurons respond to stimuli only in a limited area of the visual field known as the receptive field [19]. Therefore, the convnet architecture uses a pattern based on a collection of overlapping fields to cover all visuals such as neuronal connectivity in humans. To recognize the image is nothing but the matrix (pixel value) of each image pattern that is given when the training begins.

Research in certain cases can use a multi-level perceptron pattern for classification purposes. In this pattern, the image to be recognized can even out the number of matrices to be recognized, for example 3x3 into a 9x1 vector [19]. However, if applied to this study, the binary image used will show an average precision score during the image prediction process, so that a little or no accuracy value is obtained when the image used has an overall pixel dependence. In addition, convnet can capture spatial and temporal dependencies in an image through the application of relevant filters, therefore convnet architecture in network applications can be trained to understand the sophistication of the input image better. The advantages of the convnet architecture used by researchers are that it can reduce the image to a form that is easier to process, without losing features that are very important to get good predictions.

In this study, a diagnostic test was carried out which was the assessment stage of the deep learning model after passing the training and testing stages of the data set. The results of the diagnostic test show that the performance of the CNN deep learning model based on accuracy, sensitivity, specificity and precision is included in the very good category, which means that it is good for detecting COVID-19.

Based on the research process carried out, there are factors that can affect the level of accuracy of a deep learning model,

namely the number of input images as a training data set, the more training data used, the more accurate the deep learning model will be in determining the classification and vice versa. This is because the more thorax image data sets that are trained in deep learning, the more they will recognize the characteristics of each image and will add references to the CNN algorithm.

The size of the matrix also greatly influences the output of the CNN deep learning model. Image size was reduced to 224 × 224 and normalized based on the mean and standard deviation of the image in the ImageNet training data set [20]. In this study, the image size was reduced to 50 x 50 on the grounds that the processing capacity of the device used was limited. In fact, this study proves that using an image measuring 50 x 50 will have an impact on the level of accuracy in the CNN deep learning model, this is due to a reduction in the number of pixels and a decrease in resolution in the thorax image which causes the image information on the digital thorax to decrease, this is also indicated by the accuracy of the deep learning model in detecting certain clinical characteristics because it has not been optimally recognized by the deep learning model.

Then the larger the matrix size will affect the accuracy of the CNN deep learning model to be higher. But on the other hand, the larger matrix size will also slow down the performance of the deep learning model in classifying the COVID-19 and normal thorax because it does not match the capacity and quantity of the deep learning model.

CNN deep learning model is applied to improve image classification accuracy (Litjens et al., 2017). Based on the results of the study, the precision value and negative predictive value (NPV) indicated that the thorax was not detected as expected in the CNN deep learning model and errors occurred in determining predictions, meaning that the CNN deep learning model was not 100% able to increase accuracy in image classification and not overall. can detect Covid-19 accurately.

The test results by CNN's deep learning model on both COVID-19 and normal thorax test data show that the prediction error is false negative (covid-19 thorax is predicted to be normal). Abnormalities in the thorax are generally distributed bilaterally, peripherally, and basally. Some of the signs seen on the chest image are Ground Glass Opacification (GGO) with a peripheral or posterior distribution, especially in the lower lobes, bilateral, peripheral, and basal consolidation, bronchopneumonia characterized by bronchovascular thickening [14][1].

An effective performance measurement tool for machine learning is ROC, based on a diagnostic test of a dichotomous classification and compared with the gold standard. The AUC curve is a range of values that determines the performance capability of a deep learning model, whether or not it fails based on the area of the curve, the wider the AUC or closer to symmetrical to the sensitivity value, the better the deep learning model [18].

In the deep learning model, the AUC value of 0.9232 is obtained, then based on these results, it is stated that the CNN deep learning model is in the "very good" performance category (0.90-1.00), which means that the CNN deep learning model is feasible and effective to detect digital thorax image with Covid-19 or normal. The confidence interval (CI 95%) is 0.862-0.983, which means that if the deep learning model is used to detect COVID-19 on thorax images of 100 patients, then the correct conclusion is 92 people, while based on the 95% confidence interval, the AUC can be seen in population ranged from 86 to 98 people with the right conclusion.

Based on the AUC value obtained, it shows that there are still errors from the application of the CNN deep learning model in detecting Covid-19, while in the process of determining the diagnosis, it must be determined on a clinical basis in order to get the correct diagnosis. In other words, the CNN deep learning model can be used under certain conditions.

CONCLUSION

The performance of the CNN deep learning model is decent and very good in detecting Covid-19 in radiographic images with an AUC value of 0.9232 range (0.90-1.00) "very good".

Suggestion

It is necessary to improve and develop the ability to classify the performance of deep learning models based on the type of clinical support in determining the diagnosis of Covid-19, such as bronchopneumonia, pneumonia and others.

REFERENCES

[1] World Health Organization, "Situation Report 64," *Coronavirus Dis. 2019*, vol. 2019, no. April, p. 2633, 2020, [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019.

[2] et al Guan W-J, Ni Z-Y, Hu Y, Liang W-H, Ou C-Q, He J-X, "Clinical characteristics of 2019 novel coronavirus infection in China," *CC-BY-NC-ND 4.0 Int. Licens.*, 2020, doi: https://doi.org/10.1101/2020.02.06.20020974.

[3] Y. H. et al. N. Chen, M. Zhou, X. Dong, J. Qu, F. Gong, "Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan , China : a descriptive study," *Elseiver Ltd.*, no. January, pp. 507–513, 2020.

[4] Q. Li *et al.*, "Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia," *N. Engl. J. Med.*, vol. 382, no. 13, pp. 1199–1207, 2020, doi: 10.1056/nejmoa2001316.

[5] W. L. et al. T. Ai, Z. Yang, H. Hou, C. Zhan, C. Chen, "Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases," *Radiol. Soc. North Am.*, vol. 2019, 2019, doi: 10.1148/radiol.2020200642.

[6] L. Wang, Y. Wang, D. Ye, and Q. Liu, "Review of the 2019 novel coronavirus (SARS-CoV-2) based on current evidence," *Int. J. Antimicrob. Agents*, vol. 55, no. 6, p. 105948, 2020, doi: 10.1016/j.ijantimicag.2020.105948.

[7] World Health Organization, "Coronavirus Disease (COVID-19) Technical Guidance: Patient Management (Use of chest imaging in COVID-19)," *Radiat. Heal. Publ.*, p. 56, 2020, [Online]. Available: https://www.who.int/publications/i/item/use-of-chest-imaging-in-covid-19.

[8] Y. S. Hariyani, S. Hadiyono, and T. S. Siadari, "Deteksi Penyakit Covid-19 Berdasarkan Citra X-Ray Menggunakan Deep Residual Network," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 8, no. 2, p. 443, 2020, doi:

10.26760/elkomika.v8i2.443.
[9] T. Ozturk, M. Talo, E. Azra, U. Baran, and O. Yildirim, "Automated Detection of COVID-19 Cases Using Deep Neural Networks with X-ray Images," *Comput. Biol. Med.*, no. January, 2020.
[10] Correspondence, "Artificial intelligence in medical imaging: Game over for radiologists?," vol. 126, no. February, p. 108940, 2020, doi: 10.1016/j.ejrad.2020.108940.
[11] Z. Y. Zu *et al.*, "Coronavirus Disease 2019 (COVID-19): A Perspective from China," *RSNA.org*, vol. 2019, 2019.
[12] B. J. Erickson, P. Korfiatis, Z. Akkus, and T. L. Kline, "Machine learning for medical imaging," *Radiographics*, vol. 37, no. 2, pp. 505–515, 2017, doi: 10.1148/rg.2017160130.
[13] R. Primartha, *Belajar Machine Learning Teori dan Praktik*. Bandung: Informatika Bandung, 2018.
[14] J. Lee *et al.*, "Deep Learning in Medical Imaging : General Overview," *Korean J. Radiol.*, vol. 18, no. 4, pp. 570–584, 2017.
[15] S. Trebeschi *et al.*, "Deep Learning for Fully-Automated Localization and Segmentation of Rectal Cancer on Multiparametric," *Sci. Rep.*, no. March, pp. 1–9, 2017, doi: 10.1038/s41598-017-05728-9.
[16] J. T. Norweck *et al.*, "ACR – AAPM – SIIM Technical Standard for Electronic Practice of Medical Imaging," *J Digit Imaging*, pp. 38–52, 2013, doi: 10.1007/s10278-012-9522-2.
[17] Darma Putra; Westriningsih, *Pengolahan Citra Digital*. 2010.
[18] H. Polat and H. D. Mehr, "Classification of pulmonary CT images by using hybrid 3D-deep convolutional neural network architecture," *Appl. Sci.*, vol. 9, no. 5, 2019, doi: 10.3390/app9050940.
[19] S. Saha, "A Comprehensive Guide to Convolutional Neural Networks," *Toward Data Science*, 2018. https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53.
[20] P. Rajpurkar *et al.*, "CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning," *Arxiv*, pp. 3–9, 2017, [Online]. Available: http://arxiv.org/abs/1711.05225.