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The analysis of differences at Binary Image in COVID-19 and ARDS Patients from chest X-Ray examination

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Abstracts

Corona virus disease 2019 (COVID-19), a viral infection that was discovered at the end of December 2019 in Wuhan, China. The spread and transmission of this virus is very fast even to all countries in the world. Meanwhile, Acute Respiratory Distress Syndrome (ARDS) is an emergency condition in the field of pulmonology that occurs due to fluid accumulation in the alveoli causes gas exchange disorders so that oxygen distribution to tissues were reduced. In this study, Chest X-Ray (CXR) image processing done in COVID-19 and ARDS patients with the aim of analyzing the differences in binary image using the Otsu Thresholding method. This study prioritizes improving the quality of the original CXR image by segmentation using calculating the Peak Signal-to-Noise Ratio (PSNR) and Mean Square Error (MSE) values. The results showed that the difference between CXR images in COVID-19 patients and ARDS lies in the extent of spread, in COVID-19 patients the extent of spread varies depending on the length of time the virus has invaded and not all of it starts from the alveolus, while ARDS tends to be constant and starts from the lungs. The lower part of the lung, specifically the alveoli.

Keywords: Covid-19; ARDS; Otsu; PSNR; MSE; Binary image

1. Introduction

The first Corona virus disease 2019 (COVID-19), a viral infection that was discovered at the end of December 2019 in Wuhan, China. The spread and spread of this virus is very fast even to all countries in the world [1]. The etiology of the new coronavirus is shown in the sample studied [2]. WHO has named COVID-19 and Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) as the causes [3]. COVID-19 was declared by WHO as a pandemic in early 2020 [4]. Transmission of this virus is confirmed that transmission of pneumonia can occur from human to human [5].

Acute Respiratory Distress Syndrome (ARDS) is an emergency condition in the field of pulmonology that occurs due to fluid accumulation in the alveoli causes gas exchange disorders so that oxygen distribution to tissues were reduced. The etiology of ARDS due to primary pulmonary disorders can occur due to aspiration, pneumonia, toxic inhalation, pulmonary contusions, while extrapulmonary abnormalities occur due to sepsis, pancreatitis, blood transfusion, trauma and the use of drugs such as heroin [6]. ARDS is a serious complication of sepsis occurring in 60% of cases of sepsis with a mortality rate of 30% to 60%. Increased capillary permeability is a major cause of ARDS [7].

Chets X-Ray (CXR) is a medical method used to diagnose conditions of the lungs. The use of X-rays in the examination of the lungs is the most commonly used technique. The results of the X-ray process provide a different image between healthy and unhealthy lungs [8], such as normal lungs or the lungs of patients with COVID-19 and ARDS. Previous research by Sumarti [9] using CXR imagery to analyze the progress of 9 hospitalized COVID-19 patients with the active contour method showed that 89% of patients experienced a decrease, while 11% experienced an improvement in their condition. Another study by Rajinikanth et al. [10] using the Otsu Thresholding method on CT-scan images to identify the severity of COVID-19 patients based on pixel ratios produces better accuracy than standard diagnoses. Research by Satapathy et al. [11] using the Otsu method on CT-Scan images of COVID-19 patients produces better accuracy compared to other methods presented.

In this study, CXR image processing was carried out on patients with COVID-19 and ARDS with the aim of analyzing the differences binary image using the Otsu Thresholding method [12]. This study prioritizes improving the quality of the original CXR image by segmentation by calculating the Peak Signal-to-Noise Ratio (PSNR) and Mean Square Error (MSE) values.

2. Experiments Procedure

The data used in this study is a dataset obtained from the website, namely Github [13]. The data consists of 10 CXR image data of COVID-19 patients and 4 CXR image data of ARDS patients representing different subjects. This research was conducted by improving the quality of the original image in the form of Red Green Blue (RGB) to binary image in black and white using Otsu Thresholding method with MATLAB software. The procedure in this study consists of stages in the segmentation process in the lung area of COVID-19 and ARDS patients. The first stage is image segmentation, the second stage is the Otsu thresholding method, final step is calculating the PSNR and MSE values.

The first stage is image segmentation. Image segmentation means dividing an image into homogeneous regions based on certain similarity criteria between the gray level of a pixel and the gray level of its neighboring pixels, then the results of this segmentation process will be used for further processing [14].

The second stage is the Otsu Thresholding method which functions to distinguish between

the background and foreground based on the difference in light and dark levels in the image. The purpose of the Otsu Thresholding method is to automatically divide the histogram of the gray image into two different areas without using any assistance [15]. There are several calculations performed to obtain the thresholding value. The initial stage is to make a histogram. At each level of gray can be seen the number of pixels. The gray level of the image can be expressed from i to L. Pixel 0 is level i starting from 1, for L, the maximum is 256 with a pixel value of 255.

The probability at level i for each pixel is:

$$P_i = \frac{n_1}{N} \quad (1)$$

where:
Pi =Pixel probability to i,
ni =Number of pixels with gray level i,
N = Total Total Number of pixels in the image.

The value of the cumulative moment to zero and the value of its cumulative sum expressed as follows:

$$\omega(k) = \sum_{i=0}^{k} P_i \quad (2)$$

Meanwhile, to determine the cumulative mean as follows:

$$\mu(k) = \sum_{i=0}^{k} i.P_i \quad (3)$$

The global mean intensity expressed as follows,

$$\mu_T(k) = \sum_{i=0}^{L-1} i.P_i \quad (4)$$

The value of k in equations (2), (3) and (4) represents the gray level of each pixel range to be calculated. The next step is to determine the variance between classes. The equation for the between class variance is,

$$\sigma_B^2(k) = \frac{[\mu_T\omega(k) - \mu(k)]^2}{\omega(k)[1-\omega(k)]} \quad (5)$$

The maximum value is obtained from the calculation of the variance between classes. The largest value from the whole class is used as the threshold value (t) which is used for the process of dividing the segmentation area.

The last stage is a performance evaluation technique by looking for PSNR and MSE values to determine the improvement in good image quality between CXR images of COVID-19 patients and ARDS. In digital images there is a standard for measuring image quality errors, namely the MSE and PSNR values. The ability of the image quality improvement method can also be measured by visual techniques, namely looking at the resulting image and comparing it with the original image, but in medical images it is not easy to see the abnormality without having a good knowledge base, so the results of measuring visual techniques vary from person to person [16].

3. Result and Discussion

The binary image of the Otsu Thresholding result on the CXR image of a COVID-19 patient is shown in Figure 1. Coronavirus is a single strain, unsegmented, and encapsulated RNA virus. This virus belongs to the Nidovirales group, the Coronaviridae family, which is cube-shaped with S protein, located on the surface of the virus. Protein S is the main structure of gene writing and the main antigen of the virus. This protein is in charge when the virus enters and attaches to the host cell [17].

The resulting Otsu Thresholding image on a CXR image of an ARDS patient is shown in Figure 2. ARDS is defined as a precipitating lung injury or new respiratory development that worsens within one week. The presence of bilateral infiltrates on CXR images and pulmonary edema are not caused by a heart problem [18].

Analysis applying thresholding method is a way to recognize images based on threshold values. One method to get the threshold value is the Otsu method. The Otsu method is a popular method among all thresholding methods and the best method in obtaining the threshold value automatically. In many studies, Otsu Thresholding is applied to minimize the variance of black and white pixels, recognizing the performance comparison of edge detection methods [19].

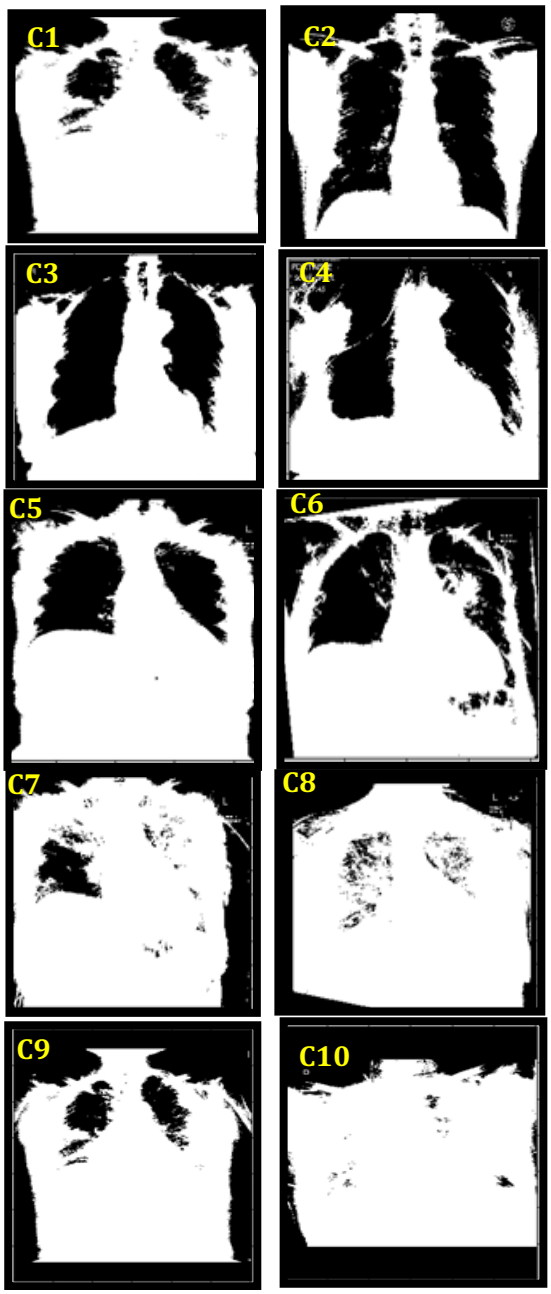

Figure 1. Otsu Thresholding on CXR image of COVID-19 patient

The results of direct observations of Otsu Thresholding results on CXR images of COVID-19 patients and ARDS in general have some differences. In the CXR image of the COVID-19 patient, the spread is more widespread or always growing, while in the CXR image of the ARDS patient, the spread of the disease starts from the bottom of the lungs, more specifically the alveolus area. In CXR images of ARDS patients, the area of spread tends to be constant or takes a longer time, while in COVID-19 patients, the extent of virus spread is fast and changes more widely as time goes on. COVID-19 patients can experience complications, one of which is ARDS, but ARDS patients do not necessarily pass the phase of COVID-19 patients. This is in accordance with the existing theory that COVID-19 patients will go through several phases, one of which is the ARDS phase or severe pneumonia [20]–[22].

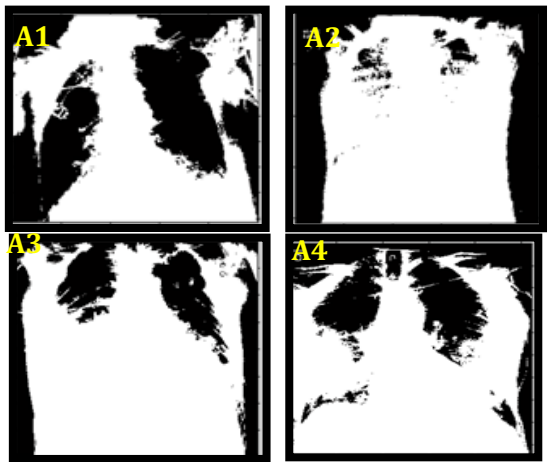

Figure 2. Otsu Thresholding on CXR image of ARDS patient

Analysis of improving the quality of CXR image results from Otsu Thresholding in COVID-19 and ARDS patients was carried out by calculating PSNR and MSE. Table 1 shows the results of calculating PSNR and MSE in COVID-19 patients, while Table 2 shows the results of calculating PSNR and MSE in ARDS patients.

Table 1 shows that in the image of COVID-19 patients, the largest PSNR value is 5.75 dB and the smallest value is 2.88 dB, while the largest MSE value is 27235.40 dB and the smallest MSE value is 14072.67 dB. While in Table 2, the ARDS patient image has the largest PSNR value of 4.67 dB and the smallest PSNR value of 3.25 dB, while the largest MSE value is 24786.23 dB and the smallest MSE value is 18062.98 dB. This means that the improvement

in the image quality of the Otsu Thresholding results is very good and will make it easier to distinguish between the results of the COVID-19 and ARDS images [16]. This is different from the results of other studies using an image algorithm in the form of Deep Neural Network (DNN). The model generates predictions on wrong quality CXR images for ARDS patients, where the lung image is diffuse and a lot of lung ventilation is lost [23].

Table 1. Hasil PSNR and MSE calculation results at CXR images of COVID-19 patients

Image Identity	MSE	PSNR
C1	23452.13	3.53
C2	17038.94	4.92
C3	27235.40	2.88
C4	14072.67	5.75
C5	20536.47	4.11
C6	26156.03	3.06
C7	25426.07	3.18
C8	21243.20	3.96
C9	25800.08	3.12
C10	18059.69	4.67
Avarage	21912.06	3.91

Table 2. PSNR and MSE calculation results at CXR image of ARDS patients

Image Identity	MSE	PSNR
A1	18062.98	4.67
A2	21220.38	3.97
A3	18979.53	4.45
A4	24786.23	3.29
Average	20762.28	4.09

Previous studies have focused on identifying potential ARDS sub phenotypes due to heterogeneous clinical, radiological, pathological and biological features. The complex interactions underlying the damage and compensatory mechanisms that affect the alveolocapillary unit in ARDS have been of scientific concern for longer: the deleterious inflammatory cascade launched after lung injury stems from primary (pneumonia) or secondary (ex. sepsis, aspiration, noncardiogenic shock) ARDS [24]. Sepsis, life-threatening organ dysfunction due to a regulated body response to suspected or proven infection [25]. Death within 72 hours of hospital admission is primarily due to the condition that causes ARDS. Meanwhile, after 72 hours of admission, nosocomial pneumonia and sepsis were the most common causes of death [26]. In another study, the mortality of ARDS patients infected with COVID-19 was 28.8%. According to a median PaO2/FIO2 of 198.5 mmHg in patients with COVID-19 in this study, the corresponding mortality rate is consistent with the definition of ARDS [5].

In future research, more data can be used so that accurate and more specific results are obtained at the time of data analysis. This research can also be further developed using other modalities such as CT-Scan [11] or improve image quality by using other methods such as intensity adjustment [27].

4. Conclusion

CXR image processing has been carried out on COVID-19 and ARDS patients using binary image with the Otsu Thresholding method. The difference between CXR images in COVID-19 patients and ARDS lies in the extent of spread, in COVID-19 patients the extent of spread varies depending on the length of time the virus has invaded and starts not all from the alveolus, while ARDS tends to be constant and starts from the lower lungs, specifically the alveoli. Based on the results of PSNR and MSE analysis on CXR images of COVID-19 and ARDS patients, it shows that the Otsu Thresholding method is very good for improving the quality of the original image.

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