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Digitization and Improvement of Lung X-ray Scan Display with WWW Filter and Histogram Equalization Method

Muhammad Kusban [a,1,*], Tri Nur Wahyudi [a,2], Farid Rahman [a,3]
[a] Universitas Muhammadiyah Surakarta, Surakarta, Indonesia
[1] Muhammad.Kusban@ums.ac.id *
* Corresponding Author

ABSTRACT

Detection of lung disease is generally done manually by trained professionals. The condition of pulmonary disorders has worsened since the outbreak of the 2019 coronavirus disease (COVID-19), which is a significant threat to people's lives and health due to its high infectivity and rapid spread. Lung X-ray images are one way to detect various lung diseases and COVID-19 disorders. However, the image's appearance is usually affected by pixels with uneven grayscale and isolated noise, making it weak in detecting the symptoms encountered. To solve this problem, a WWW filter method for preprocessing is proposed, as well as incorporating histogram equalization. In particular, histogram equalization is applied to increase the image's contrast. The WWW filter combines wavelet, Wiener, and weighing methods to get a clear view of the lungs. The histogram process will provide a significant contrast value, making it easier for experts to further lung diagnosis. From the trial conducted, the PSNR value of 14.0931 to 19.9037 and an increase in EME from 23.1308 to 75.2877. The experimental results prove that the proposed algorithm can effectively detect pulmonary disease symptoms and is expected to be useful for diagnosing COVID-19.

KEYWORDS
Covid-19
PSNR
EME
WWW filter
Histogram equalization

1. Introduction

For digital image processing, contrast-enhancing technology is helpful for many people, especially people working in the field of image enhancement, as well as doctors who work in image diagnosis of internal organs [1]. Histogram Equalization (HE) is one of several techniques in the field of image processing that is effective in increasing [2] contrast. HE can reduce gray levels by combining neighboring/adjacent gray colors so that the HE technique can widen the high and low contrast levels towards a constant value of [3, 4]. HE can minimize the pixel height towards the average value so that the appearance of the image frequency becomes more even [5]. This process of flattening the image value causes the contrast value to increase [6]. HE cannot process an image with dark or light areas that differ significantly from other regions [7]. For this reason, other processes are needed, such as image filters for image normalization with different brightness levels of light and dark that are striking [8, 9]. One of the HE methods is adaptive histogram equalization (AHE) developed by Pizer [10]. AHE maps each pixel to the proportional intensity of the pixels surrounding it. The AHE application is mainly for enhancing photo images. The weakness of AHE is that it adds noise and artifacts in [11, 12]. The presence of noise and artifacts will certainly reduce the important information in the image. The development of AHE was carried out by Reza [13], namely the contrast limited adaptive histogram equalization (CLAHE) method can reduce artifacts in AHE [14]. The CLAHE method is widely used in the medical field to reduce artifacts and refine the x-ray image of [15]. Another development of the HE method is the recursively separated and weighted histogram equalization (RSWHE) technique that is used to increase the brightness and contrast of the [16] image. RSWHE maps the input histogram into two or more sub-histograms recursively and then performs the weighting process with the power law [17] function. The RSWHE process can be divided into two parts, namely recursive sub-image histogram equalization (RSIHE) and recursive mean separate histogram equalization (RMSHE) [18]. The difference between the two methods with RSWHE is in using weight values not applied in [19].

2. Method

Image enhancement (image enhancement) is an image processing technique that increases essential information and reduces or eliminates secondary information to improve identification quality. The purpose of the image enhancement process is to better adjust the condition of an image to the following strategy that will be encountered by [20]. Furthermore, the following are some definitions that support research, such as HE and CLAHE, followed by the steps and research methods carried out.

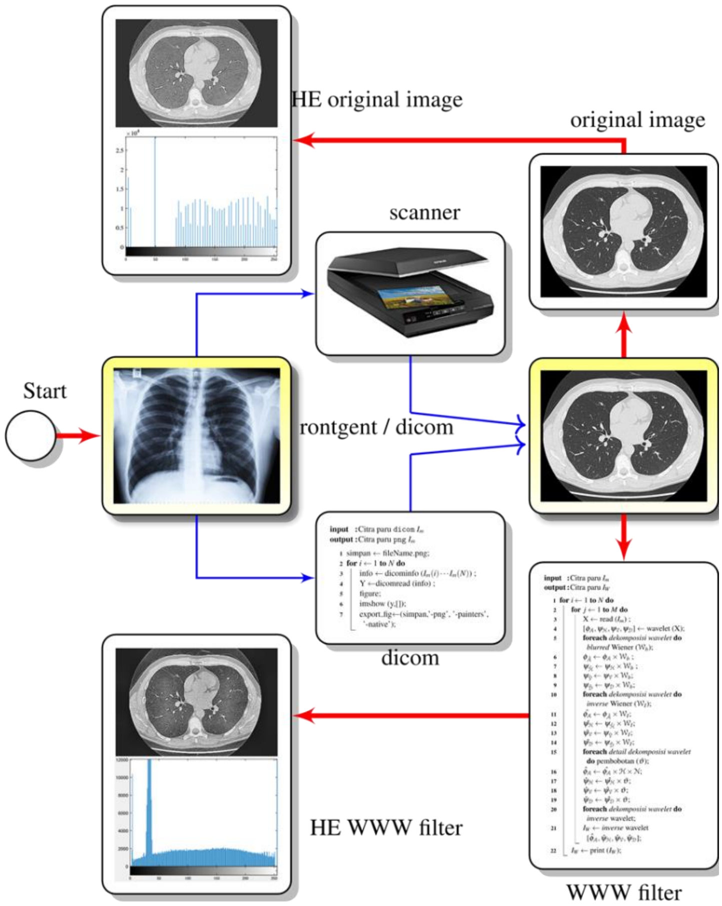

Fig. 1. Schematic of the performance of the digitizing system and the process of improving the appearance of lung X-ray images

2.1. Lung Image Digitization

When the x-ray process occurs, the output is generally in the form of a dicom file with the extension dcm and a photo negative. Digitizing negative photos can be done by scanning a tool such as a Canon scanner. For files in the dicom format, the use of the Matlab command function can be seen in the following Algorithm 1 referring to the reviews of previous researchers [21, 22].

input: Citra paru dicom I_m

output: Citra paru png I_m

simpan ← fileName.png;
for $i \leftarrow 1$ **to** N **do**
  info ← dicominfo ($I_m(i) \cdots I_m(N)$) ;
  Y ←dicomread (info) ;
  figure;
  imshow (y,[]);
  export_fig←(simpan,'-png', '-painters', '-native');

Algoritme 1: Dicom image digitization to png file

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2.2. WWW Filters

Before the HE process occurs, there is a system improvement in increasing the contrast value of the image by using an image filter. The technique used is the WWW filter, which comes from three algorithms: wavelet, Wiener, and weighing.

Fig. 2. Appearance of cameraman image for two conditions (a) original image (b) image resulting from using WWW filter

A wavelet is a mathematical expression used in digital signaling to describe wave components with different durations. The wavelet with a finite tempo store an average value of zero. For image processing, wavelet filters can overcome weak signals due to noise and can also be used to reduce the size of file. The wavelet transfer or decomposition process has multi-resolution characteristics, i.e., the signal will produce important coefficient values around the local point, in addition to having high benchmark similarity forecasts for non-linear signals. Wavelet filters can be used to shrink and even eliminate very small coefficients and increase residual values when operating in non-linear mapping. The use of wavelet filters is widely used in various applications, especially in the field of biomedicine and biometrics [23].

The wavelet filter can visually represent striking scale differences in geometric patterns. Complete pattern information can be obtained from wavelet decomposition for the palm image's local and global detail values. The main problem in biomedicine and biometrics is the sizeable computational load of the entire image that must be processed. To overcome this problem, it is necessary to cut the image size in a way that still has the existing main characteristics. For this reason, it is proposed to use the approximate value of the fourth-level wavelet decomposition. The second-level wavelet decomposition approximation has the advantage of smaller image sizes and can represent the required pattern of information. After using the wavelet filter, then proceed with the use of the Wiener filter.

input: Lung images I_m
output: Lung images I_W

for $i \leftarrow 1$ **to** N **do**
  for $j \leftarrow 1$ **to** M **do**
    $X \leftarrow$ read (I_m) ;
    $[\phi_{\mathcal{A}}, \psi_{\mathcal{H}}, \psi_{\mathcal{V}}, \psi_{\mathcal{D}}] \leftarrow$ wavelet (X);
    foreach *decomposition wavelet* **do** *blurred* Wiener $(\mathcal{W}_b)$;
    $\phi_{\hat{\mathcal{A}}} \leftarrow \phi_{\mathcal{A}} \times \mathcal{W}_b$;
    $\psi_{\hat{\mathcal{H}}} \leftarrow \psi_{\mathcal{H}} \times \mathcal{W}_b$;
    $\psi_{\hat{\mathcal{V}}} \leftarrow \psi_{\mathcal{V}} \times \mathcal{W}_b$;
    $\psi_{\hat{\mathcal{D}}} \leftarrow \psi_{\mathcal{D}} \times \mathcal{W}_b$;
    foreach *decomposition wavelet* **do** *inverse* Wiener $(\mathcal{W}_I)$;
    $\hat{\phi}_{\mathcal{A}} \leftarrow \phi_{\hat{\mathcal{A}}} \times \mathcal{W}_I$;
    $\hat{\psi}_{\mathcal{H}} \leftarrow \psi_{\hat{\mathcal{H}}} \times \mathcal{W}_I$;
    $\hat{\psi}_{\mathcal{V}} \leftarrow \psi_{\hat{\mathcal{V}}} \times \mathcal{W}_I$;
    $\hat{\psi}_{\mathcal{D}} \leftarrow \psi_{\hat{\mathcal{D}}} \times \mathcal{W}_I$;
    foreach *detail decomposition wavelet* **do** weighing (ϑ);
    $\hat{\phi}_{\mathcal{A}} \leftarrow \hat{\phi}_{\mathcal{A}} \times \mathcal{H} \times \mathcal{N}$;
    $\hat{\psi}_{\mathcal{H}} \leftarrow \hat{\psi}_{\mathcal{H}} \times \vartheta$;
    $\hat{\psi}_{\mathcal{V}} \leftarrow \hat{\psi}_{\mathcal{V}} \times \vartheta$;
    $\hat{\psi}_{\mathcal{D}} \leftarrow \hat{\psi}_{\mathcal{D}} \times \vartheta$;
    foreach *decomposition wavelet* **do** *inverse* wavelet;
    $I_W \leftarrow$ *inverse* wavelet $[\hat{\phi}_{\mathcal{A}}, \hat{\psi}_{\mathcal{H}}, \hat{\psi}_{\mathcal{V}}, \hat{\psi}_{\mathcal{D}}]$;
  $I_W \leftarrow$ print (I_W);

Algoritme 2: WWW filter to enhance lung X-rays

The Wiener filter can reduce signal noise by minimizing the mean squared error between the random process forecast and the desired [24]. The purpose of using the Wiener filter is to find the minimum mean square error value so that the difference between the original signal and the generated signal is as tiny as possible. In the image processing technique, the Wiener W filter can be used to reduce the appearance of blurred images due to object movement during the acquisition process. In the application, the Wiener method is applied to all four wavelet decompositions. Next is the weighing technique (ϑ).

The method of assigning weights (weighing) is commonly used in the case of research that takes a partial sample, then is used to represent the entire sample of data [25]. The weight method is needed as an added value to compensate for the unrepresented sample value. In the case of a wavelet filter, the resulting value has limitations with the truncation of extreme importance in high frequencies. Using a weighting method is also helpful in reducing potential data imbalances. The weights are adjusted according to the inverse ratio of the input frequency data. These three methods are used in the 2 algorithm with the application results visible in Image 2.

2.3. Histogram Equalization

The histogram equalization (HE) technique aims to distribute gray levels in an image. Therefore, each gray level has an equal chance of occurring. HE changes the brightness and contrast of dark images and low image contrast to improve image quality. The histogram will be tilted to the lower end of the grayscale for dark images, and image information will be obtained from the dark side of the histogram. To create a more even histogram, the gray levels are redistributed at the dark ends so that the image appears more straightforward. A histogram of the digital image with an intensity level in the range [0, L−1] is a discrete function represented in the following form.

$$HEik = nk \tag{1}$$

where ik is the intensity of the −k value, nk is the number of image pixels with an intensity of ik. Histograms are often normalized by the total number of pixels in an image. If M ×N is the size of the image-object, then the histogram normalization will be correlated with the probability of occurrence of ik in the image.

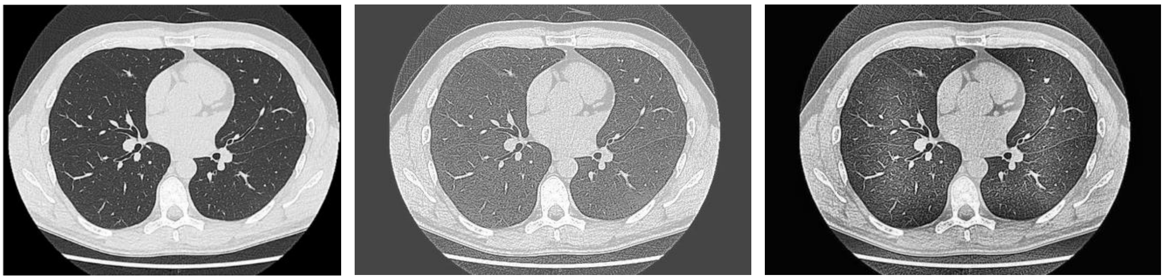
HE provides a uniform histogram distribution using the principle cumulative density (Cik) function of the input image. For each sub histogram j in the region [aj, bj] the histogram equalizes into the form in Equation (2).

$$HEik = aj + (bj - aj) \times Cik, 1 \leq i \leq \text{n} \quad (2) \tag{2}$$

The HE process limits the brightness of low-contrast images, so the process is not sufficient for enhancing a form of medical image that generally has low contrast. Especially for medical images, it is necessary to increase the excellent contrast and the maximum availability of information so that with these two conditions, it is hoped that competent experts can diagnose the disease correctly. To achieve this goal, the adaptive gamma correction technique has been used to enhance low-contrast medical images further, as shown in the following Equation (3).

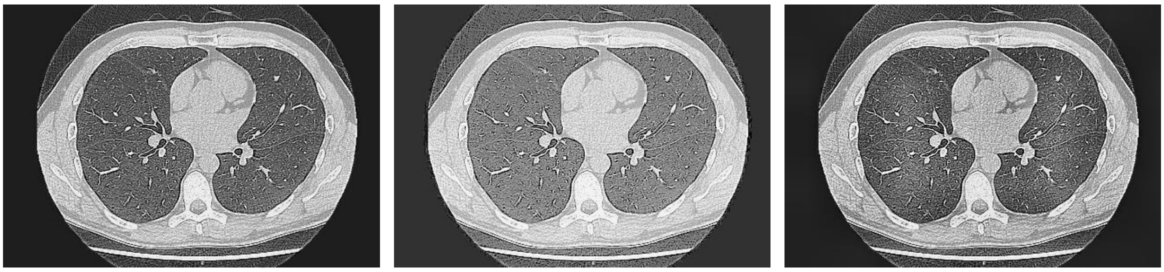
$$HEik = I^{\max}\left(\frac{I_{i_k}}{I_{\max}}\right)^{\rho} \tag{3}$$

The adaptive gamma correction process is essential for the further enhancement of medical images. But for, low contrast and medical images with a structured background of complex shapes will produce some noise artifacts in visually essential areas. To eliminate this problem, we use homomorphic filtering. This filtering operates in the frequency domain and helps correct non-uniform illumination artifacts from low-contrast images.



a b c

Fig. 3. Lung image (a) original image, (b) HE image, (c) CLAHE image



a b c

Fig. 4. Pre-filtered lung image with WWW filter process (a) filtered image (b) HE image (c) CLAHE image

2.4. CLAHE

The improved HE variant is called adaptive histogram equalization (AHE). AHE performs histogram equalization over small areas (patch) in the image so that AHE increases the contrast of each region individually. Therefore, AHE adaptively increases the local contrast and edges in each image region to the local pixel distribution. So, AHE is local information and does not have global information nature. If it coincides with the local noise value that reaches the image, the noise value will be increased in this AHE process. To overcome this weakness, CLAHE applies a contrast fix for the selected region with the specified threshold limit.

The CLAHE process starts by converting RGB (red, green, and blue) to the HSV color space (hue, saturation, and value) as human sensory colors similar to the HSV version. Furthermore, the HSV value component is processed by CLAHE without affecting the hue and saturation. The initial histogram is cropped, and each gray level is redistributed to the trimmed pixels. The value of each pixel is reduced to a user-selectable limit. Finally, the resulting image from the HSV process is transformed back into the RGB color space.

2.5. Increase Contrast

Contrast is the unit of difference between the maximum and minimum pixel intensities. Contrast is a term for different lighting or colors of an object so that the presentation of the thing differs from one another. The human visual system is sensitive to contrast compared to absolute lighting, so it can view objects the same way or with the same value regardless of varying illumination. Things with maximum contrast cause the other side of the image to experience a decrease in contrast because it is dynamic. Brightening the image will increase the contrast in the dark areas but decrease the contrast in the light regions, while darkening the image will have the opposite effect. Different definitions of K(x,y) contrast are used in different situations. When the luminance contrast is used as an example, the Equation (4) takes the following form.

$$K(x,y) = \frac{\Delta L}{\tau L} \tag{4}$$

where Δ is the difference, and τ is the average. While the contrast formula for widening the image histogram by increasing the value contained in it is stated in the following equation (5).

$$K(x,y) = \frac{f(x,y) - f_{\min}}{f_{\max} - f_{\min}} \tag{5}$$

2.6. PSNR and EME

The enhancement algorithm aims to improve the image quality so that the processed image is better than the original image and is generally used for further processing. Such improvement can be assessed subjectively by visual inspection of the image display. However, precise and complete characteristics cannot be achieved by subjective evaluation. There is no universal formula measure that can determine the objective and subjective validity of the chosen algorithm. However, in general, the two algorithms used are PSNR and EME. Image quality can be measured by the peak signal to noise ratio (PSNR) method. The PSNR technique improves image quality while maintaining a natural appearance without amplifying existing noise. The higher the PSNR value, the better the image quality reconstruction. PSNR is the ratio between maximum power and noise-induced power.

$$\text{PSNR} = 10\log_{10}\left[\frac{(L-1)^2}{\frac{1}{2}\sum_i\sum_j |x(i,j) - y(i,j)|^2}\right] \tag{6}$$

where x(i, j) is the intensity of the input image and y(i, j) is the intensity of the processed image. Furthermore, effective measure of enhancement (EME) is a quantitative measure of image enhancement obtained by dividing the image into several parts as shown in the following Equation (7).

$$\text{EME} = \frac{1}{K_1K_2}\sum_{L=1}^{K_2}\sum_{K=1}^{K_1} 20\log\left[\frac{I_{\max}(k,l)}{I_{\min}(k,l)}\right] \tag{7}$$

where K1,K2 is the number of horizontal and vertical blocks of the image, Imax(k,l),Imin(k,l) is the maximum and minimum pixel values in the block. The greater the EME value, the greater the brightness level.

Table 1. HCC model table

X-Ray Photo	Phe Pclahe Prmshe Pclarmshe	Ehe Eclahe Ermshe Eclarmshe
Original	14,0931 19,3065 27,2780	19,453 23,1308 114,7789 140,2592140,0742
WWW filter	19,9037 27,3023 22,9854	24,4749 75,287777,503 143,5826140,5544

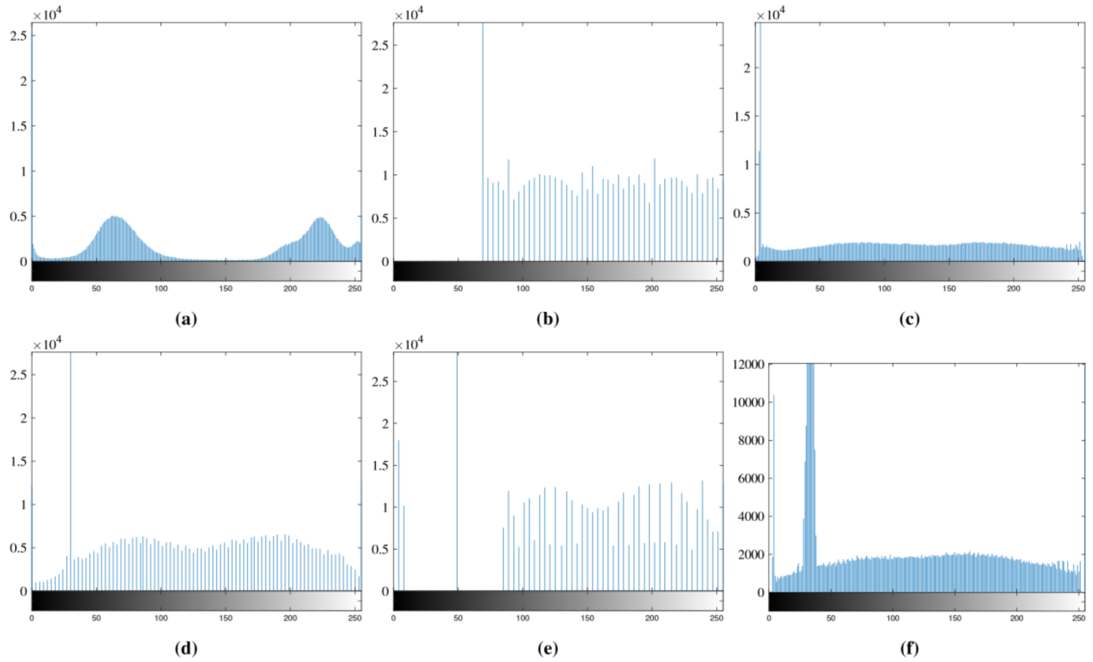


Fig. 5. Histogram lung image (a) original image, (b) HE image, (c) CLAHE image, (d) filtered image with WWW, (e) HE WWW filtered image, and (f) CLAHE WWW filtered image

3. Results and Discussion

Implementation of Research in Community Service activities begins with first making software Matlab, which will automate the x-ray film negatives into image files with PNG and JPG extensions. The PNG value if the image data is processed further because the quality of the appearance is better than JPG. The process continues by using the WWW filter algorithm as a filter for all previously generated images. All data saved in two modes: original and filtered. For sampling healthy photos or those that have been affected by COVID-19, use the directory reference that is open-access on the web page: http://www.via.cornell.edu/lungdb.html http://www.via.cornell.edu/lungdb.html.

The original appearance of the X-ray image is blurry and indistinct. By using the 1 which contains the command Matlab for x-ray files in files with the extension DCM. If the image condition is still in a negative film condition, the process is carried out first with a scan tool. Files are collected in two directories, namely original image and WWW image, filtered by the WWW filter method. The image used has a size of [627×940] for the dimension file type uint8. For 3D images, use the rgb2gray command to become a 2D image. Each object is treated with stretching using the imhist command to obtain HE images, both original and filtered WWW images. Next, the command histeq is used to get the CLAHE value. The output of this pixel widening is shown in Image 3 for the original image and Image 4 for the filtered image. The test values using the histogram method are then tabulated in the 1 table.

It can be seen from Figure 4 (a) that it has a better level of visual clarity when compared to Image of 3 (a). The WWW filter clarifies the original image and looks close to the 3D appearance, which emphasizes the dark spots of the original lung image. It is also clearer for the image 3, where the filtered image (2) (b) shows more detail on the jacket and pants cameraman. There are even pockets and buttons on the shirt which were not previously visible in the original image (Image 2 (a)). In pixel, the distribution shows that the frequency value of the image 5 (d), which adopts the use of the WWW filter, has a more even distribution rate than the original image of the image 5 (a). Showing from Figure 5 that the CLAHE method has a more even frequency density than the HE and imhist methods. Furthermore, the proof of PSNR and EME statistical calculations The 1 gives a significant difference of 5,8106 from the WWW filter image with the original image. The significant difference is even greater than the difference between the original EME image and the WWW filtered image EME of 75.2877−23.1308 or a difference of about 52.1569.

4. Conclusion

The WWW filter method can increase the PSNR level, increasing the lung image's clarity and contrast value by 19.9037, which, if not using this technique, can only reach a value of 14.0931. The combination with the pixel widening method or dynamic histogram can also increase the PSNR value by 27.3023 for WWW filters and 19.3065 for the original image. Another calculation, namely the EME method, strengthens the evidence of the analysis. It is hoped that the achievements obtained will be helpful for doctors in internal medicine, especially pulmonary, and can be considered by other researchers for further development. This research needs to be developed further to help doctors diagnose the symptoms and reading of COVID-19 so that it is hoped that with the advancement of the field of image enhancement, we will be able to detect symptoms of the disease earlier.

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