Computer-Aided Diagnosis (CAD) to Detect Abnormalities in Lung Pediatric Radiography using Particle Swarm Optimization Method

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Abstract. The diagnosis of lung organ requires accurate analysis and interpretation. Abnormal parts such as nodules are sometimes covered by other complex lung tissue that is normal tissue. Therefore innovation is needed in analyzing and classifying normal tissue and the nodule. This study developed a Computer-Aided Diagnosis (CAD) for radiographic of pediatric lung using segmentation Particle Swarm Optimization (PSO) method to detect the abnormality in lung image. Particle Swarm Optimization (PSO)-based segmentation method is combined with Fuzzy C-Means (FCM) clustering method and Wiener filter to refine the lung region and search for abnormalities, especially for pneumonia and tuberculosis, based on the value of the image pixel. The performance evaluation of this CAD was done by calculating the Receiver Operating Characteristics (ROC) using 136 images and compared with the reference from doctor evaluation. The overall error of this method is 11.43% or has an accuracy value of 88.57%, while its sensitivity is 90.00%, specificity is 85.00%, and precision is 93.75%. This method has a good success rate in detecting abnormal lung image. However, this segmentation method cannot detect abnormalities located on the edge of the lung, caused by the superposition of the rib image.

1. Introduction

More than 10 million people worldwide die annually from chest diseases. Based on survey, the mortality rates for chest diseases in 1990 were 2.2 million because of chronic obstructive pulmonary disease and 2 million because of tuberculosis [1]. The abnormality of organs in the chest cavity, one of which is a lung organ, requires very accurate analysis and interpretation. Nodules that are expected to be obviously visible are sometimes covered by another complex lung tissue which is normal tissues. Therefore innovation is needed in analyzing and classifying normal tissue and the nodule. Computer-Aided Diagnosis is a tool developed in providing a ‘second opinion’ to detect abnormalities in lung tissue [2, 3]. This process will be packaged in the form of computer-based digital image processing that requires segmentation process to support the success of the classification process. In addition, comparative studies from CAD are still widely recommended because the classification of lung tissue is still a challenging task [4, 5]. Research on CAD in adult lung radiography was conducted by Ralind using Fuzzy Clustering Means (FCM) which aims to see abnormalities in adult lung images from 200 X-ray radiographic image data. The results of her research showed that the performance of the FCM method had an accuracy value of 57.7%, sensitivity of 50.0%, specificity is 89.5%, overall error of 42.3% and precision of 95.1% [6]. The FCM method in that study can only show an outline of visual display of abnormalities but does not provide satisfactory accuracy. Therefore in this study an approach using Particle Swarm Optimization method combined with the FCM method is proposed.

2. Method

This research was conducted by Computed Radiography (CR) image of the pediatric lung, 1-15 years old, from Rumah Sakit Anak dan Bunda Harapan Kita. The image format was DICOM image "for presentation" to the inspection standards PA, AP (antero-posterior) and supine. There were 136
images used in the study. Those were 20 normal images and 116 abnormal images which consisted of 40 Bronchopneumonia Duplex images and 76 Interstitial Pneumonia images. From 136 images, 66 images were used as the model data (20 Bronchopneumonia Duplex images and 46 Interstitial Pneumonia) and 70 images were used as the test data (20 normal images, 20 tuberculosis images, and 30 pneumonia images).

CAD development of children CR lung was divided into three phases: preparation, image segmentation, and evaluation. The preparation phase was conducted by grouping samples of lung CR images of children by disease and then proceeded with normalization and image cropping using imageJ. All image samples in the DICOM format were changed to TIFF. After that the image normalization was done with the image histogram equalization command because the thoracic images obtained from the hospital were heterogeneous or did not have uniform contrast and brightness levels. After normalizing the image pixel values that previously ranged from 0-255, it was changed to 100-255. After the image had been normalized, the image was then cropped early to remove all unwanted parts of the image such as markers, neck and head areas outside the lungs and to speed up the running time of the program when segmenting. After that, the final cropping was done using the MATLAB program. The final cropping was done in semi-automatic segmentation using the active-contour method.

The CAD program was developed with MATLAB versionR2013. Some commands used in the program included the active contour, filter, Fuzzy Clustering Means (FCM) segmentation and Particle Swarm Optimization (PSO)-based segmentation algorithms. The image segmentation phase was done by Fuzzy Clustering Means (FCM) segmentation, filtering and combined with PSO. In addition to that, it was processed at the initial stage (initial segmentation). Initial segmentation was done with the minimum point search method histogram and multilevel thresholding. The minimum point of the histogram was used again to find the number of regions/clusters in the image and to determine a threshold value, while multilevel thresholding aimed to determine the initial cluster of each pixel in the image [7]. The thresholding process was the process of separating between the object and the background. In each image histogram always contained two peaks [8]. The first peak indicated an object, while the second peak indicated the background. Therefore, to separate them, the point of minimum (valley) histogram was used as a threshold limit value (threshold). The following is the process of image segmentation model data and test data.

The evaluation phase was performed by calculating the ROC (Receiver Operating Characteristics) resulted from the proposed method against the reference image from expert evaluation. The reference image was physician evaluation results. The calculated ROCs were accuracy, sensitivity, specificity, precision, and overall error. ROC uncertainty was obtained using five times cross-validation. Cross-validation was useful in order to determine the stability of the proposed method.

3. Result
Inspired by some of the previous researchers who used the FCM algorithm in segmenting images [6], the first step in the image segmentation process in this study was to use the Fuzzy Clustering Means (FCM) program first. FCM is an algorithm that is quite well-known for its soft clustering process and is an ideal image segmentation that is commonly used in medical imaging of the lungs. Therefore, in this research, a combination of the FCM algorithm and Particle Swarm Optimization (PSO) was applied to deal with the segmentation problem. The combination of FCM segmentation with PSO was conducted so that the bone image can be slightly disguised following the surrounding clusters.

FCM segmentation was carried out by the automatic histogram minimum point search method where the determination of the number of clusters is done automatically so that there is no coercion of the number of clusters in the image [7]. This was performed to obtain the appropriate number of clusters individually because each image has different characteristics [6]. The image that had been processed using FCM segmentation was given with advanced segmentation using the PSO method. The determination of the number of clusters in the PSO method was performed several times. The selection of the number of clusters was determined by trying one by one to achieve certain desired
results. The difference in the number of clusters from 2, 3, 4, 5, 10, 15, and 20 did not provide a significant change in the image so that the PSO segmentation was run on each image by using 5 clusters.

FCM + PSO method still had a wide pixel value range of 160 – 255, that it had not been able to detect the diagnosis according to the doctor and the contrast is not as expected. This can be seen in Figure 1. (b) in which the FCM + PSO image of bone disorders decreases but the area that seems abnormal was not segmented as abnormal. So, the image that had been segmented using FCM was treated with several filters, namely Gaussian filter, Imfilter, Median filter, Histeq, and Wiener filter, where the provision of several filters was expected to reduce the influence of noise and ribs that can interfere with the evaluation results of the diagnosis in the next PSO program. The effect of noise and existing ribs was seen the same as the abnormal area because it had a high pixel value. So that it can cause a large deviation to the evaluation of the doctor.

Figure 1 shows the abnormal pulmonary image of interstitial pneumonia of 5 years 4 months 2 days-aged children with the results of giving several filters that had been combined with the PSO method, and it turned out that most of the filters used were not suitable with the PSO method. From Figure 1, the results of image segmentation were close to the original image and had a cluster of infections that can be distinguished from healthy lungs, namely, FCM + Wiener filter + PSO.

![Image of abnormal interstitial pneumonia in children aged 5 years 4 months 2 days with the use of several filters](image)

**Figure 1.** Image of abnormal interstitial pneumonia in children aged 5 years 4 months 2 days with the use of several filters (a) Original Image, (b) FCM + PSO image, (c) FCM + Gaussian filter + PSO image, (d) FCM + Im filter + PSO image, (e) FCM + Median filter + PSO image, (f) FCM + Histeq + PSO image, (g) FCM + Wiener filter + PSO image.

Through observations on 66 abnormal images, the obtained range of abnormal image pixel values in the image was then used as the pixel value of the model data. The range of pixel values in the cluster data model for abnormal images in FCM + Wiener filter + PSO images is 209 - 255. PSO
segmentation is carried out on 70 test data images consisting of 20 normal images, and 50 abnormal images. An evaluation was carried out to calculate the ROC on the FCM + Wiener filter + PSO method. ROC measurements were carried out five times with the cross-validation method.

Table 1. The success rate of the FCM + Wiener filter + PSO method based on ROC values in abnormal pulmonary child images.

| ROC                  | Accuracy          | Sensitivity       | Specificity       | Precision         | Overall Error    |
|----------------------|-------------------|-------------------|-------------------|-------------------|-----------------|
|                      | 88.57% ± 1.6%     | 90.00% ± 2.3%     | 85.00% ± 0.0%     | 93.75% ± 0.1%     | 11.43% ± 1.6%   |

The FCM + Wiener filter + PSO method successfully detected according to the doctor's diagnosis on 17 normal segmented normal images and made 3 abnormal image detection errors that were abnormally segmented. Table 1 shows the result of ROC value on the specificity producing a fairly good value of 85.00%. Figure 2 (a) is an example of normal image segmentation results using the FCM + Wiener filter + PSO method.

Figure 2. FCM + Wiener filter + PSO image with diagnostic suitability (a) Normal image and normal segmented (TN), (b) Abnormal image and abnormal segmented (TP).

In this study, the samples used in the diagnosed abnormal images had abnormalities in Pneumonia and Bronchopneumonia Duplex. Based on the results of the evaluation, the calculated ROC value as shown in Table 2, ROC segmentation results Interstitial Pneumonia that is relatively higher than Bronchopneumonia Duplex. ROC Interstitial Pneumonia results show the value of accuracy at 88.00%, sensitivity at 90.00%, specificity at 85.00%, and precision at 90.00%.

Table 2. The success rate of the FCM + Wiener filter + PSO method is based on the ROI value in the pulmonary image of a child with a diagnosis of Interstitial Pneumonia and Bronchopneumonia Duplex.

| ROC                  | Interstitial Pneumonia | Bronchopneumonia Duplex |
|----------------------|------------------------|-------------------------|
| Accuracy             | 88.00% ± 2.3%          | 87.50% ± 2.1%           |
| Sensitivity          | 90.00% ± 3.8%          | 90.00% ± 4.2%           |
| Specificity          | 85.00% ± 0.0%          | 85.00% ± 0.0%           |
| Precision            | 90.00% ± 0.4%          | 85.71% ± 0.6%           |
| Overall Error        | 12.00% ± 2.3%          | 12.50% ± 2.1%           |
In people with pneumonia, a collection of small air sacs at the end of the respiratory tract in the lungs will swell and fill with fluid. Figure 3 is an example of the original image and the image of the result of pneumonia abnormality diagnosed by a doctor. The impression on the diagnosis is interstitial pneumonia, visible infiltration in the right and left perihilar.

![Figure 3](image)

**Figure 3.** Pulmonary images of children with a diagnosis of interstitial pneumonia and abnormal segmentation by the FCM + Wiener filter + PSO method (a) Original Image before processing, (b) Image from FCM + Wiener filter + PSO segmentation.

In Figure 3, the impression of interstitial pneumonia in the form of right and left perihilar infiltrates is indicated by a red circle with an arrow. There is a gray area with moderate density and indistinct boundaries around the right and left hilum which is indicated by the appearance of patches or small dots. In the colored segmentation image (right) above, a cluster of red clouds appears around the right and left hilum. This shows the success of FCM + Wiener filter + PSO segmentation in segmenting abnormal images. The FCM + Wiener filter + PSO method has a pixel value range of 209-255.

In bronchopneumonia, inflammation occurs in the bronchioles and a small amount of surrounding lung tissue. Figure 4 is another example of an abnormally segmented image which has several regions of an abnormally segmented cluster. This image has the impression of duplex and cardiomegaly bronchopneumonia, appears enlarged cast size with an embedded apex and horizontal heart waist, 68% CTR, thickened hilum, lung with increased bronchovascular pattern, infiltrates in the right upper pitch, left perihilar and right pericardial. Infiltrates in the right upper lung field are shown in circle 1, and quite clearly seen in the segmented images using the FCM + Wiener filter + PSO method, cluster form of red patches around the upper left rib. Left perihilar infiltrate and right pericardial are shown in circles 2 and 3, as well as segmentation results, show a cloud-shaped cluster in the form of red spots around the left hilum and right heart.

![Figure 4](image)

**Figure 4.** Pulmonary images of children with a diagnosis of Bronchopneumonia Duplex and Pleural Effusion with abnormally segmented FCM + Wiener filter + PSO method, (a) Original Image before processing, (b) Image from FCM + Wiener filter + PSO segmentation results.
4. Conclusion
The criteria for abnormal images in this study are higher pixel values than the average model data shown in red in RGB images. An abnormality that is located apart from being on the edge of the lung which is indicated by high pixel values is caused by the superposition of the rib image so that in the edge region, the segmentation method cannot see abnormalities. The success rate of CAD in 116 samples using the FCM + Wiener filter + PSO method on abnormal children's pulmonary images with respect to the results of the doctor's evaluation has a value of 88.57% ± 1.6, while the five ROC parameters (accuracy, sensitivity, specificity, precision, and overall error) have deviations of below 5%.

Acknowledgment
This work is supported by the research grant of Indexed International Publication of Student Final Project (Hibah Publikasi Internasional Terindeks untuk Tugas Akhir (PITTA) Mahasiswa), Universitas Indonesia, Grant No. NKB-0656/UN2.R3.1/HKP.05.00/2019. The acknowledgment would be incomplete without thanking to Septia Ardiani who obtained the data from Rumah Sakit Anak dan Bunda Harapan Kita.

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