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Wavelet Analysis for Identification of Lung Abnormalities using Artificial Neural Network

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***Abstract*—This research analyzed the use of daubechies wavelet as a feature extraction and confusion matrix as the principal parameter of accuracy percentage level in neural network. Detection process began with image pre-processing, lung area segmentation, feature extraction, and training phase. Classifications of the system output consisted of normal lung, pleural effusion, and pulmonary tuberculosis. Seventy five amounts of thorax samples were used as training data and thirty five thoraxes were used as test data. The experiment results showed that the decomposition at level 7 with order db6 was the best configuration for feature extraction which attained up to 91.65% of accuracy.**

Keywords—thorax, image processing, daubechies wavelet, feature extraction, confusion matrix, artificial neural network.

I. INTRODUCTION

A lot of computer based methods have been presented to help the work of radiologist. Examination of thorax (chest x-ray) is one of the method that usually done by the hospital for patient in many cases. Chest x-ray shows the image of the heart, lungs, respiratory, blood vessels, spine, and ribs. Lung is an organ located in the thorax that is most subject to diseases. Some of them are tuberculosis and pleural effusion.

Chest x-ray are used to diagnose many conditions involving chest wall, thorax and bone structure inside the thoracic cavity including the lungs [1]. Pulmonary tuberculosis is an infectious disease caused by *bacillus tuberculosis microbacterium*. Pleural effusion is a condition where there is excessive fluid in pleural cavity, which if left unchecked this condition will endanger the sufferer's life. Pleura is a thin layer of tissue that covered the lungs and lining the inner wall of the chest cavity [2]. In Indonesia, Pulmonary Tuberculosis is the 2nd leading cause of death after heart disease and other blood vessels. Aside from that, Indonesia is the 3rd country in the world that has most Pulmonary Tuberculosis patient after China and India. Pulmonary Tuberculosis could be found in numerous population with low socio-economic conditions and attack the productive age group (15-54 years old) [3].

II. RELATED WORK

Reference [4], [5] analyzed the use of image processing to identify an x-ray image. Reference [4] focused on texture analysis and [5] used image enhancement for x-ray images using histogram equalization.

Reference [6], [7] used wavelet for iris recognition. In [6], wavelet is used as edge detection technique in Matlab. in [7], used wavelet transform and mahalanobis distance, he compared the influence of wavelet decomposition level and order towards accuracy level. [8] Identify cancer existence in mammography using haar wavelet. Performance validation of neural network is used in [9] to build detection system for lung cancer.

III. METHODOLOGY

The proposed Lung Abnormalities Detection System can identify three output classifications, normal lung, pleural effusions, and pulmonary tuberculosis.

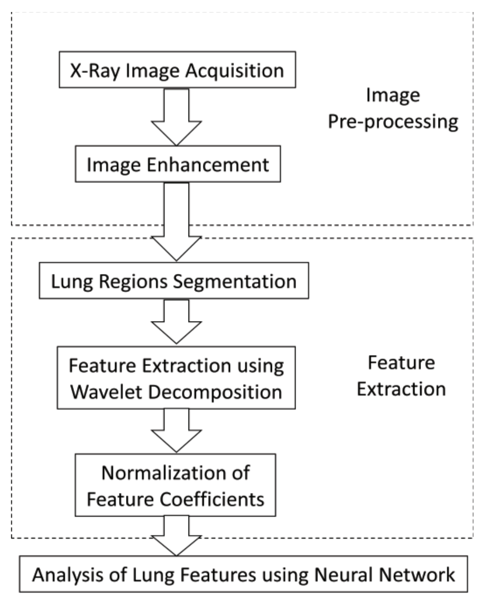

Figure 1. System Flow of Lung Abnormalities Detection

System design began with data classification based on diagnosis, normal lung, pleural effusion, and pulmonary tuberculosis. The data was taken in the Radiology Emergency Installation section of Wahidin Sudirohusodo Hospital with the amounts of 90 images. The images consist of 52 normal lung samples, 23 pleural effusion samples, and 15 pulmonary tuberculosis samples. These sample images are subdivided into two, samples for training data and samples for test data. The amount of samples for the training data are 43 normal lung samples, 20 pleural effusion samples, and 12 pulmonary tuberculosis samples. The remaining 15 samples for the test data (9 normal lung, 3 pleural effusion, pulmonary tuberculosis 3) will be used to test accuracy rate of the system identification. Another 20 samples from other sources were added as secondary test data.

A. *Image Processing*

Image processing stage consisted of: pre-processing, segmentation, decomposition, and normalization.

Pre-processing phase included histogram equalization, grayscaling, thresholding, blur, edge detection, dilate, fill hole, bwareaopen, and clear border.

Segmentation process are performed by using 'mask' in Matlab to obtain the lung region. The image obtained will be consisting 2 parts, first part are the lungs and the other contains the background which is not part of the lungs. Figure 2(a) shows the image before pre-processing and figure 2(b) shows image after segmentation.

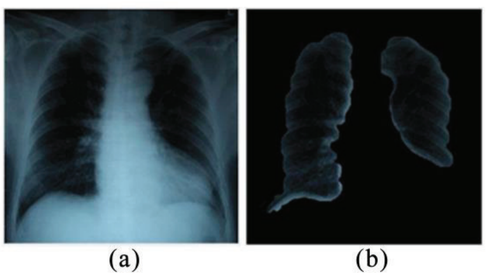

Figure 2. Image before and after segmentation

B. *Feature Extraction*

Feature extraction performed after segmentation process using daubechies wavelet. Decomposition result consisted of coefficients would be taken as the image feature. Only approximation coefficients used as the input for neural network training.

This process performed on db2 until db10 and started from level 5 until level 10. These processes are saved as a mat file and became dataset configuration. Every dataset configuration are given a target variable consists of 3 classes based on their diagnosis.

Furthermore, normalization of dataset configuration is performed. Normalization performed to convert the feature into a certain size, in order to get the appropriate standard feature extraction for each image of the thorax. It is also performed to optimize Matlab memory usage and avoid errors [10]. In this research, the feature normalized into the range of 0.1 to 0.9.

C. *Training*

Dataset configuration of each level and 'db' are given 3 target classes. Class 1 for normal lung, class 2 for pleural effusion, and class 3 for pulmonary tuberculosis. After that, every dataset configuration are trained using neural network.

The amount of hidden layer used in training process is 10 neurons, focusing on the output of confusion matrix for the percentage of accuracy. Algorithm used in training process is 'trainscg' function. Function 'trainscg' is a network training function that updates the weights and biases based on the scaled conjugate gradient method [11]. Prior to testing the system accuracy, training network conducted several times to obtain the best performance which is closest to the desired target and could recognize patterns well.

D. *Testing the Data*

After training each dataset configuration, dataset with the best accuracy are obtained. Networks dataset that attain 100% accuracy are then used to identify the data test using GUI system. Figure 3 shows the GUI of system identification.

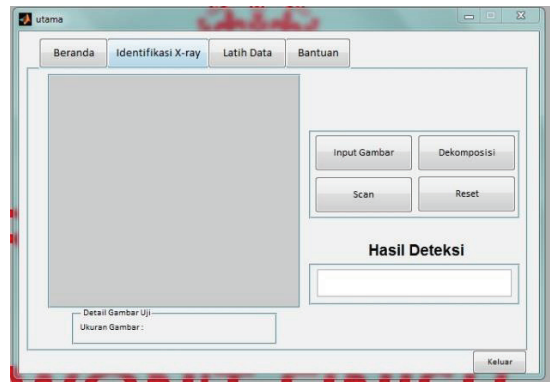

Figure 3. System Identification GUI

IV. PERFORMANCE ANALYSIS

Performance analysis started from the training process of each dataset configuration. Dataset with 100% accuracy can be seen on Table I.

TABLE I. DATASET WITH 100% ACCURACY

No	Configuration		Accuracy (%)
	level	db	
1	5	db2	100
2		db3	100
3	6	db2	100
4		db3	100
5		db4	100
6		db5	100
7	7	db4	100
8		db5	100
9		db6	100
10		db7	100
11		db8	100
12	8	db4	100
13		db6	100
14	10	db8	100

Subsequently, each dataset configuration in Table I were tested using two types of test data, primary test data and secondary test data. The result can be seen in Table II, where the highest accuracy obtained on decomposition at level 7 db6. Table II showed testing data result using primary data test.

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TABLE II. DATA TESTING RESULT FOR DATASET CONFIGURATION WITH 100% ACCURACY

No	Configuration		Amount of True Diagnosis	Accuracy (%)
	level	ordo		
1	5	db2	6	40
2	5	db3	9	60
3	6	db2	7	46.7
4	6	db3	7	46.7
5	6	db4	7	46.7
6	6	db5	8	53.3
7	7	db4	7	46.7
8	7	db5	9	60
9	**7**	**db6**	**14**	**93.3**
10	7	db7	12	80
11	7	db8	10	66.7
12	8	db4	7	46.7
13	8	db6	12	80
14	10	db8	10	66.7

Accuracy level from Table II obtained from:

$$Accuracy\ Level = \frac{Total\ True\ Diagnosis}{Total\ Data\ Test} \times 100\% \quad .....(1)$$

Table III and IV are a comparison between doctor's diagnosis and system diagnosis. Table III is using primary data test and Table IV is using secondary data test with the network from decomposition at level 7 db6.

TABLE III. TESTING WITH PRIMARY DATA TEST

No.	Doctor's Diagnosis	System Diagnosis
1	Normal Lung	Normal Lung
2		Normal Lung
3		Normal Lung
4		Normal Lung
5		Normal Lung
6	Normal Lung	Normal Lung
7		Normal Lung
8		Normal Lung
9		Normal Lung
10	Pleural Effusion	Pleural Effusion
11		Pleural Effusion
12		Pleural Effusion
13	Pulmonary Tuberculosis	Pulmonary Tuberculosis
14		**Pleural Effusion**
15		Pulmonary Tuberculosis

On Table III, total amount of true diagnosis identified by system are 14 images from the total of 15 testing data. Therefore, system accuracy for primary data test is:

$$Accuracy = \frac{14}{15} \times 100\% = \mathbf{93,3}\%$$

Furthermore, testing data continued with secondary data test taken from the internet. The result can be seen in Table IV.

TABLE IV. TESTING WITH SECONDARY DATA TEST

No	Doctor's Diagnosis	System Diagnosis
1	Normal Lung	Normal Lung
2	Normal Lung	Normal Lung
3	Normal Lung	Normal Lung
4	Normal Lung	Normal Lung
5	Normal Lung	Normal Lung
6	Normal Lung	Normal Lung
7	Normal Lung	Normal Lung
8	Normal Lung	Normal Lung
9	Normal Lung	Normal Lung
10	Normal Lung	Normal Lung
11	Pleural Effusion	Pleural Effusion
12	Pleural Effusion	Pleural Effusion
13	Pleural Effusion	Pleural Effusion
14	Pleural Effusion	**Normal Lung**
15	Pleural Effusion	Pleural Effusion
16	Pulmonary Tuberculosis	Pulmonary Tuberculosis
17	Pulmonary Tuberculosis	**Normal Lung**
18	Pulmonary Tuberculosis	Pulmonary Tuberculosis
19	Pulmonary Tuberculosis	Pulmonary Tuberculosis
20	Pulmonary Tuberculosis	Pulmonary Tuberculosis

On Table IV, total amount of true diagnosis identified by system are 18 images from the total of 20 testing data. So the system accuracy for secondary data test is:

$$Accuracy = \frac{18}{20} \times 100\% = \mathbf{90}\%$$

Accuracy level for all data test is:

$$\text{System Accuracy} = \frac{93.3+90}{2} = \mathbf{91.65}\%$$

System Analytical comparisons based on the decomposition level and order (level 7, db6) with medical disease diagnosis can be seen in Table V.

TABLE V. WAVELET ANALYSIS

No	Feature average value	Diagnosis*
1	0.284492560152408	Effusion
2	0.284492560152408	Effusion
3	0.284492560152408	Effusion
4	0.284492560152408	Effusion
5	0.284492560152408	Effusion
6	0.284602274752096	Effusion
7	0.284606096094450	Effusion
8	0.284627362013345	Effusion
9	0.284676816448046	Effusion
10	0.284825904114957	Effusion
11	0.284842326557020	Effusion

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No	Feature average value	Diagnosis*
12	0.285019017308677	Effusion
13	0.285035739114945	Effusion
14	0.285628927226884	Effusion
15	0.286051865016179	Effusion
16	0.286594523873866	Effusion
17	0.288759313486993	Effusion
18	0.289382720825609	Effusion
19	0.290539010506379	Effusion
20	0.292201307892714	TB
21	0.292287302821517	TB
22	0.293776891923141	TB
23	0.294132970250509	TB
24	0.294209529948630	TB
25	0.296364596195392	TB
26	0.298978559681274	TB
27	0.299250022690791	TB
28	0.300651925916889	Effusion
29	0.301091521734584	Normal
30	0.301091521734584	Normal
31	0.301091521734584	Normal
32	0.301091521734584	Normal
33	0.301091521734584	Normal
34	0.301091521734584	Normal
35	0.301091521734584	Normal
36	0.301091521734584	Normal
37	0.301091521734584	Normal
38	0.301091521734584	Normal
39	0.301091521734584	Normal
40	0.301091521734584	Normal
41	0.301327670740330	Normal
42	0.301339616206605	Normal
43	0.301377208527722	Normal
44	0.301464650577594	Normal
45	0.301510567559111	Normal
46	0.301575263327892	Normal
47	0.301586102526429	Normal
48	0.301591312729169	TB
49	0.301704010811958	Normal
50	0.301813733821871	Normal
51	0.301830066573576	Normal
52	0.301997818163686	Normal
53	0.302000158991835	Normal
54	0.302040186361003	Normal
55	0.302288869337252	Normal
56	0.302508628017242	Normal
57	0.302821751110035	Normal
58	0.303566649585995	TB
59	0.305347881217081	Normal
60	0.305626473902067	Normal
61	0.305882984067965	Normal
62	0.306050300133455	Normal
63	0.306927973415813	Normal
64	0.307657727514523	Normal
65	0.307864812428895	Normal
66	0.308114052491067	Normal
67	0.308126066180244	Normal
68	0.308502520600752	Normal
69	0.309938801909904	Normal
70	0.310684811212121	Normal
71	0.311560689940227	Normal
72	0.316081764648140	Normal
73	0.319118621999894	TB
74	0.322635486053758	TB
75	0.323709404985276	Normal

*Normal represents normal lung,
Effusion represents pleural effusions,
TB represents pulmonary Tuberculosis.

In general, as interviewed result in [12], medical explanations for each diagnosis are:

- Pleural Effusions: the lung area is white because of fluid effusion, usually spread on the bottom of lung area. If there are a large number of fluids, it can be spread to all areas of the lungs.
- Pulmonary Tuberculosis: top area (apex) of the lung generally colored white caused by bacteria that gathers on the area.
- Normal Lung: lung areas are clean (black).

The average value of image features in table V is the result of normalization data that has been sorted from smallest to largest value. Initially, image features are ranging from 0-255 (grayscale). 255 is white, 0 is black, and between 0-255 is grayscale. So based on medical explanation can be concluded that the image of a pleural effusion will have a lot of white colored area more than the image of pulmonary tuberculosis, whereas normal lung images tend to be black. So, when represented by the average value of the normalized data, values for normal lung image should be larger than pulmonary tuberculosis and values for pulmonary tuberculosis should be larger than pleural effusion.

CONCLUSION

A combination of Wavelet transform and neural networks resulted in a good method of image feature extraction and pattern recognition to identify diseases on chest x-ray. The experiment using 75 training data samples showed that the system was able to identify 100% accuracy of abnormalities when testing with training data samples and 91.65% accuracy when testing with new data samples. The use of orders and different levels of Daubechies wavelet decomposition affected the accuracy of the system as well as neural network configuration settings. Further development of the system could be done with more images and diagnosis variety.

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