Prediction of Tuberculosis from Chest X-ray Images by using Image Processing and Deep Learning Classification

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Abstract
Annual health check-ups include a large number of chest x-rays, which consume a lot of time and increase the chance to cause errors in the results. Therefore, we decided to create a program that can predict tuberculosis from chest X-ray images by using image processing techniques to enhance the quality of chest X-ray images with noise reduction and deep learning to classify between normal lungs and lungs with tuberculosis. This is to lighten the load of doctors on the diagnosis of chest X-ray images and to reduce the errors.
The method is divided into 3 main parts. The first part is to study the details of the chest x-ray and consult a tuberculosis specialist. Then, study the types and applications of deep learning and image processing. The next part is planning the program structure by combining each type of deep learning with each type of image processing to create the program with the highest precision. This will result in the different accuracy of the 16 programs. Then write a program to classify images in Python language. The last part is testing the generated program to determine the accuracy percentage and improve the program for higher efficiency and accuracy.
After training four programs out of sixteen programs with 146 epochs, we found that those that used the ResNet model with Non-local means, Median, and Bilateral filters had the accuracy of 95.918 percent. The three programs mispredicted the same images up to 75 percent of the mispredictions. This means all 3 programs have the same vulnerabilities or errors. However, the program using ResNet model with Gaussian filter has the lowest accuracy of the four programs which is 93.878 percent. 42.86 percent of the mispredictions of this program are the same as those of the previous programs. At the same time, there is one image that the program can predict correctly while the other programs cannot made. Since each program may predict the same image but give different results. Consequently, we have the idea that in actual use the prediction should be from a combination of several filters to make the prediction as accurate as possible. Finally, we decided to transform the program to be used as an application or software to make it easier to use.

1. Introduction

Nowadays, chest X-rays are commonly used medically, especially for annual health check-ups of people in various organizations. X-ray film is an image used to diagnose a disease or defect in the body with radiation. The image is black-white and has different color intensity depending on the ability to absorbs radiation of various parts of the body. Chest X-ray films can be used to diagnose a wide variety of diseases, such as emphysema, pneumonia, vascular disorders, or heart-related conditions, including tuberculosis. Tuberculosis is a contagious disease that can be transmitted through the air by coughing, sneezing, or living with a TB patient. Symptoms include a chronic cough, fever, weakness, night sweats and weight loss.
According to World Health Organization statistics, they estimate the incidence of tuberculosis as high as 10.4 million and the number of TB deaths are as high as 1.7 million. But the prediction of tuberculosis

using a chest X-ray film is limited, since most chest X-ray is used in the annual health check-ups of various organizations, which causes doctors to diagnose a large number of chest X-ray film. Therefore, it could waste their time and it might also cause an error in diagnosis results because their eyes are fatigued as they use them for long hours.

As a result, we decided to create a program to predict tuberculosis from chest x-ray images by using image processing techniques to enhance the quality of chest X-ray images with noise reduction and deep learning to classify between Normal lungs and lungs with tuberculosis. As the technique is high-precision, it can be well adapted to medical technology, it is easy to use, it can be automatically categorized, and it uses a large database. In addition, there are a variety of type to choose. This is to lighten the load of doctors on the diagnosis of chest x-ray images and to develop computer-related processing and image classification using image processing and deep learning.

2. Materials and Methods

2.1 Study and plan

1. Study the details of the chest x-ray and consult a tuberculosis specialist
2. Study the types and applications of deep learning and image processing.
3. Search for some databases free source on the internet and request additional databases from Khon Kaen hospital. The database consisted of chest x-ray films of the people with TB and without TB and are divided into 3 parts at a ratio of 70:15:15, as training set, validation set, and test set. The training set is a set of X-ray films used to be imported for the program to study the similarity and difference of the imported images, the validation set is the set of X-ray films used to be imported to test the performance of the model, the accuracy of the image classification after each train was determined, and the test set is a set of X-ray films used to be imported after the complete model was obtained, to test the performance of data processing models that have not been analyzed before.

Table 1 The number of chest X-ray images and the database ratio

Type of chest x-ray film	Normal lung			Lung with TB			Total		
	train	val	test	train	val	test	train	val	test
Number of pictures	241	53	52	235	46	46	476	99	98

4. Plan the program structure by combining each type of Deep Learning using Convolutional Neural Network with different types of image processing to create the program with the highest accuracy. Since each type of deep learning has different process for creating algorithms and learning to differentiate patterns of datasets. This will result in the different accuracy of the program. Likewise, each type of image processing has different image processing processes, so using different types of deep learning and image processing will result in the different accuracy of the program.

Table 2 program structure

Program		Deep learning			
		ResNet	VGG	AlexNet	GoogleNet
Image processing	Gaussian	P. 1	P. 5	P. 9	P. 13
	Median	P. 2	P. 6	P. 10	P. 14
	Bilateral	P. 3	P. 7	P. 11	P. 15
	Non-local Means	P. 4	P. 8	P. 12	P. 16

The deep learning chosen for use in the program consisted of 4 types. Each type of them is widely accepted due to its performance and continuous improvement. They especially can be efficiently applied to the medical field. The deep learning used in the program is that

1) Resnet : The model was obtained by combining the results of the 2 previous layers and the results of the next 2 layers. This is to prevent the loss of the original result causing the high precision results and processing in a short time. Moreover, its structure obviously different from the

others and can protect the vanishing gradient problem.

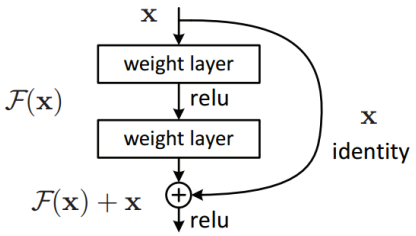

Figure 1: The process of Resnet's model (Aqeel Anwar 2562).

2) VGG : The model that has been developed from various models aims to decrease the number of variables used. Therefore, this model will take a short time to comply and can be applied to properly differentiate the category of things and still give high accuracy. However, it probably causes a vanishing gradient problem affecting the program to train more difficult and possibly causes the learning process to halt.

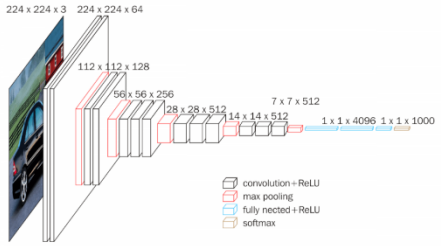

Figure 2: The process of VGG's model (Aqeel Anwar 2562).

3) AlexNet : This model is widely used in research since it is the first group of models using Convolutional Neural Network. The advantages are it allows to use the GPU for training and it is suitable for separating color images. However, the simplicity of the model probably makes the program hardly find the pattern of images.

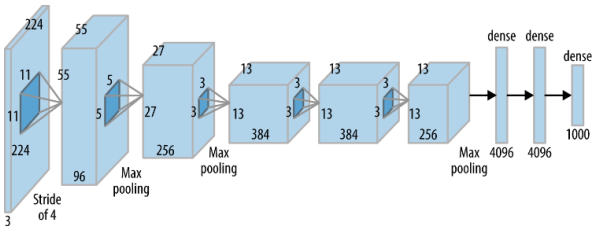

Figure 3: The process of AlexNet's model (Aqeel Anwar 2562).

4) GoogleNet : The model applied with various kernels aims to create a suitable pattern that is able to process in diverse ways. Moreover, it requires low memory causing a fast and efficient rate of learning.

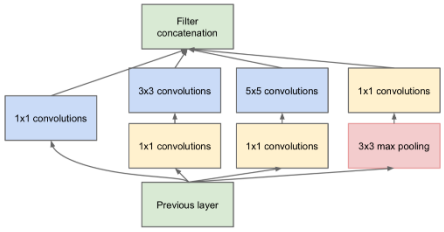

Figure 4: The process of GoogleNet's model (Aqeel Anwar 2562).

Image processing that will be used in the program consisted of 4 types. After the images are enhanced by each filter, the noise in the images will be removed. This is to help the program can differentiate the images easily. The image processing used in the program is that

1)Gaussian filter : The filter uses the normal distribution function which is the algorithm using to blur the images from the distribution of pixels. It aims to reduce the noise in images.

2)Median filter : The filter has the function that can adjust the color intensity of the focusing point in the pictures by change it to be as same as the average of its surrounding points. The purpose of this filter is to lower the noise appearing in images but still maintain image clarity.

3)Bilateral filter : This filter has been developed from Gaussian filter adding the image pixel value calculation function by weighting the distance and color difference. This is applied for using in adjust the smoothness of the images to remove noise in images.

4)Non-local means filter : The filter works by using the average of pixels in images apply with the focusing point to decrease the noise appearing in images but still sustain image clarity.

2.2 Code and improve the program

Coding the program used to classify the images by using python language combining with several various libraries

such as Pytorch and OpenCV. The program consisted of 2 major parts including the training part and the testing part. In the training part, the program will develop the algorithm after obtaining the accuracy from the test program. The program will adjust the parameter or weight to minimize the loss value of the training causing the improvement of accuracy. The testing part is used to determine the accuracy of the program. The process is quite similar to the previous part but the training function will be eliminated. Therefore, the program has the function to only analyze the images and not to use this set of images to train the program. This to ensure that the set of images used for the test have not been analyzed and used for training.

Figure 5: The example of code in training part

Figure 6: The example of code in testing part

Import the images of the x-ray films to use in training sessions.

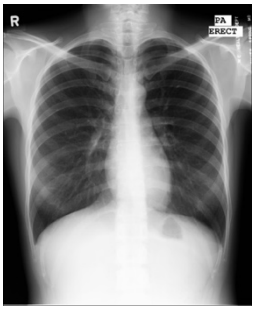

Figure 7: Original chest x-ray film

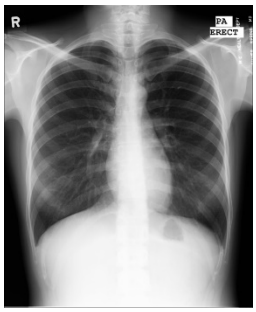

Figure 8: Chest x-ray film enhanced. by Median filter

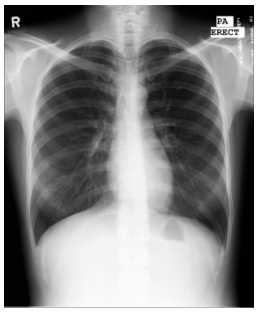

Figure 9: Chest x-ray film enhanced by Bilateral filter

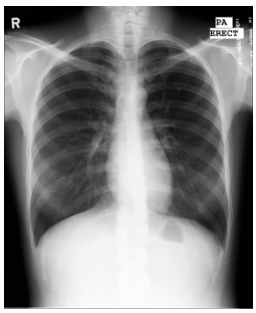

Figure 10: Chest x-ray film enhanced by Non-local Means filter

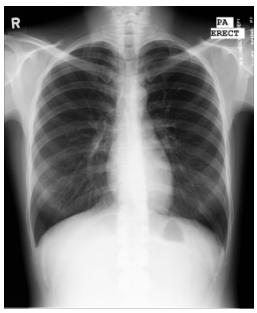

Figure 11: Chest x-ray film enhanced by Gaussian filter

Train the computer to analyze data and classify images by bringing the train set to the program to find patterns and create an algorithm that can be used to classify the images between the lung with TB and without TB. After obtaining the accuracy from the test, the program will update the algorithm to be more accurate. Then the program will test itself using the validation set to determine the accuracy of the test results. During each training session, the program will calculate the accuracy after testing the validation set. To test the test set and continue to improve the program, the accuracy has to be more than 97 percent.

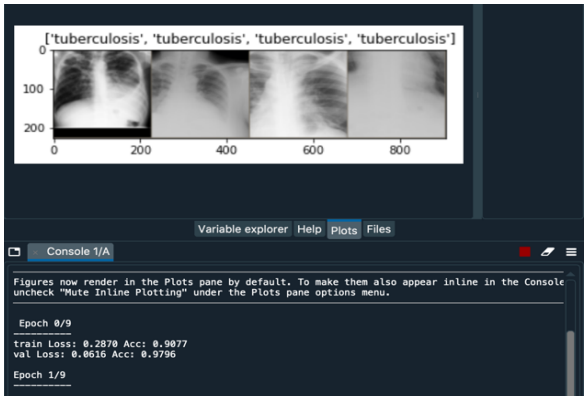

Figure 12: The process of the training program

2.3 Test and develop the program

Test the generated program by enhancing the images by using image processing and classifying the images by deep learning to determine the accuracy and give results as showing in table 3. The first column represents the order of chest x-ray films following by the correct diagnosis result assuring by the doctor. The third column illustrates the result from the program using Resnet. The fourth column onwards show the result from the program that combing ResNet with different filters. The normal lung is represented by n while the lung with tuberculosis is represented by t. The highlighted cell is the film that has different diagnosis results from different programs.

Table 3 The example of results from the generated program

No.	Test	ResNet					
		-	G	N	M (146)	M (130)	B
1	n	n	n	n	n	n	n
2	n	n	n	n	n	n	n
3	t	t	t	t	t	t	t
4	n	n	n	n	n	n	n
5	t	t	t	t	t	t	t
6	t	t	t	t	t	t	t
7	n	n	t	n	n	n	n
8	t	t	t	t	t	t	t
9	n	n	t	n	n	n	n
10	n	n	n	n	n	n	n

Study the results and the error gaining from the generated program.

Improve and fix the program to be more accurate and efficient by adding a variety of pictures, increase the number of training sessions and increase the variety of filters and deep learning models used in the program.

3.Result and discussion

3.1 The accuracy results after train 146 epochs

Table 4 The result of the generated program including image processing and deep learning

	Image processing			
	Gaussian	Nonlocal	Median	Bilateral
Deep learning Resnet	93.878 %	95.918 %	95.918 %	95.918 %

After four programs were trained with the same number of 146 epochs, three out of the four programs, those using ResNet model of deep learning with Non-local means, Median and Bilateral filters of image processing, had the same accuracy of 95.918 percent. By the observation, the three programs are predicted the same images up to 75 percent of the mispredictions. This means all three programs might have the same vulnerabilities or errors. Moreover, this indicates that the images that the program mispredicted are complex and difficult to analyze. However, the problem can be solved by inputting the aforementioned images to program and training the program to make the program find the pattern of the images. Later, when the program has to predict the images that have similar pattern with those images, the program will be able to make more accurate and precise prediction. For the program using ResNet model with Gaussian filter, it had the lowest accuracy out of the four programs which was 93.878 percent. The program has mispredicted 7 images. 3 of the 7 images were also mispredicted in the previous three programs while the remaining images were

predicted correctly in the previous programs. Nevertheless, at the same time, there is one image that the program was able to predict correctly, but the other three programs were wrong. Therefore, it can be noted that Gaussian filter can reduce some noise that the remaining three filters cannot. However, since each program predicted the same image but gave different results. Consequently, the developers have the idea that in the actual use the prediction should be from a combination of several filters to make the prediction as accurate as possible. In addition to the aforementioned results, the developers have observed the accuracy while training programs and have found that the program using ResNet model with Median filter could achieve the accuracy of 97.959 percent after training only 130 epochs. Nonetheless, after training 16 epochs more, the accuracy of the program was reduced to 95.918 percent. As a result, it can be concluded that more training time doesn't always lead to greater accuracy. The developers will use the information obtained for the further application and will also use larger databases to have a variety pattern of images to make the program more accurate.

4.Conclusion

After creating programs to predict tuberculosis from chest X-ray images by combining models from deep learning with filters from image processing and testing them, the program using ResNet model with Gaussian filter had the accuracy of 93.878 percent while the programs using ResNet model with Non-local means, Median and Bilateral filters had the same accuracy, 95.818 percent. In the future, the developers plan to find additional databases and appropriate training time to make programs have a higher accuracy and finish the remaining 12 programs. Moreover, the developers decided to transform the program to be in an application or software form to make it easier to use.

Acknowledgements

We would like to express our special thanks of gratitude to our teacher Miss Arjaree Thirach and Kamnoetvidya Science Academy for giving an advice, an opportunity to conduct this project, and financial support, as well as, Miss Pailin Ratanawatkul and Mr. Maytus Piriyajitakonkij, specialist in Tuberculosis and machine learning, respectively.

Finally, we would like to thank our parents and friends who helped us in finalizing this project.

References

Aykanat, M. (2017). **Classification of lung sounds using convolution neural networks.** EURASIP Journal on Image and Video Processing, 1-9.

Bhandari, A. (2020). **Convolutional neural networks for brain tumor segmentation.** Insights into Imaging, 1-9.

Devi, O. (2016). **Medical Image Processing-An Overview.** International Journal of Innovations in Engineering and Technology (IJIET), 362-365.

Guan, B. (2019). **Arm fracture detection in X-rays based on improved deep convolutional neural network.** Computers and Electrical Engineering, 1-11.

Howard, A. G. (2014). **Some Improvements on Deep Convolutional Neural Network Based Image Classification.** Retrieved from Semantic Scholar: https://arxiv.org/pdf/1312.5402.pdf

Nielsen, M. (2019, December). **Neural Networks and Deep Learning.** Retrieved from Neural Networks and Deep Learning: http://neuralnetworksanddeeplearning.com/index.html

Rogowska, J. (2002, February 1). **Image processing techniques for noise removal, enhancement and segmentation of cartilage OCT images.** Retrieved from IOPScience: https://iopscience.iop.org/article/10.1088/0031-9155/47/4/307/pdf

Yadav, S. S. (2019). **Deep convolutional neural network based medical image classification for disease diagnosis.** Journal of Big Data, 1-18.