CLASSIFICATION OF LUNG DISEASES FROM X-RAY IMAGES USING DEEP LEARNING

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

The lung disease, due to COVID-19 for example, has caused devastation around the world. Even in the most developed nations, the growing number of cases has overwhelmed healthcare facilities. Radiographic imaging is still the most convenient screening method for lung diseases. A certified radiologist interprets the chest X-ray image according to their experience level. As such, the interpretations might vary for different radiologists based on the observed characteristics and due to possibility of human error. To counter this problem, an automated lung disease classification system using chest X-ray was proposed. The classification was achieved by using deep learning approach because artificial intelligence has been proven to help reduce human error in medical applications. In this project, five deep learning architectures namely ResNet18, ResNet50, ResNet101, Alexnet, and VGG16 architectures were selected for transfer learning and classification of lung diseases. The lung X-ray images were classified into five output classes, namely COVID-19, pneumonia, tuberculosis, nodule or normal lungs. Images from multiple public datasets were acquired to be used as train set and test set for this automated lung disease classification model. The five deep learning models were successfully tested, and the highest accuracy was 96.3%, achieved with the Alexnet architecture.

ABSTRAK

Penyakit paru-paru, seperti yang diakibatkan oleh COVID-19, telah menyebabkan kehancuran di seluruh dunia. Bahkan di negara-negara yang paling maju, jumlah kes yang semakin banyak telah membanjiri kemudahan penjagaan kesihatan. Pengimejan radiografi merupakan kaedah pemerikasaan yang paling sesuai untuk penyakit paru-paru. Ahli radiologi yang diperakui menafsirkan gambar sinar-X dada mengikut tahap pengalaman mereka. Oleh itu, penafsiran mungkin berbeza untuk ahli radiologi yang berbeza berdasarkan ciri-ciri yang diperhatikan dan disebabkan kemungkinan kesalahan manusia. Untuk mengatasi masalah ini, sistem klasifikasi penyakit paru-paru automatik dari sinar-X dada dicadangkan. Klasifikasi tersebut dicapai dengan menggunakan pendekatan pembelajaran mendalam kerana kecerdasan buatan telah terbukti dapat membantu mengurangkan kesilapan manusia dalam aplikasi perubatan. Senibina ResNet18, ResNet50 ResNet101, Alexnet, dan VGG16 dipilih untuk pembelajaran transfer dalam proyek ini untuk mengklasifikasikan penyakit paru-paru menjadi lima kelas, iaitu COVID-19, pneumonia, tuberculosis, nodul, dan paru-paru normal. Beberapa set data awam digabungkan dan digunakan sebagai set Latihan dan set ujian untuk model klasifikasi penyakit paru-paru automatic ini. Lima model pembelajaran mendalam Berjaya diuji dan ketepatan tertinggi adalah 96.3%, dicapai dengan seni bina AlexNet.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
AI	-	artificial intelligent
CAP	-	community-acquired pneumonia
CNN	-	Convolutional Neural network
COVID-19	-	Coronavirus disease
CT	-	Computerized tomography
CXR	-	Chest X-ray
FeNO	-	Fractional exhaled nitric oxide
FN	-	False Negative
FP	-	False Positive
Grad-CAM	-	Gradient Class Activation Map
GUI	-	graphical user interface
HU	-	Hounsfield Units
JSRT	-	Japanese Society of Radiological Technology
MATLAB	-	Matrix Laboratory
MRI	-	magnetic resonance imaging
NIH	-	National Institutes of Health
PCA	-	principal component analysis
PET	-	position emission tomography
RT-PCR	-	reverse transcription-polymerase chain reaction
STN	-	spatial transformer network
TB	-	Tuberculosis
TN	-	True Negative
TP	-	True Positive
UTM	-	Universiti Teknologi Malaysia
WHO	-	World Health Organization
YOLO	-	You Only Look Once

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CHAPTER 1

INTRODUCTION

1.1 Background

Lung disease is defined as any condition in the lungs that prevents the lungs from performing correctly[1]. Lung disease is one of the main causes of death in Malaysia [2]. Lung diseases can be categorised into 3 main types, such as lung tissue disease, airway disease, and lung circulation disease. Each of the disease category affects the lungs in a different way. Most of the common lung diseases fall into more than one category at once according to their impact [3]. Airway disease refers to diseases like asthma; affecting the airways that carry gases into and out of lungs [4]. Any scarring or inflammation of the lung tissue is categorised as lung tissue diseases [5]. The example of lung tissue diseases includes sarcoidosis, Sjogren's syndrome, scleroderma, and others. Lung circulation disease is caused by the damage of vessels in lungs and reduction in oxygen absorption [6]. The most common example for lung circulation disease is pulmonary hypertension. Most of the lung diseases shared common symptoms like cough, wheezing, shortness of breath, chest illness and others [7]. Doctors will determine the proper diagnostic tests to assess an individual based on the patient's symptoms.

The available diagnostic tests for lung diseases can be divided into four categories, which are simple tests, advanced tests, invasive tests, and imaging test [8]. Both simple tests and advanced tests basically help to measure how much volume of air the patient's lungs can hold by requiring the patient to blow air into a tube. The advanced test will provide more accurate results compared to simple tests by including additional steps during the test. The example of simple tests include spirometry [9] and FeNO test [10] while the example of advanced tests include plethysmography [11] and diffusion capacity test [12]. Invasive test refers to the test where the trained operator inserts a medical instrument into patient's body via cut skin or natural orifice [13].

Invasive test usually provides results with higher sensitivity and precision compared to other tests but it required expertise in handling the test and is time-consuming [14]. The example of imaging tests includes chest X-Ray (CXR), computerized tomography (CT), magnetic resonance imaging (MRI), position emission tomography (PET) scans and others. CXR imaging is the most common and preferred diagnostic examination in clinical care as it is painless, fast, relatively economical, and non-invasive. The radiography image is mainly used for detection, staging, follow-up, and quantification of lung disease [15].

In Malaysia, most of the lung illnesses are discovered when the diseases have progressed to the late stages [16]. The development of tools and systems that allow for faster and more precise diagnosis is critical in the world today. Image based lung diseases classification system play an important role in this and are now being expanded. Most of the existing research has focused on lung diseases classification based on textural characteristics and it demonstrated its effectiveness in classification potential [17]. Deep features, on the other hand, have emerged as a more promising path ahead in recent research. This is because it demonstrates a new level of robustness and wide depth of features that were previously unavailable. However, the training time and computational load of using huge feature sets is a key disadvantage of such approaches. Besides that, the performance of classification system is highly dependent on the training result from extracted features. Deep learning approach has recently gain popularity in the real-world application due to its ability to perform feature extraction and classification automatically [18].

Deep learning concept appeared firstly during 2006 as a new field of research within machine learning [19]. It has been widely implemented in many research fields related to pattern recognition. Deep learning model uses a cascade of multilayer of nonlinear processing units to perform feature extraction and classification. The learning process of deep learning could be supervised or unsupervised. Supervised learning refers to learning process with labelled target classes while unsupervised learning refers to learning process without labelled target classes [20]. One of the advantages of deep learning is its ability to perform automatic feature extraction instead of classifying handpicked feature based on domain-specific knowledge. This helps in detecting and classifying certain medical conditions effectively [21]. Many deep learning algorithms are trained to solve specific tasks, and if the feature changes, the models must be rebuilt from scratch. Transfer learning overcomes such drawback by utilizing knowledge acquired for old task to solve another new task. Transfer learning gives better performance result with smaller sample size data due to its pre-trained weights and improved efficiency. The pre-trained model is a model that was trained on a large benchmark dataset like ImageNet to solve a general problem [22]. The example for pre-trained model includes VGG16, ResNet, AlexNet, EfficientNet, GoogleNet, and others.

1.2 Problem Statement

CXR image-based lung disease detection is highly dependent on the diagnosis of the radiologists. According to Ang et al [23], there are 38.8% of misdiagnosis in community-acquired pneumonia (CAP) in Penang General Hospital while Poh et al. [24] reported 64.5% of inaccurate diagnosis of pneumonia by the emergency department of Hospital Tuanku Ja'afar Seremban. Most of the misdiagnosis was due to human error during the diagnosis of CXR images.

Most lung disease classification research only focused on one to two types of diseases. Some of the lung diseases shared similar characteristics that may confuse the algorithm. Hence, existing lung classification system may have lower performance when extended to classifying varieties of diseases due to the increased difficulty.

Besides, there are existing research that claimed to have higher accuracy by using smaller datasets. Smaller dataset could mean that some images had been excluded, particularly if those images did not provide good results. Hence, the lung disease classification system may not be able to achieve the same level of accuracy when dealing with larger and noisy datasets, thus making it impractical to be implemented for actual medical applications.

1.3 Research Objectives

(a) To implement a lung disease classification system on MATLAB platform using lung X-ray images and transfer learning method in deep learning neural network

(b) To classify the lung X-ray images into five target classes of lung conditions (normal, pneumonia, tuberculosis, COVID-19, and nodule) with more than 90% accuracy

(c) To evaluate the performance of deep learning networks for classification of lung diseases

1.4 Scope of Work

(a) The lung diseases classification system utilized the lung samples from multiple selected public datasets.

(b) The neural network was trained using X-ray images of healthy lung and diseased lungs, with nodule, tuberculosis, pneumonia and COVID-19.

(c) AlexNet, ResNet18, ResNet50, ResNet101, and VGG16 were selected as pre-trained networks to be used in transfer learning process.

(d) The lung samples obtained from public datasets have only one single type of disease per image.

1.5 Report Organization

The purpose of this report is to develop a lung disease classification system using a transfer learning approach and to assess the system using a variety of deep learning networks. The overall five chapters in the report are organized in the following sequences: introduction, literature review, research methodology, preliminary results, as well as the conclusion and recommendation.

The first chapter introduces and give brief information about the purpose of the study. The introduction concludes the overview of the entire topic of study. The problem statements, research objectives and the related scopes on each objective are all included in this chapter.

Chapter 2 provides a literature review of the research on lung diseases classification system. This chapter gives a general review on the background of lung diseases, image type, public dataset, and deep learning technique. Then, the trends in developing deep learning-based lung diseases classification system are included. Lastly, research on lung diseases classification system is discussed focusing on the outcome measure used by each system.

Chapter 3 is focusing on the research methodology. All research activities in image acquisition, network training, network testing was presented in detail. These include the pre-processing and the experiments conducted to implement the system. The flow of developing the lung diseases classification system is described and presented in graphical form. This includes the performance metrices.

Chapter 4 presents the results and discussion. The overall experimental and simulation results such as input image pre-processing, training process, and testing process are presented and analysed in this chapter. The result from the experiment are presented in graphical form like table and chart for easier analysis.

Chapter 5 is the summary and conclusion of the entire research paper. It summarises the essential elements of the main study topic as well as concluding the final obtained result to justify the result is acceptable or not. Any recommendations for further research as well as the limitations encountered during the study are explored.

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