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Automated Classification of Alzheimer's Disease Based on MRI Image Processing using Convolutional Neural Network (CNN) with AlexNet Architecture

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Automated Classification of Alzheimer's Disease Based on MRI Image Processing using Convolutional Neural Network (CNN) with AlexNet Architecture

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Abstract. Alzheimer's disease is a type of brain disease that indicate with memory impairment as the early symptoms. These symptoms occur because the nerve in the brain involved in learning, thinking and memory as cognitive function have been damaged. Alzheimer is one of diseases as the leading cause of death and cannot be cured, but the proper medical treatment can delay the severity of the disease. This study proposes the Convolutional Neural Network (CNN) using AlexNet architecture as a method to develop automated classification system of Alzheimer's disease. The experiment is conducted using Magnetic Resonance Imaging (MRI) datasets to classify Non-Demented, Very Mild Demented, Mild Demented, and Moderate Demented from 664 MRI datasets. From the experiment, this study achieved 95% of accuracy. The automated Alzheimer's disease classification can be helpful as assisting tool for medical personnel to diagnose the stage of Alzheimer's disease so that the appropriate medical treatment can be provided.

1. Introduction

Alzheimer's disease (AD) is a progressive condition causing brain cells wasted and die. According to Alzheimer's Disease International the number of people affected by Alzheimer's will increase every 3 seconds, it is estimated that by 2030 there will be 75 million people infected and 131.5 million by 2050 [1]. Azheimer's disease is a common cause of dementia affecting people in the age group of 65 years and over [2]. Alzheimer's disease has four stages, namely, very mild dementia, mild dementia, moderate dementia, and severe dementia.

Early detection of Alzheimer's disease is important. Detecting Alzheimer's disease as soon as possible can provide better treatment. Several studies on detecting Alzheimer's disease have been carried out by several researchers. Silvia Basaia et al. [3] investigated the prediction of the individual diagnosis of Alzheimer's disease (AD) and mild cognitive impairment that will convert to AD (c-MCI) based on a single cross-sectional brain structural MRI scan. This research used Convolutional Neural Network (CNN) with Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset and non-ADNI dataset that consists of 407 healthy controls (HC), 418 AD, 280 c-MCI, 533 stable MCI (s-MCI). The

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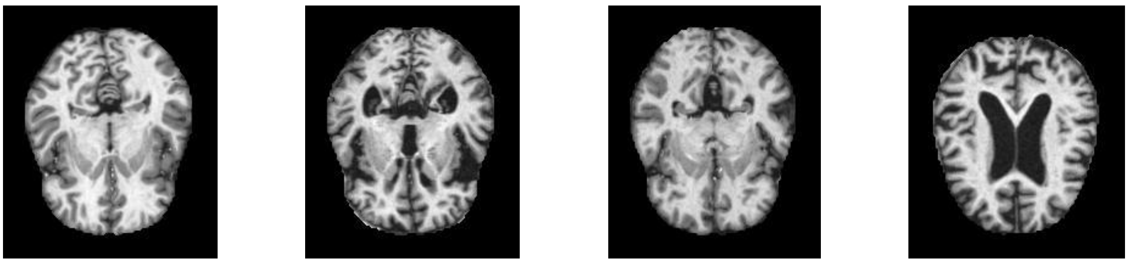
result showed that the accuracy of AD vs HC classification tests using both the ADNI dataset only is 99% and the accuracy of the combined ADNI with non-ADNI dataset is 98%. Jun Zhang et al. [4] have research related to a landmark-based feature extraction method for AD diagnosis using longitudinal structural MR images and a Support Vector Machine (SVM) for distinguishing AD subjects or mild cognitive impairment (MCI) subjects from healthy controls (HC). The result of this research showed an accuracy of 88.30% for AD vs HC and 79.02% for MCI vs HC. Research about Alzheimer's Disease Computer-Aided Diagnosis on Positron Emission Tomography Brain Images Using Image Processing Techniques have done by Mouloud Adel et al. [5].

Classification in this research was performed using Support Vector Machine (SVM) classifier. In this study using two dataset, local dataset that enrolled 171 adults 50–90 years of age, including 81 patients with AD and 61 health control/normal control (HC/NC) and 29 mild cognitive impairment (MCI). The result showed accuracy of 90.48% for AD vc NC and 81.09% for MCI vs NC. Previous studies have referred to various methods for treating Alzheimer's disease. In this study, the authors propose to classify the stages of Alzheimer's disease based on digital image processing. The method for classifying the various stages of Alzheimer's disease uses Convolutional Neural Network (CNN) with AlexNet architecture.

2. Magnetic Resonance Image Datasets of Alzheimer

This study uses MRI datasets collected by Sarvesh Dubey, which can be accessed in https://www.kaggle.com/tourist55/alzheimers-dataset-4-class-of-images [6]. The datasets consist of MRI images of Alzheimer's diseases stages such as Very Mild Demented, Mild Demented and Moderate Demented. The example of the data for each class is shown in Figure 1. Dementia is a term used to explain the symptoms of mental decline that severely enough to interfere intellectual and social abilities.



Non-Demented Very Mild Demented Mild Demented Moderate Demented

Figure 1. MRI data with four of Alzheimer dementia's stages

In the very mild and mild dementia stages, people may be able to move independently in a variety of ways, but most likely need assistance with some activities. Common symptoms at this stage include recent memory loss and personality changes but they can still carry out activities such as driving. People may have difficulty communicating and carrying out routine tasks, including daily activities such as bathing and dressing, begin to experience changes in personality and behaviour such as hallucinations, delusions, paranoia, and increased memory loss. The moderate stage is the longest stage of Alzheimer's dementia and Alzheimer's sufferers need a higher level of care as the diseases progresses. In the severe stage of Alzheimer's, people will experience a physical condition that gets worse. At this stage, people may experience skin infections, weight loss, loss of capability to communicating, loss of physical capabilities such as walking, sitting, difficulty swallowing.

3. Convolutional Neural Network (CNN)

Convolutional Neural Network is one of the algorithms of deep learning as development of the Multilayer Perceptron (MLP) which is designed to process two-dimensional structure such as image. CNN is included in the type of Deep Neural Network because of the high network depth [7]. Each layers of CNN learn to detect a variety of images. Image processing is applied to process image at a different resolution, and the output of each image is processed and used as input to the next layer. As shown in Figure 2, the architecture of CNN can be divided into feature extraction and classification [7]. In the feature extraction section, there are three operation stages, namely convolutional operation, Rectified Linear Unit (ReLU) and pooling. The classification section also has two stages of operation, namely fully connected, and activation function.

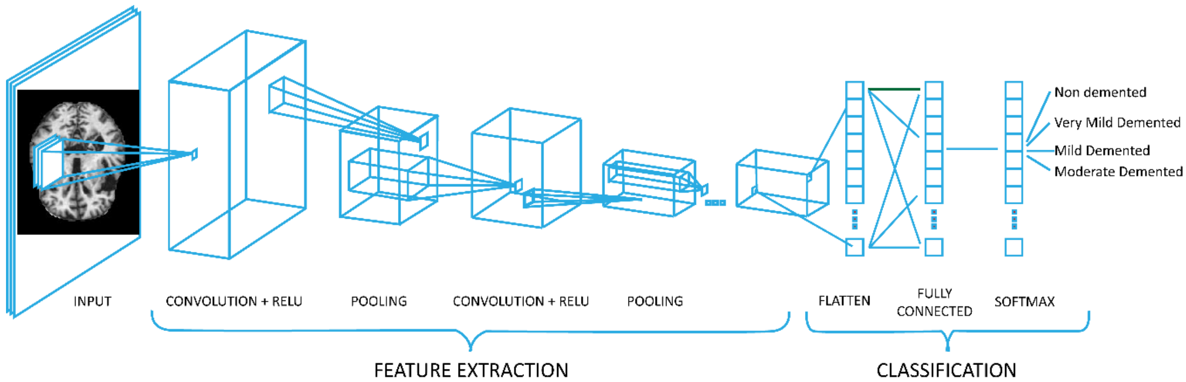


Figure 2. Convolutional Neural Network architecture used in this study

3.1. Convolutional Layer

Convolutional Layer is the first layer which performs convolutional operations between filters and image as input of CNN architecture. The filter will shift throughout the image and perform a "dot" operation between the input and the value of the filter to produce feature map as shown in Figure 3 [8]. The optimization of convolutional layer through the optimization of filter size, stride and zero padding.

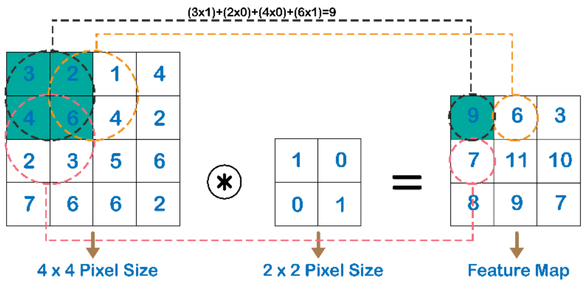


Figure 3. The Illustration of Convolutional Process in Image

3.2. Rectified Linear Units (ReLU) Activation

CNN has an activation layer called as ReLU, which using the function as shown in Equation 1. The function performs thresholding with zero value to the pixel value in image. This activation makes up all over pixel values that are less than 0 on the feature map will be made 0 [9].

$$f(x) = \begin{cases} x, \cdots x > 0 \\ 0, \cdots x \leq 0 \end{cases} \tag{1}$$

3.3. Pooling Layer
The pooling layer receives output from the convolutional layer, on this layer the image data size will be reduced [10]. In principle, the pooling layer consists of filters with specified size and stride that shifted throughout the feature map area. In its application, the pooling layer that commonly used is max pooling and mean pooling as shown in Figure 4.

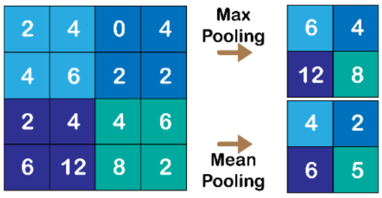


Figure 4. The illustration of pooling layers used in this study.

3.4. Fully Connected Layer
The feature maps of the feature extraction layers are processed by the fully connected layer. Unlike the convolutional layer, which the neurons are connected only into certain areas on the input, the fully connected layer connect the whole neurons. The fully connected layer transform multidimensional arrays of feature maps into one dimensional array (flatten process) so data can classify linearly [11].
3.5. Softmax Activation
Softmax Classiefer is another form of Logistic Regression that can be used to classify more than two classes [12]. Softmax is useful to convert the output from the last layer to its basic probability distribution. The advantage of Softmax is the range of output probability from 0 to 1, and the sum of the probabilities is equal to 1.

4. System Design
4.1. Proposed System Design
This study developed an automated Alzheimer's disease classification to classify Non-Demented, Very Mild Demented, Mild Demented, and Moderate Demented conditions based on MRI image processing. The system used the CNN method with AlexNet architecture that has eight hidden layers, which consists of five convolutional layers and three fully connected layer. In general, AlexNet system model that used in this study is shown in Figure 3.

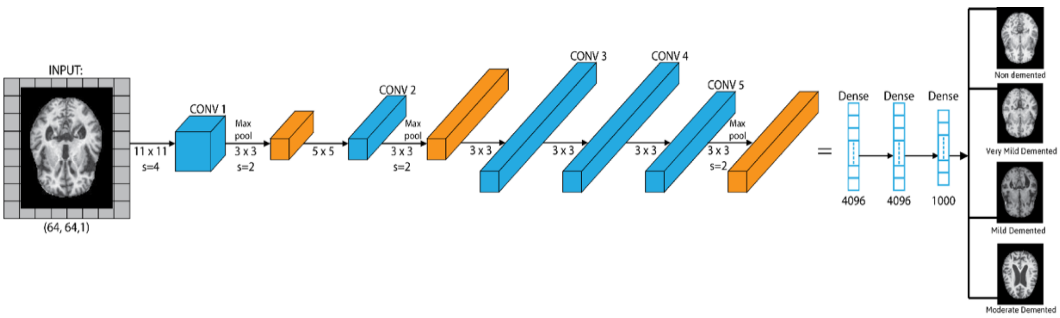


Figure 5. AlexNet System Model for Automated Alzheimer's Disease Classification

In this study, the total amount of Alzheimer's MRI dataset is 664 images that consist of 200 images for Non-Demented, Very Mild Demented and Mild demented conditions respectively and 64 images of Moderate Demented conditions. We used 75% of the data as the training data, while the rest are used as the validation data. Based on Figure 5 the MRI image as an input of AlexNet architecture is a grayscale image with the size 64×64 pixels. The MRI images then convoluted with a filter that has a certain size and a certain stride on each hidden layer. At each hidden layer used RelU activation that will convert negative value of feature maps to be zero. The first, second and fifth hidden layer of AlexNet architecture used Max Pooling that will reduces the dimension of image. At the classification layer softmax activation is used to classify the condition of Alzheimer's stages into four conditions. Tabel 1 shows the details of CNN model for Alzheimer's disease classification.

Table 1. AlexNet architecture of CNN model parameters used in this study

Layer	Output Shape	Parameter	Layer	Output Shape	Parameter
Input Image	64,64,1	0	Convolution	4,4,256	884992
Convolution	16,16,96	11712	Max Pooling	2,2,256	0
Max Pooling	8,8,96	0	Flatten	1024	0
Convolution	4,4,256	614656	Dense	4096	4198400
Max Pooling	4,4,256	0	Dense	4096	16781312
Convolution	4,4,384	885120	Dense	1000	409700
Convolution	4,4,384	1327488	Dense	4	4004

4.2. System Performance
This study measured the accuracy, recall, precision, and F1 scores as the system performance. The calculation of these performance measurements are shown in (2)(3)(4) and (5) respectively [13].

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{2}$$

$$Recall = \frac{TP}{TP + FN} \tag{3}$$

$$Precision = \frac{TP}{TP + FP} \tag{4}$$

$$F1\ Score = 2 \times \frac{recall \times precision}{recall + precision} \tag{5}$$

Here, the TP is the true positive, while TN is the true negative conditions. On the other hands, the FP and FN are the false positive and false negative conditions, respectively.

5. Result and Discussion
The MRI images dataset used in this study consist of 664 fundus images for Non-Demented, Very Mild Demented, Mild Demented, and Moderate Demented conditions. The number of training data used is 498 MRI images. In the other hand, the amount of validation data used is 166 images. MRI images are trained using AlexNet architecture with Adam optimizer using some various learning rate, namely, 0.0001, 0.001, 0.01, and 0.1, and loss binary cross-entropy. Four performance parameters are measured in this study, they are accuracy, recall, precision, F1 score, and loss. The model of accuracy and the loss of the proposed model in some various learning rate is shown in Figure 6.

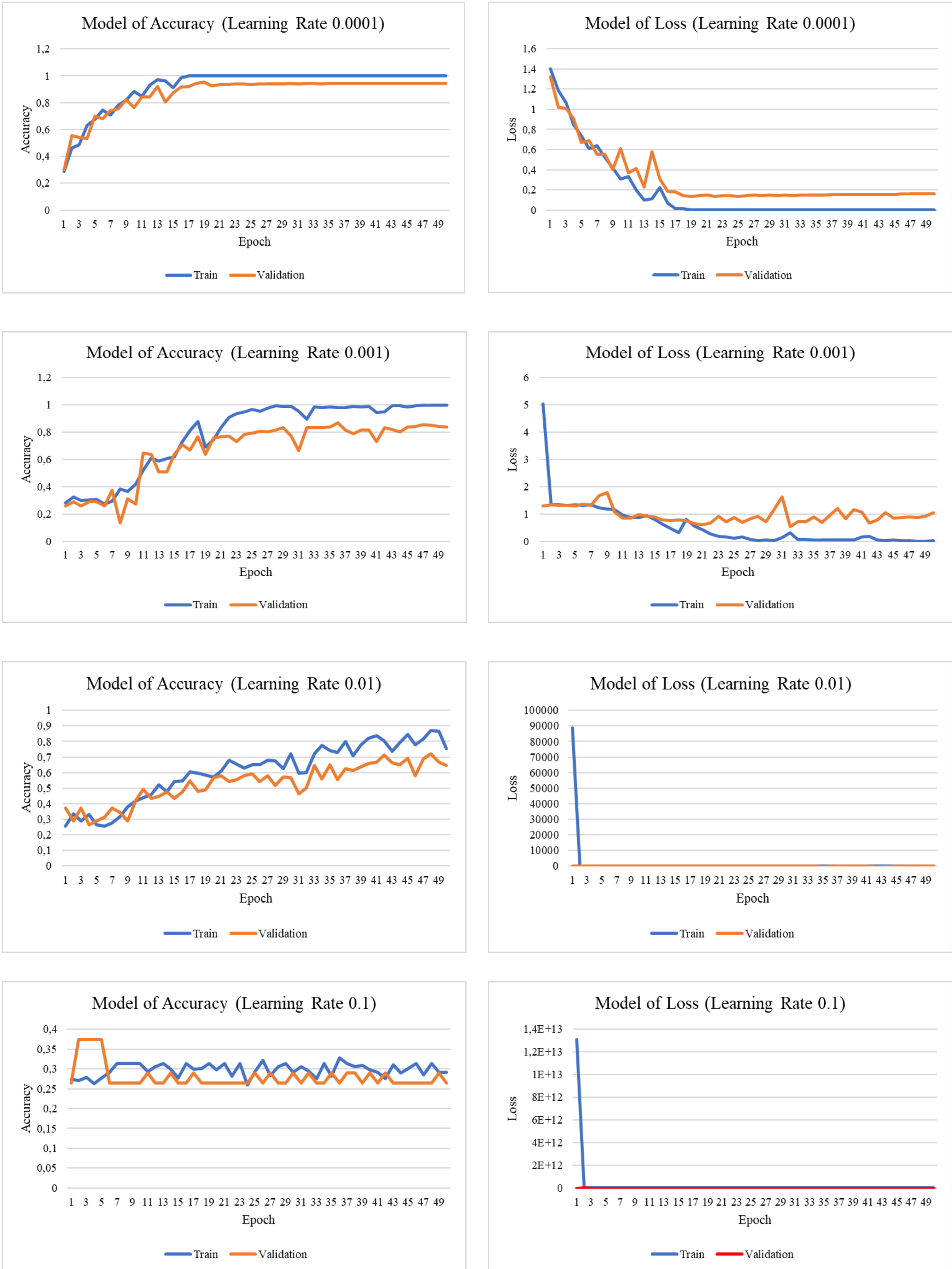


Figure 6. System Performance Comparison

Figure 6 shows comparison of each learning rate using Adam optimizer. Based on the result for this case, the higher learning rate can cause the higher value of loss or it's called overshooting. The best accuracy and loss performance are achieved using learning rate 0.0001. It shows by the increasing of accuracy for each iteration (epoch) and performing a slight difference between the accuracy of training data and the validation data. Besides that, the value of loss also decreasing for each iteration and shows a slight difference between the value of loss training and loss validation. Based on these results, it can be concluded that there is no overfitting and overshooting for this model proposed using Adam optimizer with learning rate 0.0001. The proposed model using AlexNet can recognize Non-Demented, Very Mild Demented, Mild Demented, and Moderate Demented conditions with the highest accuracy and loss of 95% and 0.1643, respectively.

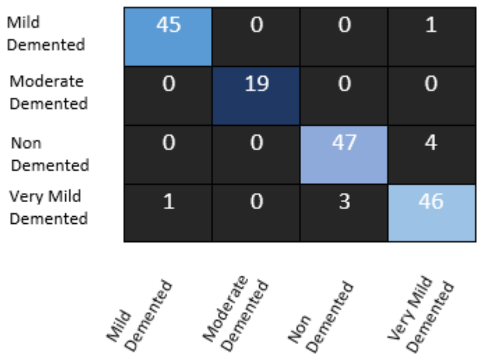


Figure 7. Validation data's confusion matrix

Figure 7 shows that from 166 validation data used, 155 data are correctly classified according to their class. The precision, recall, and F1-score which used to evaluate the system performance, have values ranged from 0 to 1, higher value indicates less error. Table 2 shows the system performance result based on the value of precision, recall, and F1-score are having high value which closed to 1. This condition indicates that the CNN model using AlexNet performs the promising result in classifying MRI Alzheimer's stages into Non-Demented, Very Mild Demented, Mild Demented, and Moderate Demented conditions.

Table 2. The performance of CNN model proposed in this study.

Class	Precision	Recall	F1-Score	No of Images
Non-Demented	0.94	0.92	0.93	51
Very Mild Demented	0.90	0.92	0.91	50
Mild Demented	0.98	0.98	0.98	46
Moderate Demented	1.00	1.00	1.00	19

6. Conclusion

An automated Alzheimer's disease classification based on MRI images processing is designed using CNN model with AlexNet architecture that consists of five hidden layers and 3 fully connected layers. The experiment showed that the proposed model using Adam optimizer with learning rate 0.0001 performs the best results in classifying MRI Alzheimer's datasets into Non Demented, Very Mild Demented, Mild Demented, and Moderate Demented conditions with an accuracy of 95%, loss of 0.1643, and the value of precision, recall, an f1-score around 0.91 - 1. In further research, beside the diagnostic system, it is important to develop a prognostic system for predicting development of Alzheimer's disease including whether the signs and symptoms of Alzheimer will improve or worsen.

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