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Analysis of deep learning methods in diabetic retinopathy disease identification based on retinal fundus image

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Abstract

Diabetic retinopathy (DR) is a serious retinal disease and is considered the leading cause of blindness and is strongly associated with people with diabetes. Ophthalmologists use optical coherence tomography (OCT) and retinal fundus imagery to assess the retinal thickness, structure, and also detecting edema, bleeding, and scarring. Deep learning models are used to analyze OCT or fundus images, extract unique features for each stage of DR, then identify images and determine the stage of the disease. Our research using retinal fundus imagery is used to identify diabetic retinopathy disease, among others, using the Convolutional Neural Network (CNN) method. The methodology stage in the study was a green channel, Contrast Limited Adaptive Histogram Equalization (CLAHE), morphological close, and background exclusion. Next, a segmentation process is carried out that aims to generate binary imagery using thresholding techniques. Then the binary image is used as training data conducted epoch as much as 30 times to obtain an optimal training model. After testing, the deep learning method with the CNN algorithm obtained 95.355% accuracy in the identification of diabetic retinopathy disease based on fundus image in the retina.

Keywords: Deep Learning Methods, Diabetic Retinopathy, Retinal Fundus Image.

1. Introduction

Deep learning is one type of Machine Learning that uses a deeply layered structure Artificial Neural Network. One of the techniques is Convolutional Neural Network. Convolutional Neural Network

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(CNN) is a multilayer perceptron specifically designed for the identification of information from a two-dimensional image [8]. In this study, deep learning was used to identify diabetic retinopathy disease. Due to the increasing number of diabetic patients and the need for regular monitoring of the retina of the patient's eye, a limited number of ophthalmologists are unable to meet the large demand, so an automated system is needed that can help reduce the burden of retina specialists and reduce excessive processing time [5]. Diabetic retinopathy (DR) is a serious retinal disease and is considered the leading cause of blindness and is strongly related to people with diabetes [10]. Ophthalmologists use optical coherence tomography (OCT) and retinal fundus imagery to assess the retinal thickness, structure, and also detecting edema, bleeding, and scarring. Deep learning models are used to analyze OCT or fundus images, extract unique features for each stage of DR, then classify images and determine the stage of the disease. Diabetic retinopathy disease is classified into four levels including mild non-proliferative DR (NPDR), moderate NPDR, severe NPDR, and proliferative DR (PDR). Mild non-proliferative DR is an early-stage disease that can develop into a proliferative DR where vision loss occurs and the eyes are filled with interstitial fluid. In the early stages, the patient is often asymptotic. However, with the development of the disease, symptoms can be blurred vision, blindness, distorted central vision, large floaters, and sometimes sudden loss of vision. Therefore, it is very important to detect the disease at an early stage and provide an accurate diagnosis and stage for the possibility of reducing disease complications and the risk of vision loss. Research using retinal fundus imagery has previously been used to classify diabetic retinopathy disease, among others, using the Convolutional Neural Network (CNN) method.

2. Related Work

Research using retinal fundus imagery has previously been used to classify diabetic retinopathy disease, among others, using the Convolutional Neural Network (CNN) method. The methodology phase began using contrast-limited adaptive histogram equalization (CLAHE) and Contrast Enhancement (CE) methods as image enhancement. This identification performs the extraction of exudates, hemorrhages, and microaneurysms manually. The results achieved 87.6%, and 83.9% for using CE and CLAHE methods [7]. Further research using the deep learning method, at the stage consists of changing the image into a greyscale image then done the process to the deep learning method. The result is very high which is up to 100% [2]. Further research conducted classification using the deep learning method, the class in question is Mild nonproliferative retinopathy, Moderate nonproliferative retinopathy, Severe nonproliferative retinopathy, and Proliferative diabetic retinopathy (PDR) [1]. Subsequent research conducted automatic detection and identified imagery as one of the classifications of diabetic retinopathy disease using the Convolutional neural network method. At the preprocessing stage, resizing and building CNN model and then classifying [6]. Also, CNN has been used to detect invasive ductal carcinoma in people with breast cancer [3] and is also used for typical face recognition problems [8]. Then [9] conducted a study by detecting red lesions in retinal fundus imagery using the YOLO V3 algorithm, from this study obtained a precision value of 83.33 %.

3. Method

In this study, deep learning method analysis was conducted that aims to obtain high accuracy in identifying diabetic retinopathy disease through retinal fundus image. In this study, accuracy will be improved in identifying diabetic retinopathy disease using image processing techniques that aim to perform vascular extraction first before entering the deep learning method process. As for the workflow of our methodology can be seen in figure 1 below

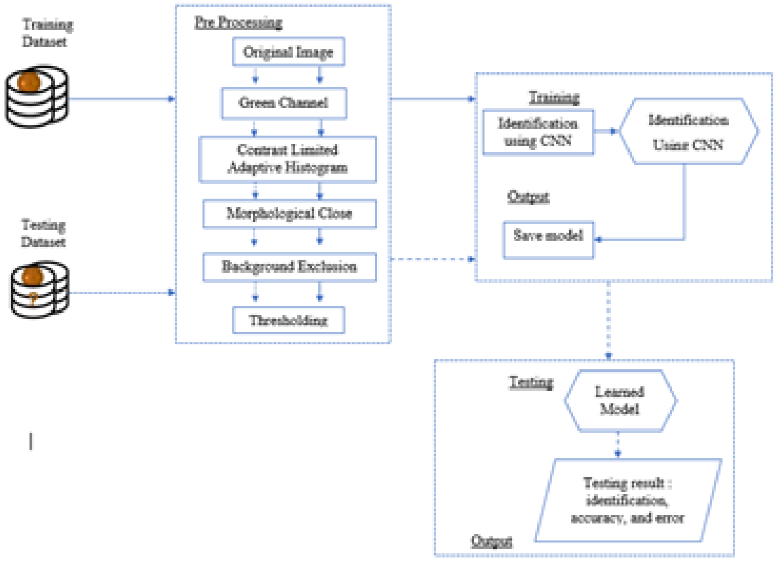

Figure 1: The Workflow of our methodology

Our methodology in the research to be conducted is divided into 3 parts are inputs, processes, and outputs that will be described below:

3.1. Input

The image used is the retinal fundus taken through the fundus camera. The fundus retina is an image consisting of an interior layer of the eyeball, covering the retina, optic disk, and macula. The inputs in this study were divided into five parts namely retina-detected non-diabetic retinopathy, mild non-proliferative DR (NPDR), moderate NPDR, severe NPDR, and proliferative DR (PDR).

3.2. Process

At this stage, it is the process of processing the image of the retinal fundus. The process consists of preprocessing, and classification.

3.2.1. Preprocessing

At the preprocessing stage, the image of the retinal fundus is processed to extract good features. This stage includes the green channel, Contrast Limited Adaptive Histogram Equalization (CLAHE), morphological close, and background exclusion. Next, a segmentation process is carried out that aims to generate binary imagery using thresholding techniques.

3.2.2. Classification

In this study, the method used for the identification process was a convolutional neural network.

3.3. Process

3.3.1. Training Process

Before entering this training stage, CNN modeling was carried out. Among them determine the number of hidden layers, number of neurons, activation function, optimizer loss, batch size, and epoch. All images that have passed the process stage will be inputs that will go into the convolutional layer. The first stage is done randomly assigning input weight and bias values. The number of neurons on the input layer is adjusted to the parameters received from the dataset used.

Then the calculation of the hidden layer output matrix, which is the result of the processing of inputs that have been received by neurons on the hidden layer of neurons on the input layer. And next will be done a calculation of output weight. The result of this process is a matrix that represents the weight of each neuron in the output layer.

3.3.2. Testing Process

This stage is done to find out the effectiveness of the convolutional neural network method in identifying diabetic retinopathy disease.

4. Algorithm

Deep learning is one of the areas of machine learning that utilizes artificial neural networks to be able to implement problems with large datasets. This algorithmic technique provides a very powerful architecture for Supervised Learning. By adding more layers, the learning model can better represent the data in the form of labeled imagery. In this field of machine learning, there are techniques to use the extraction of features from training data and special learning algorithms to classify imagery as well as to recognize sounds. However, this method still has some drawbacks both in terms of speed and accuracy [4]. CNN is one type of feed-forward artificial neural network that is the architecture of deep learning. CNN is a multilayer perceptron specifically designed for the identification of information from a two-dimensional image [8]. CNN's algorithm has two processes: convolution process and sampling process. In CNN there are several layers, including:

4.1. Convolutional Layer

It consists of a rectangular box of neurons. Each neuron takes input from a rectangle from the previous layer, the weight for each rectangle is the same for each convolutional layer.

4.2. Max-pooling layer/subsampling layer

After the convolutional layer, there is a pooling layer that takes a small long square block from the convolutional layer and subsample to produce a single output from the block.

4.3. Fully-Connected layer

After the convolutional layer and max-pooling layer, the fully-connected layer takes all the neurons from the previous layer and connects to every single neuron there is. This is the final layer, so there is no possibility for a convolutional layer or max-pooling layer can be seen in figure 2 below

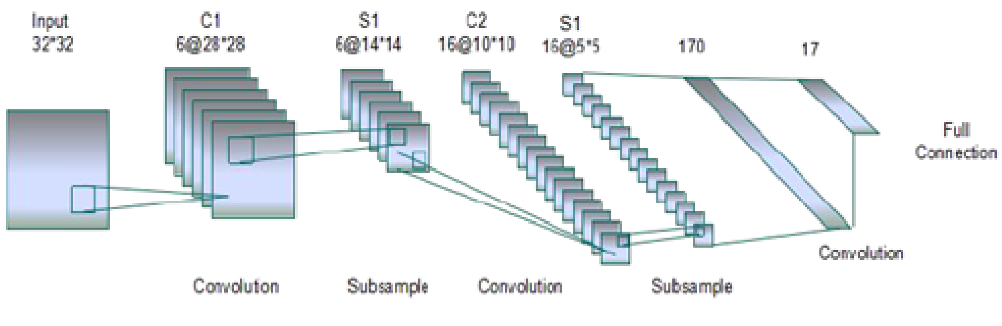

Figure 2: CNN Architecture [8]

5. Experiment

At this stage, the input used is the retinal fundus image data obtained from the `https://www.kaggle.com/c/aptos2019-blindness-detection/data`. This data will be divided into train data and test data with a ratio of 9:1. Here the datasets totaling 3662 images consisting of 5 labels, which can be seen in table 1 below

Table 1: Dataset description

Number	Labels	Diagnosis	Number of Image
1	0	No Diabetic Retinopathy	1805
2	1	Mild	370
3	2	Moderate	999
4	3	Severe	193
5	4	Proliferative Diabetic Retinopathy	295

The data will be used as testing data for 366 images and the remaining 3692 images will be used as training data.

6. Result and Analysis

Here are some sample datasets that have been inputted into the training data. In this study, the training process was conducted after preprocessing. Preprocessing is done by converting the original input fundus image into a thresholding image form can be seen in figure 2 below

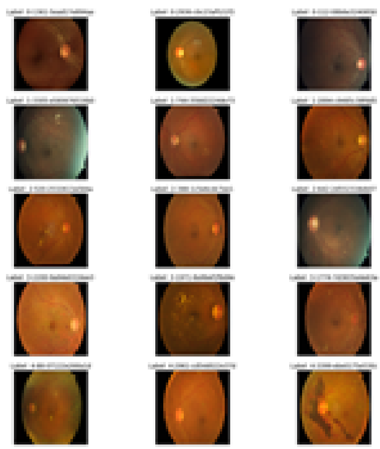

Figure 3: Datasets Sample

The data that has been done preprocessing will be changed into binary image form by using the thresholding technique. Here are some samples of preprocessing results from figure 3 above that have been done can be seen in figure 4 below

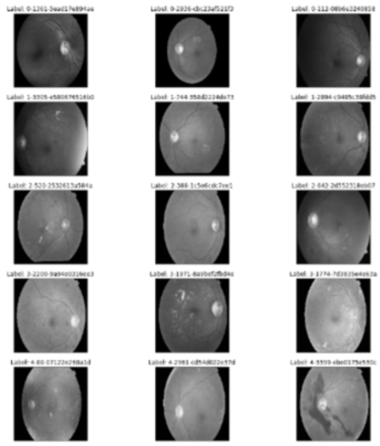

Figure 4: Sample Data Training that has undergone preprocessing

Figure 4 above is a sample of the training data that has been done preprocessing. It can be seen that the fundus image on the retina has been altered in the form of a binary fundus image at the preprocessing stage. To avoid overfitting and underfitting on the training data, several conditions are carried out so that the identification process runs optimally. In this study, monitoring the loss value in the minimum validation/testing, running epoch as much as 30 times so that there is no decrease in the value of validation loss. After doing epochs as many as 30 times, then the training data model is stored so that it can be used as the best model. After performing the process to avoid overfitting and underfitting. The following is the result of optimizing training data with epoch 30 times can be seen in the graph of loss, accuracy, loss validation, accuracy validation in the image below.

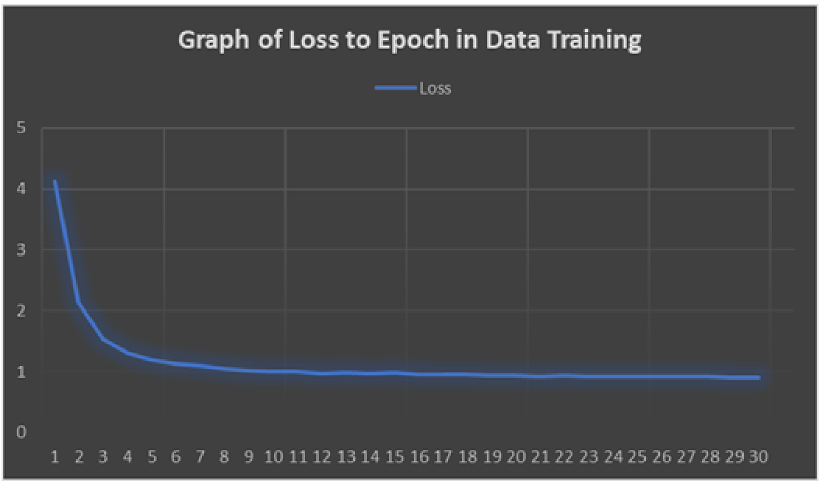

Figure 5: Graph of Loss against Epoch

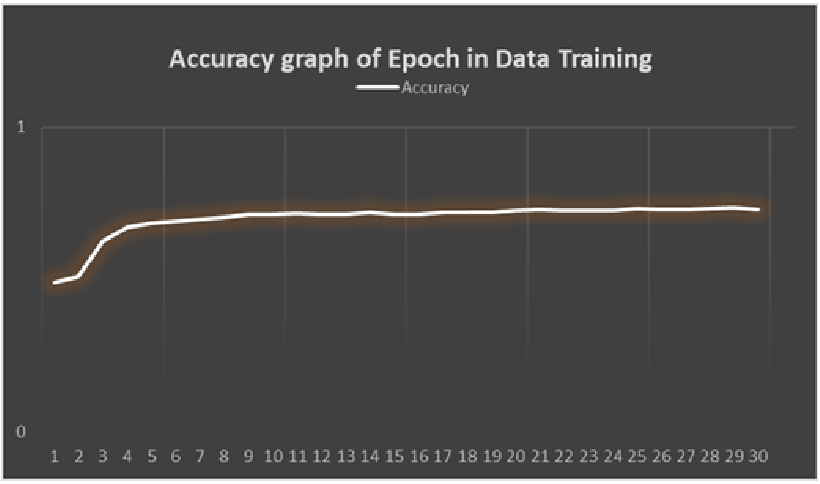

Figure 6: Accuracy graph against Epoch

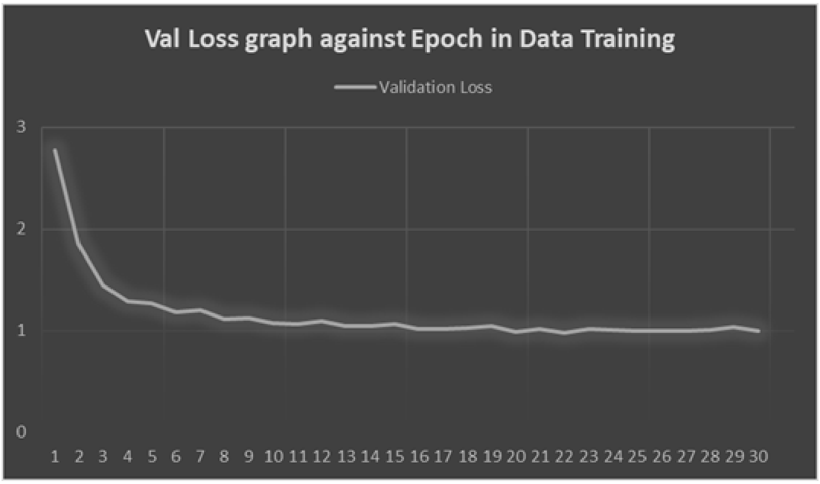

Figure 7: Graph validation loss against Epoch

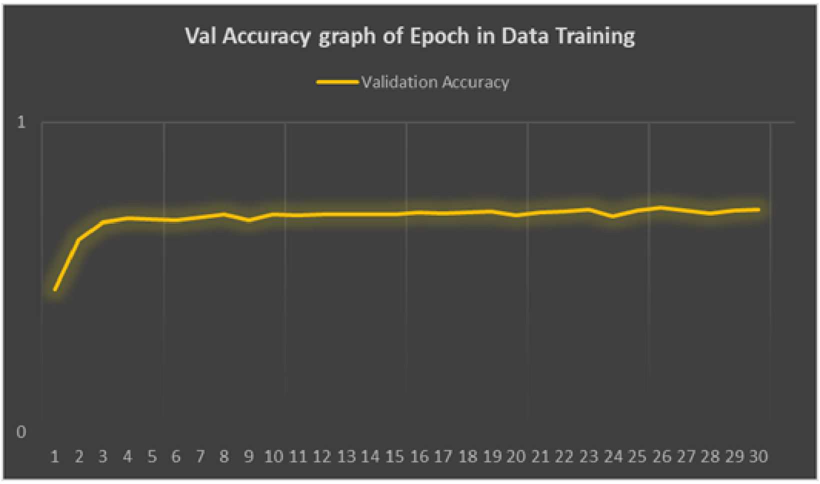

Figure 8: Validation Accuracy Graph

Figures 5, 6, 7 and 8 above are graphs of data training optimization results by doing epoch 30 times. Can be seen from the chart above the value of loss and validation loss will decrease if more epoch did. On the contrary with accuracy and validation accuracy, the value is increasing. So it can be said that the more epoch did, the more optimal data training and avoid overfitting and underfitting so that an optimal model of training data will be formed. So from the graph above can be seen in the form of smooth which indicates the training data model has been in the optimal form. Identification of diabetic retinopathy disease in this study using deep learning method with Convolutional Neural Network (CNN) algorithm. Test data used is data obtained from `https://www.kaggle.com/c/aptos2019-blindness-detection/data` totaling 366 images. After identifying diabetic retinopathy disease using deep learning method with Convolutional Neural Network (CNN) algorithm, confusion matrix is obtained in table 2 below

Table 2: Confusion Matrix

f_{ij}		**Predict Class (j)**				
		0	1	2	3	4
True Class (i)	0	176	2	1	0	1
	1	3	33	1	0	0
	2	0	0	96	3	1
	3	2	1	1	16	0
	4	2	0	1	0	26

From the confusion matrix in Table 2 above, accuracy, recall, and precision can be calculated as a reference to deep learning performance in identifying diabetic retinopathy disease. The following table 3 is the result of the performance of the deep learning method with Convolutional Neural Network (CNN) algorithm in identifying diabetic retinopathy disease based on the retinal fundus image.

Table 3: Performance of deep learning method with Convolutional Neural Network algorithm (CNN)

Accuracy	Recall	Precision	*F1-Score*
95,355	90,524	92,181	91,344

7. Conclusion

After researching with several stages, it can be concluded that:

- The Deep Learning method can identify images.
- The Convolutional Neural Network (CNN) algorithm can identify images with an accuracy of up to 95.355%.
- The more the number of epochs performed, the optimal data training model used.

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