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Classification of diabetic retinopathy and normal fundus images based on texture features using Multilayer Perceptron (MLP)

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ABSTRACT
Diabetic retinopathy is a disease caused by uncontrolled blood sugar levels and occurs continuously. Funduscopic examination with an ophthalmoscope tool to determine diabetic retinopathy. This study aims to classify funduscopy images in distinguishing normal eyes and diabetic retinopathy based on texture characteristics using the multilayer perceptron (MLP) method. Texture feature extraction as a class recognition process that aims to produce characteristics based on the texture of each image. The texture features used are histogram and GLCM with 10 parameters. Research data is sourced from the Zenodo website and the National Library of Medicine. Based on the results of the study, it shows that the multilayer perceptron method with the help of Weka machine learning in classifying eye fundus images to distinguish normal eye cases and diabetic retinopathy produces an accuracy value of 83.75% at k-folds 20 cross validation with sensitivity and specificity values of 49.20% and 95.09%.

Keywords:
Diabetic Retinopathy, Texture Feature Extraction, Multilayer Perceptron (MLP).

Introduction

Diabetes mellitus is the Greek medical term for diabetes or sugar. Diabetes means flowing and mellitus means sweet. This is because the nature of urine suffered by people with diabetes mellitus is sweet (Sapra & Bhandari, 2023). Diabetes mellitus occurs because the metabolic system in the pancreas is disrupted. This is caused by the amount of insulin in the pancreas decreasing so that blood sugar levels increase or hyperglycemia (Lestari, Zulkarnain & Sijid, 2021). Diabetes mellitus or often referred to as diabetes is caused by a metabolic system disorder in the pancreas (Lestari, Zulkarnain & Sijid, 2021). In 2021, the International Diabetes Federation (IDF) organization estimates that the prevalence rate of diabetes mellitus in the world reaches around 537 million people aged 20-79 years or 10.5% of the same population at that age. This figure is expected to continue to increase as the years go by (IDF, 2021).

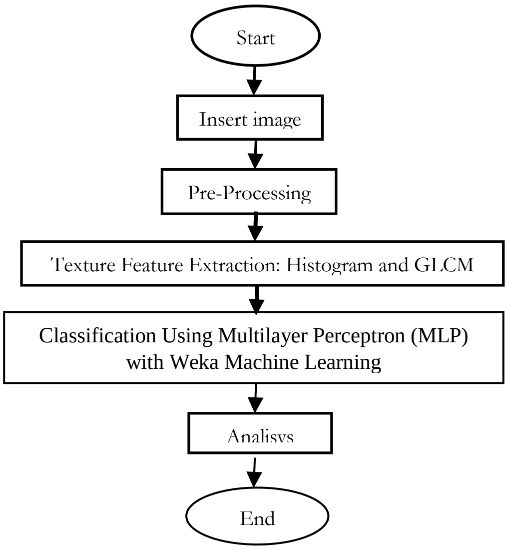
If diabetes mellitus is not treated immediately, it will lead to complications. One of them is diabetic retinopathy which attacks the retina of the eye. (Yusran, 2017). Diabetic retinopathy is a complication of diabetes mellitus that attacks the blood vessels of the retina of the eye. This is because the glucose level in the blood is high and prolonged, causing nutrients to the retina to experience blockages characterized by the appearance of eye ancurysms, dilated veins, bleeding and also fatty exudates. As a result, there is leakage of new abnormal blood vessels and impaired vision can even result in permanent blindness (Purnama, Nintyastuti & Rizki, 2023).

To detect abnormalities in the eye, a funduscopic examination is needed (Susetianingtias et al., 2017). Funduscopy or ophthalmoscopy is a direct examination of the posterior segment of the eye including the lens, retina, human vitreous, retinal blood vessels, macula and optic nerve disc. The tool used by the ophthalmoscope is a tool that helps illuminate and enlarge the image of the eye. There are two types of ophthalmoscope tools, namely direct and indirect (Elizabeth, 2021).

Image processing is done to change the shape of the image as desired. The processing used digitally is an array containing complex or real values represented by a certain bit sequence (Sulistiyanti et al., 2016). This study was conducted to determine the classification of diabetic and normal retinopathy funduscopy images using texture characteristics with the multilayer perceptron (MLP) method assisted by Weka machine learning.

Methods

This research uses quantitative research methods, namely research methods whose data are related to numbers and statistics in solving problems. The research was conducted in January 2024 at the Integrated Laboratory of FST, Campus III, Walisongo State Islamic University Semarang. Data retrieval comes from the Zenodo website as a database while for information from the data on the National Library of Medicine website. The tools used in this research are a laptop with specifications DESKTOP-23A6KQM Intel(R) Celeron(R) N4000 CPU @ 1.10GHz 1.10 GHz, 4.00 GB RAM (3.83 GB usable), 14inch (1366*768) HD, Intel UHD Graphic 600 integrated graphics card, 1TB HDD, python google collaboratory, machine learning Weka version 3.9.6, Microsoft Word and Microsoft Excel. While the research material used is a digital image of the eye retina from the Zenodo website as many as 757 images obtained at the Department of Ophthalmology of the Hospital de Clinicas, Facultad de Ciencias Médicas, Universidad Nacional de Asunción, Paraguay. The following are the stages of conducting the reseacrh in Figure 1.



Figures 1. Flowchart of Research Steps

Insert Image
The initial stage of the research procedure begins with entering the funduscopy examination image obtained from the Zenodo website.

Pre-processing
Images from the Zenodo website that are still in the form of color images or RGB will be processed grayscaling to get a grayscale image, which is an image that has a gray scale with the smallest intensity value of 0 in the form of black and white as the color with the largest intensity value of 255 (Wahyudi, Triyanti & Ruslianto, 2015). After obtaining a grayscale image, the image will go through a filtering process. The filter used is a median filter, which is a non-linear filter developed by Tukey that functions to reduce noise and smooth the image (Fadillah & Gunawan, 2019).

Texture Feature Extraction
Texture feature extraction is performed to obtain characteristics based on the texture of each image in the class (object) recognition process which aims to provide detailed information on the differences between classes in several images and allow images to be in different classes. Texture feature extraction is very important to produce characteristics based on the texture of each image (Septiarini & Wardoyo, 2015). This stage does not require segmentation because texture feature extraction aims to provide detailed information about the differences between classes in several images. The texture feature extraction method used is histogram and GLCM.

1. Histogram
Histogram equation as a technique to increase the contrast in the image or as a statistical probability distribution of grayscale digital images (Ahmad & Hadinegoro, 2012). The features contained in the histogram are as follows:

a. Mean (m)

$$m = \sum_{i=0}^{L-1} i.p(i) \tag{1}$$

where m is mean intensity, i is the gray direction of the image, $p(i)$ is probability of occurrence of i and L, i and L is highest gray level value.

b. Standard deviation (σ)

$$\sigma = \sqrt{\sum_{i=1}^{L-1} (i-m)^2 p(i)} \tag{2}$$

c. Variant (σ^2)

$$\sigma^2 = \sum_{i=1}^{L-1} (i-m)^2 p(i) \tag{3}$$

d. Entropy

$$Entropy = \sqrt{\sum_{i=1}^{L-1} p(i) log_2(p(i))} \tag{4}$$

e. Skewness

$$Skewness = \sqrt{\sum_{i=1}^{L-1} (i-m)^3 p(i)} \tag{5}$$

f. Kurtosis

$$Kurtosis = \sqrt{\sum_{i=1}^{L-1} (i-m)^4 p(i) - 3} \tag{6}$$

2. Gray Level Co-occurrence Matrix (GLCM)
Gray Level Co-occurrence Matrix (GLCM) is a second-order extraction or image texture analysis method with a cooccurrence matrix which is a matrix that describes the neighbor relationship between pixels in an image from various distances and directions. This second order considers the relationship that occurs between pairs of pixels in the original image. This is because the first order ignores pixel proximity and only uses statistical calculations according to the original image pixel values (Hall-Beyer, 2017). The following GLCM texture characteristics are used as follows:

a. Energy

$$Energy = \sum_i \sum_j p^2(i,j) \tag{7}$$

b. Contrast

$$Contrast = \sum_i \sum_j (i-j)^2 \, p(i,j) \tag{8}$$

c. Correlation

$$Correlation = \frac{1}{\sigma_x \sigma_y} \sum_i = 1 \sum_j = 1 (i-\mu_x)(j-\mu_y) p(i,j) \tag{9}$$

d. Homogeneity

$$Homogeneity = \sum_i \sum_j \frac{\mathrm{p}(i,j)}{1+|i-j|} \tag{10}$$

where p(i,j) is GLCM matrix at row i and column j, i is Row number, j is Column number, μ is mean, and σ is Standard deviation of pixel values.

Classification

At this stage the method used for classification is multilayer perceptron with the help of Weka machine learning which aims to separate funduscopy images between patients with diabetes mellitus who have been complicated by diabetic retinopathy and normal.

Multilayer perceptron (MLP)

Multilayer perceptron (MLP) is a feedforward artificial neural network that is located between the input layer and the output layer and has one or more hidden layers, each of which is connected to the next layer. MLP belongs to the class of deep learning. The algorithm used to train this model is backpropagation in improving the accuracy of the training model (Suwarno & Abdillah, 2016). MLP works only in the forward direction. All nodes will be fully connected to the network and all nodes will forward their values to nodes that come in the forward direction (Singh, 2024).

Weka or often referred to as the Waikato Environment for Knowledge Analysis is a package of machine learning tools for education, research or various applications. In the real world, Weka has benefits for solving various data mining problems. In addition, another advantage of Weka is that it is easy to use and provides the implementation of algorithms in state of the art learning that can be applied on the command line. Weka also provides tools for classification, data pre-processing, clustering, regression, and visualization and association (Purnamasari et al., 2013).

Data Analysis

Data analysis in this study is to determine the level of success obtained in the image classification process that has previously been processed and passed through the stages above. This data analysis uses parameters in the form of accuracy, sensitivity, and specificity values as found in equations 11 to 13.

The measurement index has the function of determining the performance of the image processing method used and as a counter to its success rate. The index value used is the confusion matrix shown in the Table 1(Supriyadi, 2017).

Table 1. Confusion matrix

		Predicted Class	
		Positive	**Negative**
Actual Class	**Positive**	TP	FN
	Negative	FP	TN

The following is the measurement index formula based on the confusion matrix value:

1. Accuracy is the percentage of each data that is identified and considered correct.

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} x\ 100\% \tag{11}$$

2. Sensitivity has the ability to predict a certain class according to the data set and TPR (True Positive Rate).

$$Sensitivity = \frac{TP}{TP + FN} x\ 100\% \tag{12}$$

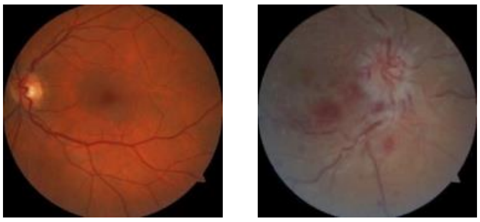
3. Specificity as a value that states the size of the two class assignments that correspond to the TNR (True Negative Rate).

$$Specificity = \frac{TN}{TN + FP} x\ 100\% \tag{13}$$

where TP is True Positive i.e. normal eyes detected as normal eyes, TN is True Negative i.e. diabetic retinopathy detected diabetic retinopathy, FN is False Negative i.e. diabetic retinopathy detected as normal, and FP is False Positive i.e. normal eye detected diabetic retinopathy.

Result and Discussions

Based on the research methodology used, the results of data processing from the classification process of normal eye fundus images and diabetic retinopathy based on texture characteristics with the multilayer perceptron (MLP) method. In the process of entering data or images obtained from the Zenodo website, there are 757 images with 187 normal eye images and 570 diabetic retinopathy images (Figure 2).

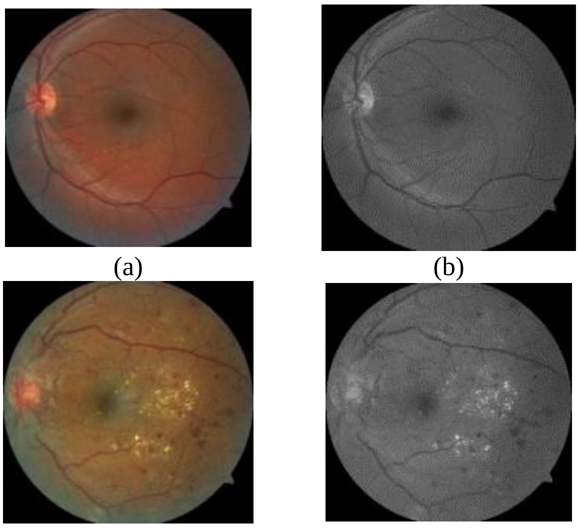


(a) (b)

Figures 2. Eye Fundus Images (b) Normal Eye Image, and (b) Diabetic Retinopathy Image

The normal eye structure has perfect retinal vasculature and small blood vessels consisting of the retina, fovea, macula, posteror pole and blind spot or optic disc. Whereas in diabetic retinopathy images there is damage to the small blood vessels of the eye, namely the presence of microneurysm which occurs because the smallest wall of the vessel is weakened. The wounds on the vessel can cause exudates, which are yellowish dots in the retina area.

The initial stage for image processing is pre-processing which consists of grayscaling and filtering. The grayscaling process is done to simplify the processing process because it has one intensity value at each pixel (Figure 3). Where the red, blue and green colors are expressed as a single value and the intensity value is the same. After the image becomes grayscale, it will be processed with a median filter to improve image quality (image enhancement) and to reduce distortion (noise) in the image. This is done because sometimes the image used has poor quality which causes difficulties for processing and the information in the image is difficult to recognize (pattern recognition).



(a) (b)

(c) (d)

Figures 3. Gray Discoloration of Eye Fundus Image (a) Normal Eye RGB Image, (b) Citra Mata Normal Setelah Proses Grayscale dan Medan Filter, (c) Diabetic Retinopathy RGB Image, and (d) Diabetic Retinopathy Image After Grayscale and Field Filter Processes

The texture feature extraction process is carried out after the grayscalling and filtering stages with the help of Python Google Collaboratory. The results obtained in this texture feature extraction process are in the form of numbers that are moved to notepad and moved back to excel form to make it easier to go to the next stage. After the data enters excel, the file format is changed to csv online. The texture feature extraction method is histogram and GLCM. A total of 10 data attributes were taken consisting of 6 attributes of the histogram method, namely standard deviation, variance, mean, entropy, kurtosis and skewness (Table 2). The other 4 attributes of the GLCM method are contrast, energy, homogeneity and correlation. This texture feature is very important in the diagnosis process because it has a function to describe certain local patterns repeatedly and the regularity of the arrangement in certain areas of the image for local characteristics as well as matrix characteristics such as roughness, smoothness and regularity.

Table 2. Comparison of Classification Process

No	Folds	Accuracy	Sensitivity	Specificity
1	Training	84.54%	40.11%	99.12%
2	5	83.09%	41.71%	96.67%
3	10	81.90%	52.41%	91.58%
4	15	82.17%	49.73%	92.81%
5	20	83.75%	49.20%	95.09%
6	25	83.49%	51.34%	94.04%

The steps taken to determine normal eyes and diabetic retinopathy by classification using the multilayer perceptron method assisted by Weka machine learning. The classification process requires a trainingset and testingset process. Trainingset data is the result data that serves to determine the correctness of the multilayer perceptron process while the testingset is the result of the actual classification on the multilayer perceptron. In the testingset, k-folds cross validation variations are performed, namely 5, 10, 15, 20 and 25. The accuracy value obtained at table 2 by varying folds cross validation is fairly good but has not yet obtained maximum results. This is because there are still errors during the classification process where the results obtained do not match the actual data such as examples that should be diabetic retinopathy but in the classification process read normal eyes. Things like that cause the resulting accuracy value to be less than optimal. In addition, it can also be influenced because the selected image is not good and the pre-processing stage is not maximized.

Conclusion

Based on the analysis of the classification of eye fundus images in distinguishing between normal eyes and diabetic retinopathy using the multilayer perceptron (MLP) method, the best accuracy value is at 20 folds cross validation of 83.75% with sensitivity and specificity values of 49.20% and 95.09%.

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Conflicts of interest

The authors affirm that they have no conflicts of interest.

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