# Automated Diagnosis System of Diabetic Retinopathy Using GLCM Method and SVM Classifier

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***Abstract*— Diabetic Retinopathy (DR) is the cause of blindness. Early identification needed for prevent the DR. However, High hospital cost for eye examination makes many patients allow the DR to spread and lead to blindness. This study identifies DR patients by using color fundus image with SVM classification method. The purpose of this study is to minimize the funds spent or can also be a breakthrough for people with DR who lack the funds for diagnosis in the hospital. Pre-processing process have a several steps such as green channel extraction, histogram equalization, filtering, optic disk removal with structuring elements on morphological operation, and contrast enhancement. Feature extraction of preprocessing result using GLCM and the data taken consists of contrast, correlation, energy, and homogeneity. The detected components in this study are blood vessels, microaneurysms, and hemorrhages. This study results what the accuracy of classification using SVM and feature from GLCM method is 82.35% for normal eye and DR, 100% for NPDR and PDR. So, this program can be used for diagnosing DR accurately.**

**Keywords—Diabetic Retinopathy, SVM Classifier**

## I. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder that occurs because the pancreatic system in the body cannot produce enough insulin effectively so that blood sugar levels are not balanced. As a result, there will be an increase in the concentration of glucose in the blood (hyperglycemia). The prevalence rate of this disease is quite high every year. In 2014, the World Health Organization (WHO) noted that the incidence of diabetes mellitus in 18-year-olds was 8.5% of all diabetics worldwide. In 2015 the death rate from diabetes was 1.6 million. However, the highest mortality rate occurred in 2012 which was 2.2 million people from the number of deaths that occur each year [1].

Diabetes mellitus is known as a silent killer because it is often not recognized by patients and can only be known when complications have occurred. One complication due to diabetes mellitus is Diabetic Retinopathy (DR). This disease spreads to the eye as it makes the sufferer experience visual impairments even to experience blindness. The DR usually attacks diabetics around 10 to 15 years after contracting diabetes [2]. In this case, high glucose levels will normally attack the eye's nerves and cause leakage and swelling of the eye's nerves which will form several components namely microaneurysms, hemorrhages, hard exudates, cotton wool spots, or venous loops [3]. This component becomes the benchmark for the severity of DR.

The identification process has a morphological operation process. Morphological operation is a process to eliminate images that are not needed then information that will be taken more clearly and can be continued in the next process [4]. In this study, a morphological operation used structuring element (SE) which aims to eliminate noise in the background. Wong li yun has succeeded to classifying DR with this morphological operation and backpropagation as a classification method [5]. In this study, the same morphological operation will be used and using SVM classifier because this method faster than backpropagation.

M. Ponni Bala et al explained in his paper that people have abnormalities DR usually characterized by the growth of ocular nerves on the surface of the retina of the eye so that the condition of DR disease is very severe and needs special treatment [6]. WHO stated that in 2002 5% of the world's blindness was caused by DR. It is about 5 million people got blindness [1]. Therefore, to prevent an increase in blindness due to DR, it is necessary to identify early DR diseases based on their severity to reduce worldwide blindness incident.

In this case, the DR has some severity. The severity can be classified into normal, mild, moderate, severe, and proliferative [3]. The easiest way to detect DR disease is to use an image color fundus that can be obtained at hospital. This is possible to obtain the results of microaneurysm (MA) and blood vessel hemorrhages (BV) which is useful to

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determine the severity of the infected DR and to find out the initial impact as a sign of DR that attacks the eye. Therefore, it is necessary to detect MA and hemorrhages in the eye so that it can be known the severity of DR. This DR classification is using feature extraction result which is obtained from blood containing features (MA, vessels, and hemorrhages) as a benchmark to determine the severity of DR. The feature that will be detected is BV because it already has MA and hemorrhages and can ease to retrieve data [5].

Before classifying BV, it is necessary to analyze the visual texture of the image obtained using the process available on a computer aided diagnosis system (CAD) in order to determine the severity of the DR through the image color fundus. Some of the steps which are undertaken for the detection and classification of BV using CAD include pre-processing, segmentation, feature extraction, and classification. These steps are done by using several methods to be able to process the color fundus image such are histogram equalization, median filter, binary, morphological operation, GLCM, SVM, ANN, and others.

Several studies have been conducted to detect and classify its features by using the CAD process. A research which was conducted by V. A. Aswale in 2017 on the detection of DR using SVM Classifier and PNN Classifier resulted the 93.33% SVM and 89.60% PNN accuracy. So, it can be concluded that classification with SVM is better than using PNN [7]. Furthermore, the second study regarding SVM was carried out by Md. Hafizur Rahman. It was related to automatic face detection and automatic gender classification using SVM Classifier and Neural Network. The results of the comparison between the two methods resulted in an accuracy of 65% using the Neural Network and 85.5% using SVM [8]. Pooja M. had successfully identified DR using GLCM and the area as feature extraction and SVM as classification. In this paper only classified DR into two classes, that is normal and DR. So, in this study will classify normal and DR then its data will be classified again into NPDR and PDR [9].

Based on previous studies, the CAD process which was used in this research is pre-processing using histogram equalization, and feature extraction using GLCM. In this study, the researcher takes GLCM as a method because it is a feature extraction technique with a second-order statistical feature that performs a probability calculation of an adjacency relationship between two pixels with the distance and a particular angular orientation of the current image [10]. After the statistical feature is obtained through feature extraction using GLCM, its result is used to classify DR based on features of MA, vessel, hemorrhages with the SVM method.

SVM is a pattern recognition method that aims to find the best hyper plane that divides between classes The SVM method is strongly recommended in the classification of images that focus on the brightness level. Therefore, this method is suitable for determining MA [7]. After the MA was classified using the SVM method, the result focused on the classification of normal, abnormal eyes, non-proliferative diabetes retinopathy (NPDR) and proliferative diabetes retinopathy (PDR). The researcher expects that this study can contribute to help the medical side detect early MA to find out the level of DR severity.

## II. LITERATURE REVIEW

### *A. Diabetes Mellitus*

Diabetes Mellitus is a chronic metabolic disorder that occurs because the body's pancreas system cannot produce enough insulin effectively and cause unbalanced blood sugar levels (increased glucose concentration in the blood/hyperglycemia) [11].

### *B. Diabetic Retinopathy (DR)*

Diabetes Mellitus is a disease of a silent killer. This disease is not recognized by the patient and can be known when complications occurred. One of the complications of diabetes mellitus is Diabetic Retinopathy (DR) [2]. This disease spreads to the eyes and causes the sufferer to experience vision problems even to blindness. High glucose levels will normally attack the eye nerve, causing leakage and swelling of the eye nerve which will form several components such as microaneurysms, hemorrhages, hard exudates, cotton wool spots, or venous loops [5].

### *C. Color Fundus Image*

Eyes are a human vision organ which is located in a protected cavity like an eyelid [3]. The signs of DR cannot be seen directly but it can be seen through an image called color fundus image. Color fundus image can shown in figure 1.

Fig. 1. *Color Fundus Image.*

### *D. Green Channel Extraction*

RGB image consists of three channels: red channel, blue channel and green channel. The red channel contains images with high saturation level. The blue channel does not load much information because there is a lot of noise which will have difficulties in finding the desired information, while on the green channel, the contrast level better than others. In this case, it used green channel. This will result clearly visible eye nerve and has more high brightness level than in the red channel and blue channel [7].

### *E. Histogram Equalization*

The histogram image provides the information related to the pixel intensity deployment in the image. Images that are too light or too dark will have a narrow histogram. Therefore, it is necessary to change the spread of image intensity values by using the improvement of an image. There are several functions in MATLAB which can be used for image contrast improvement such as imadjust, histeq, and adapthisteq. The contrast improvement has histogram equalization [12]. The purpose of image contrast improvement is to obtain an even histogram distribution. So, each gray level will have the same number of pixels.

### *F. Morphological Operation*

Morphological operation is a method used to improve image and can make information clearly visible by removing noise in the image [4]. Structuring element (SE) is one method in morphological operations. SE is a method of image improvement by probe the input shapes in the image matrix which will later be processed to erosion or dilation. SE is often used to remove optical disks (OD) or eliminate noise at the layer and the information obtained more accurate [7].

### *G. Filtering*

The median filter method is a filter that serves to smooth and reduce noise or disturbance in the image. This filter is very effective to remove the salt and paper type noise and also to maintain the image detail because it does not depend on the difference of its neighboring values [13].

### *H. Contrast Enhancement*

In the process of image repair, there is a function to improve gray scale and true-color images. In this study, the contrast improvement which is used is "imadjust" which aims to map the intensity values in the gray scale to obtain better intensity [13].

### *I. Gray Level Co-occurrence Matrix (GLCM)*

The technique which is used to derive two-order statistics is to calculate the probability of an adjacency relationship that occurs between two pixels at a certain distance and angular orientation. This method is known as the Gray Level Co-occurrence Matrix (GLCM) [10]. In addition, GLCM can be said to be a second-order statistical feature extraction method which uses a co-occurrence matrix which is an intermediate matrix that represents the neighbor relationship between pixels in images in various orientation directions and spatial distances [14]. To get GLCM feature, there are several ways that can be searched such as energy, contrast, Homogeneity, entropy, and correlation.

Energy denotes the size of the concentration of the pair with a certain gray intensity on the co-occurrence matrix and defined in equation1.

$$Energy = \sum_{i=1}^{L}\sum_{j=1}^{L} p(i,j)^2 \quad (1)$$

The contrast shows the size of the spread of moments of inertia or variation in the image matrix [15] [16]. If the distance is far from the main diagonal of the image matrix, the contrast value of the image is large. Contrast is defined in equation 2.

$$Contrast = \sum_{i}^{L}\sum_{j}^{L} |i-j|^2 p(i,j) \quad (2)$$

Homogeneity shows the degree of homogeneity of an image on a gray scale level. The homogeneous image will have a large homogeneity value [15]. Homogeneity is defined in equation 3.

$$Homogeneity = \sum_{i=1}^{L}\sum_{j=1}^{L} \frac{p(i,j)^2}{1+(i-j)^2} \quad (3)$$

Entropy shows the irregularity of the shape size. Entropy measures information or messages that lost from a transition signal and also calculates image information which is defined in equation 4.

$$Entropy = \sum_{i=1}^{L}\sum_{j=1}^{L} p(i,j)(-\ln p(i,j)) \quad (4)$$

Correlation represents the linear dependence measure of the gray currency matrix of the image [15]. It can be defined in equation 5.

$$Correlation = \sum_{i=1}^{L}\sum_{j=1}^{L} \frac{(i-\mu_i)(j-\mu_i)p(i,j)}{\sigma_i \sigma_j} \quad (5)$$

### *J. SVM Classifier*

SVM is a pattern recognition method that aims to find the best hyper plane that separates the class. Basically, the initial idea of SVM is to maximize hyper plane boundaries because a maximum hyper plane will give a better generalization on the classification method. The hyper plane will be a separator of two classes of data input space is +1 and -1 [17]. Hyper plane will be maximal if the distance between hyper plane and data support vector of each class is optimal. The SVM method is strongly recommended in classifying images that races at the brightness level. Figure 2 shows an SVM illustration with an optimal hyperplane.

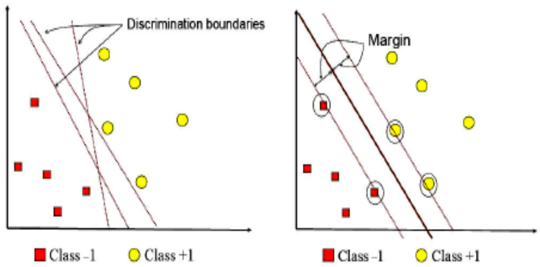


Fig. 2. SVM with the Best Hyperplane that Separates Two Classes

### *K. Confusion Matrix*

The confusion matrix is a method which is used to measure the accuracy of a classifier. This method can find out the accuracy, specificity, and sensitivity [18]. To obtain accuracy, specificity, and sensitivity scores, it is necessary to find the True Negative (TN), False Positive (FP), False Negative (FN), True Positive (TP) values on confusion matrix. Confusion matrix table can be shown on table 1.

TABLE I. CONFUSION MATRIX

| Actual | Classification | |
|---|---|---|
| | + | - |
| + | *True Positive* (TP) | *False Negatives* (FN) |
| _ | *False Positive* (FP) | *True Negatives* (TN) |

After obtained the value of TP, TN, FP, FN, it can be searched for accuracy, sensitivity, and specificity. That equation defined in equation 6, 7, and 8.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (6)$$

$$Sensitivity = \frac{TP}{TP + FN} \quad (7)$$

$$Spesificity = \frac{TN}{TN + FP} \quad (8)$$

Accuracy is a success rate in the performed classification. Sensitivity is tinged where people diagnosed the disease is indeed a person who exposed disease. The specificity will be better if normal data is identified normally.

## III. RESEARCH METHODS

### A. *Types of Research*

Research on detection of MA, vessels, hemorrhages for the diagnosis of DR severity by using the SVM method is a quantitative descriptive study. It categorized from the aspect of function in this research, It's applied research which aims to assist medical side as alternative detection MA, vessels, hemorrhages to know the severity of DR.

### B. *Data Collection and Analysis*

Data color fundus image is obtained from diaretdb with the amount of data as many as 44 data. Data color fundus image will be divided into training and test data. The training data in this study is 6 normal data and 21 DR data. The test data consists in 4 normal data and 13 data DR. The DR data will be subdivided into training data which consists of 18 NPDR data and 2 PDR data, while the test data consists of 12 NPDR data and 2 PDR data. The weakness of data from diaretdb is the absence of labeling for classification. Therefore, labeling in this classification is validated by a doctor from the Dr. Soetomo Surabaya hospital.

Furthermore, the analysis of color fundus image data such as preprocessing process, feature extraction by using GLCM and classification by using SVM. The first step is to improve the image fundus image or color fundus image. Because the color fundus image basically cannot be used as the initial parameter to identify the DR directly. Furthermore, the preprocessing process required stages of improvement including green channel extraction, equalization histogram, optical disk elimination, filtering with a median filter, contrast enhancement, and morphological operation. After the color fundus image has improved, the next step is to conduct feature extraction by using GLCM. Statistical features that are focused on feature extraction include energy, correlation, contrast, homogeneity, and entropy. This statistical feature is used as input for SVM to classify MA, vessels, and hemorrhages as determinants of the DR severity.

### C. *Testing Data Evaluation*

The first test is done by image preprocessing process from color fundus image to get MA feature, vessels, and hemorrhages. Then, the feature is analyzed with texture by using GLCM. Statistical features obtained through feature extraction of GLCM are used as inputs for SVM for MA classification, vessels, and hemorrhages as determinants of DR severity. To achieve the objectives of this research, steps are needed to be sequential and systematic. Figure 3 shows the flowchart of data processing until the classification as a determinant of the severity of DR.

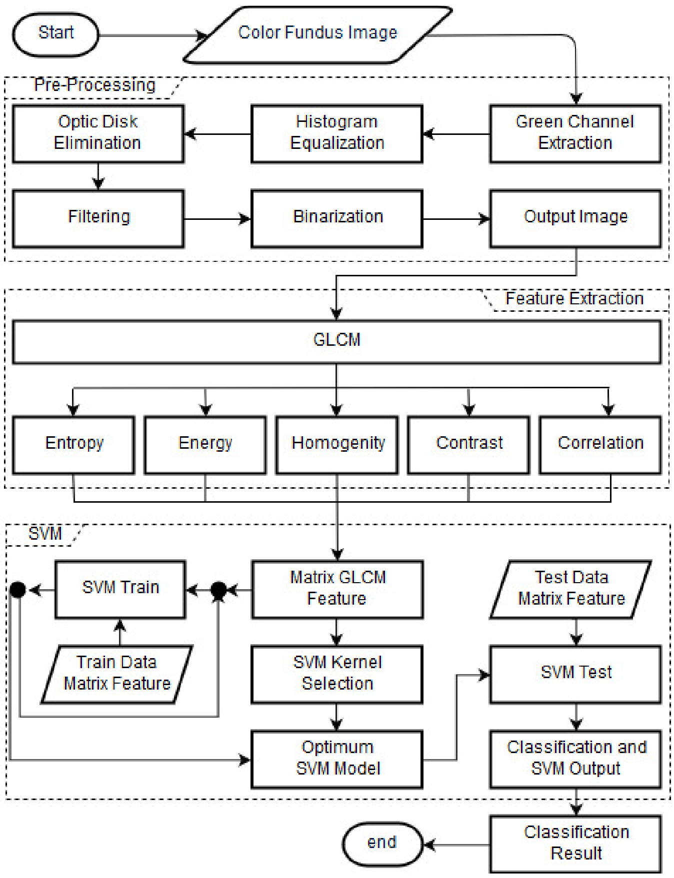


Fig. 3. Flowchart Automatic Detection DR

The steps of automatic detection of DR using SVM as follows:

a. *Pre-processing*

The color fundus image which is obtained from the hospital cannot be used directly as a parameter to identify the DR. Therefore, it is necessary to clarify the components of the DR cause in the eye. So, it can easily be known whether the eye retina has been infected with DR. This image processing stage will be the key to detect DR in the retina. There are many ways that can be used in this pre-processing stage, such as changing the image to the gray level, contrast settings, and also noise removal.

1) *Green Channel Extraction*

RGB image have three channels such as red channel, blue channel and green channel. The red channel contains images with high saturation level, the blue channel does not load much information because have a lot of noise that will hard to finding the desired information, while on the green channel the contrast level better than others then in this case used green channel. The result is the eye nerve will be clearly visible and has a high brightness level than in the red channel and blue channel.

*2) Histogram Equalization*

Histogram equalization is a technique to adjust the intensity value of the image to be processed in order to get maximum results. In this stage, a contrast-limited adaptive histogram equalization (CLAHE) is used. By using CLAHE, the image will be adjusted to the best contrast level that the result will suitable for processing. But before the CLAHE process is done, first we need complement the image to make the image more clearly when enhanced this contrast.

*3) Optic Disk Elimination*

To eliminate optical disk (OD), then morphology is required to remove the OD on the layer. At this stage structuring element (SE) is required with the default ball-shaped type radius 8. Once the morphology results obtained, the previous image is subtracted with morphological results to produce an image without OD.

*4) Filtering*

The next stage is the filter to remove the background contained in the picture. This stage applies a 3x3 median filter to remove pixels that have low light intensity. The filter result in the morphological stage is to remove noise in the background. In the morphology, the SE used is disk-shaped with a radius 15. Disk-shaped is used because it is more optimal to remove noise than other shaped. After the background has been cleared, the next process is a reduction between the results filtering with morphological results to the remaining components that are useful as a benchmark DR.

*5) Contrast Enhancement*

Furthermore, the next step is to conduct an increase in the brightness of the image so that the components are clearly visible and can be processed to get the classification feature.

*b. Feature Extraction*

After the color fundus image has improved, the next step is feature extraction process by using GLCM. Statistical features that focused on feature extraction are include energy, correlation, contrast, homogeneity, and entropy.

*c. SVM classifier*

The vector feature matrix of energy, correlation, contrast, homogeneity, and entropy GLCM is used as training and testing on SVM classifier. The selection of kernel and SVM parameters are needed because the data in this study is in the form of nonlinear data. After obtaining the optimal SVM model through the training process, testing phase is conducted. After the testing phase, the optimum model is detected by DR. Then results of classification are divided into four classifications namely, normal eye, abnormal eye, NPDR, and PDR.

## IV. RESULT AND DISCUSSION

Some process for detecting the severity of DR is required. The process includes pre-processing, feature extraction, and classification. Pre-processing used to improve image quality until the features are clearly visible. Feature extraction used to obtain statistical data from microaneurysms features and hemorrhages features. Classification used to divide into 2 classes, that is Normal-Abnormal (DR) and NPDR-PDR. The DR sample data can be shown on figure 4.

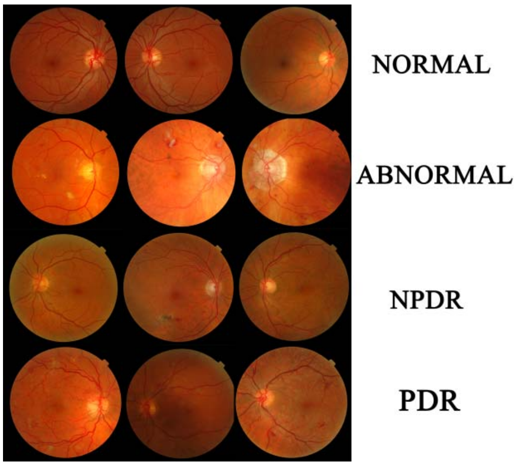


Fig. 4. Sample data of color fundus image

*A. Pre-processing*

Pre processing is the first process to obtain the data. Preprocessing data adapted to the available sequence data obtained and good for processing to the next stage. In the preprocessing process starts from the color fundus image, green channel extraction, histogram equalization, optical disk remove, filtering, and contrast enhancement. The results of preprocessing can be shown on figure 5. In Figure 5.a is the color fundus image and the green channel extraction results in figure 5.b. Image quality improvement using histogram equalization on Figure 5.c and then optical disk is eliminated using structuring element in Figure 5.d and followed by median filter to eliminate noise in Figure 5.e looks clearer than previous image and the last step is to increase the contrast of image on Figure 5.f.

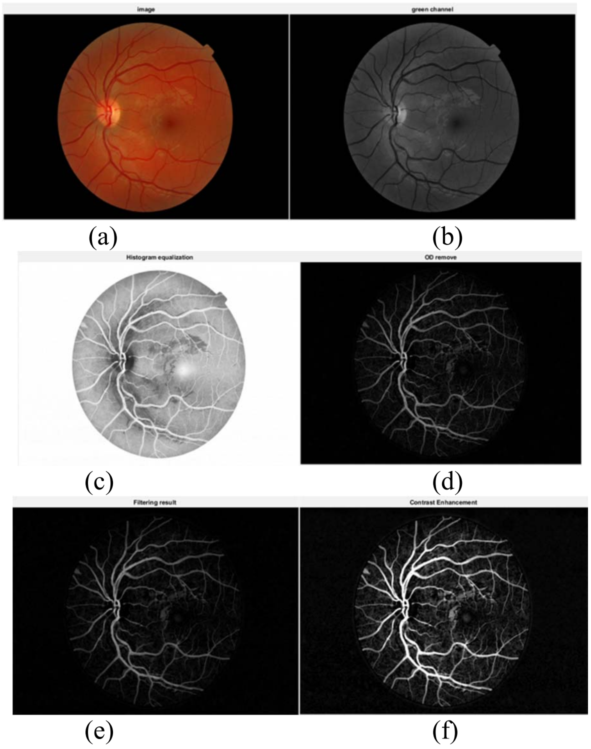


Fig. 5. (a) color fundus image (b) green channel extraction (c) Histogram equalization (d) optic disk elimination (e) filtering (f) contrast enhancement

### *B. Feature Extraction*

At this stage, the image can be taken by the final of gray scale image, because the GLCM method can only retrieve data from gray scale images. Then the data will be classified using the SVM Classifier. Sample data of this feature extraction can be shown on table 2 and table 3. That statistical data obtained will be processed on the SVM classifier to obtain classification results.

TABLE II. DATA SAMPLE FOR NORMAL AND DR

| No. | Feature extraction | | | | Class |
|---|---|---|---|---|---|
| | **Contrast** | **Correlation** | **energy** | **Homogeneity** | |
| 1 | 0.263659 | 0.909002 | 0.581941 | 0.937558 | Normal |
| 2 | 0.237590 | 0.923486 | 0.546646 | 0.936890 | |
| 3 | 0.261579 | 0.917437 | 0.536592 | 0.934314 | |
| 4 | 0.238781 | 0.913206 | 0.535697 | 0.931708 | |
| 5 | 0.284234 | 0.924740 | 0.522379 | 0.927582 | DR |
| 6 | 0.268286 | 0.916974 | 0.533217 | 0.930133 | |
| 7 | 0.361264 | 0.907719 | 0.288979 | 0.879047 | |
| 8 | 0.260572 | 0.922748 | 0.548006 | 0.933424 | |
| 9 | 0.205339 | 0.933712 | 0.563308 | 0.939471 | |
| 10 | 0.275688 | 0.912088 | 0.520706 | 0.926873 | |

TABLE III. DATA SAMPLE FOR PDR AND NPDR

| No. | Feature extraction | | | | Class |
|---|---|---|---|---|---|
| | **Contrast** | **Correlation** | **Energy** | **Homogeneity** | |
| 1 | 0.439666 | 0.859883 | 0.500604 | 0.906281 | NPDR |
| 2 | 0.387012 | 0.864807 | 0.437227 | 0.899016 | |
| 3 | 0.413319 | 0.852143 | 0.444838 | 0.896829 | |
| 4 | 0.385913 | 0.875002 | 0.539765 | 0.915449 | |
| 5 | 0.434523 | 0.863416 | 0.453694 | 0.899908 | |
| 6 | 0.428175 | 0.856331 | 0.537404 | 0.914659 | |
| 7 | 0.402631 | 0.865386 | 0.509469 | 0.910613 | |
| 8 | 0.35231 | 0.862393 | 0.581968 | 0.923809 | |
| 9 | 0.46964 | 0.866296 | 0.501231 | 0.909246 | PDR |
| 10 | 0.573235 | 0.851027 | 0.208358 | 0.82974 | |

### *C. SVM Classifier*

The input data for the SVM Classifier process is a feature that has been extracted in the GLCM method, which includes contrast, correlation, energy, and homogeneity. Then the results of the classification will be validated using confusion matrix and obtained percentage of accuracy (Ac), sensitivity (Sn), and specificity (Sp). This classification experiment was carried out using various degrees in GLCM. The results of the experiment can be shown on table 4.

TABLE IV. CLASSIFICATION RESULT

| Model | Degree | Sp | Sn | Ac |
|---|---|---|---|---|
| Normal and DR | $0^0$ | 100% | 76.92% | 82.35% |
| | $45^0$ | 100% | 61.53% | 72.58% |
| | $90^0$ | 100% | 53.85% | 64.71% |
| | $135^0$ | 50% | 46.15% | 47.06% |
| NPDR and PDR | $0^0$ | 91.67% | 100% | 92.86% |
| | $45^0$ | 91.67% | 50% | 85.71% |
| | $90^0$ | 91.67% | 50% | 85.71% |
| | $135^0$ | 100% | 100% | 100% |

From the experimental results in table 4, it can be seen that best results are obtained at $0^o$ GLCM in the Normal-DR class and $135^o$ GLCM in the NPDR-PDR. The best SVM results is True Negative (TN), False Positive (FP), False Negative (FN), True Positive (TP) that can be shown on table 5.

TABLE V. BEST RESULT OF SVM CLASSIFIER

| Model | TN | TP | FP | FN |
|---|---|---|---|---|
| Normal and DR | 4 | 10 | 0 | 3 |
| NPDR and PDR | 12 | 2 | 0 | 0 |

Based on the results of the classification in table 4, value of accuracy, sensitivity, and specificity calculated as success standard of the classification experiments presented in table 5. On table 5, there are 3 of the 13 normal data identified as DR. So, total of the data identified as DR is 7 data, which it should be only 4 DR data. it caused sensitivity percentage value of normal and DR classification is 76.92%. Meanwhile, specificity percentage value of normal and DR classification is 100% because all testing data identified into normal class. So, the accuracy percentage value of normal and DR classification is 82.35%.

On table 2, normal and DR class data are almost same, so DR data has similar characteristics data of normal class which it caused feature extraction data can't divide data into two classes and classifications of normal and DR models get poor sensitivity percentage value.

On table 3, NPDR and PDR data has specificity, sensitivity, and accuracy percentage value is 100%. It caused by the contrast data between NPDR and PDR which can divide data into two classes. In NPDR data contrast is below 0.45, meanwhile in PDR data contrast is above 0.45. So all the data of NPDR and PDR Classification identified equal as initial data.

## V. CONCLUSION

From the results of research on automatic detection of color fundus image with GLCM method as statistical data and SVM classifier, it can be concluded that from the beginning of pre-processing process, feature extraction, SVM classifier to classify between normal people and DR sufferer has an accuracy of 82.35%, and on the classification of patients with NPDR and PDR has an accuracy of 100%. So the SVM classifier method with the data obtained using GLCM can be considered successful for the application of color fundus image as a classification between normal people and people with DR.

## REFERENCES

[1] World Health Organization, "Diabetes," *15 November*, 2017. [Online]. Available: http://www.who.int/news-room/fact-sheets/detail/diabetes. [Accessed: 19-Jun-2018].

[2] N. Gori, "Detection and Analysis of Microanuerysm in Diabetic Retinopathy using Fundus Image Processing," vol. 3, pp. 907–911, 2017.

[3] A. Sopharak, B. Uyyanonvara, S. Barman, and T. H. Williamson, "Automatic detection of diabetic retinopathy exudates from non-dilated retinal images using mathematical morphology methods," *Comput. Med. Imaging Graph.*, vol. 32, no. 8, pp. 720–727, 2008.

[4] R. Srisha and A. M. Khan, "Morphological Operations for Image Processing : Understanding and its Applications Morphological Operations for Image Processing : Understanding and its Applications," *NCVSComs-13*, no. December, pp. 17–19, 2013.

[5] W. L. Yun, U. Rajendra Acharya, Y. V. Venkatesh, C. Chee, L. C. Min, and E. Y. K. Ng, "Identification of different stages of diabetic retinopathy using retinal optical images," *Inf. Sci. (Ny).*, vol. 178, no. 1, pp. 106–121, 2008.

[6] C. Aravind, "Automatic Detection of Microaneurysms and Classification of Diabetic Retinopathy Images using SVM Technique," *Int. J. Comput. Appl. Int. Conf. Innov. Intell. Instrumentarion, Optim. Signal Process. (ICIIIOSP).*, pp. 18–22, 2013.

[7] V. A. Aswale and J. A. Shaikh, "Detection of microaneurysm in fundus retinal images using SVM classifier," vol. 5, no. 4, pp. 175–180, 2017.

[8] J. Computing, "An Automatic Face Detection and Gender Classification from Color Images using Support Vector Machine," vol. 4, no. 1, pp. 5–11, 2013.

[9] P. Maule, A. Shete, K. Wani, A. Dawange, and P. J. V Shinde, "GLCM feature extraction in Retinal Image," vol. 2, no. 4, pp. 1–8, 2016.

[10] S. A, SURESH;K, "An Efficient Texture Classification System Based On Gray Level Co- Occurrence Matrix," *Int. J. Comput. Sci. Inf. Technol. Secur.*, vol. 2, no. 4, pp. 793–798, 2012.

[11] WHO, "Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation," *Diabet. Med.*, vol. 15, no. 7, pp. 539–553, 1998.

[12] R. Munir, *Pengolahan citra digital dengan pendekatan algoritmik*. Bandung: informatika, 2004.

[13] A. Usman, *Pengolahan Citra Digital dan Teknik Pemrogramannya*. yogyakarta: graha ilmu, 2005.

[14] C. Science and S. Publications, "Content Based Medical Image Retrieval with Texture Content Using Gray Level Co-occurrence Matrix and K-Means Clustering Algorithms Department of CIS , PSG College of Technology , Coimbatore , India," vol. 8, no. 7, pp. 1070–1076, 2012.

[15] R. C. . Gonzalez and R. E. Woods, "Digital image processing," *Nueva Jersey*. p. 976, 2008.

[16] N. Zulpe and V. Pawar, "GLCM textural features for Brain Tumor Classification," *Int. J. Comput. Sci.*, vol. 9, no. 3, pp. 354–359, 2012.

[17] E. Prasetyo, *Data Mining, Mengelola Data Menjadi Informasi Menggunakan Matlab*. yogyakarta: ANDI, 2014.

[18] a. K. Santra and C. J. Christy, "Genetic Algorithm and Confusion Matrix for Document Clustering," *Int. J. Comput. Sci.*, vol. 9, no. 1, pp. 322–328, 2012.