Computer Aided Diagnosis of Eye Disease for Diabetic Retinopathy

Wei Sheng Ng¹, Wan Mahani Hafizah Wan Mahmud¹*, Audrey Kah Ching Huong¹, Wan Nur Hafsha Wan Kairuddin¹, Hong Seng Gan², Raja Mohd Aizat Raja Izaham³

¹Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Malaysia.
²British Malaysian Institute,Universiti Kuala Lumpur, 53100 Gombak, Malaysia.
³Kolej Kemahiran Tinggi MARA Ledang, 84410 Ledang, Malaysia.

*wanmahani@uthm.edu.my

Abstract. Diabetic retinopathy (DR) is one of diabetes complication that could cause the vision loss, where it is caused by the damage of the blood vessels at the back of the eye. Due to this, regular eye check-up and timely treatment is needed. However, the lack of specialized ophthalmologists together with associated higher medical costs makes regular check-up costly. Therefore, any application of the technologies such as Computer Aided Diagnosis (CAD) system that could help in analysing DR efficiently in its early stage may help this current situation. Although CAD systems were developed before, but the graphic user interface for user is not developed for the ease of uses for everyone and not just limited to professional. So, in this study, a system is created in order to help the doctor to reduce their burden on the job daily and the false negative rate for the benefit of the patient. The input of the system is the Retinal fundus images (RFI) from STARE database, and the system was built with the ability to enhance and process the image for confirmation of DR. In addition, the system will help to extract out the important features based on Grey Level Co-Occurrence Matrix (GLCM) and classify it using artificial neural network (ANN) whether the patient is associated with the characteristics of DR. Also, the system will be easy to use to everyone as it will have its own graphic user interface to make it clear to everyone not just professionals so that the image from the RFI can be inserted and the result will come out in a short duration of time. The developed system able to achieve as high as 88% sensitivity, 80% specificity and 84% accuracy.

1. Introduction

Diabetes is now regarded as an epidemic, with the population of patients expected to rise to 380 million by 2025. Tragically, this will lead to approximately 4 million people around the world losing their sight from diabetic retinopathy (DR), the leading cause of blindness in patients aged 20 to 74 years [1]. Theoretically, the blood supply towards all layers of retina is done through micro blood vessels which are susceptible to unrestrained blood sugar level. However, when a large amount of glucose or fructose gathers in blood, the vessels may be crumbled and blocked because of insufficient distribution of oxygen to cells, thus leading to a severe eye injury [2]. As a result, metabolic rate slows down and leads to structural abnormality in vessels which causes DR [3].

DR is a main reason of blindness and its development is at different rates in different persons [2]. Previous study reported 90% of DR cases can be prevented through early detection and treatment [4].
But DR can easily perceive until a severe stage is reached. Therefore, regular eye check-up and timely treatment is needed. However, the lack of specialized ophthalmologists together with associated higher medical costs makes regular checkup costly [5]. That is why there is a huge demand for the latest technologies and methodologies to analyze DR efficiently and correctly in its early stage.

An automated screening system for DR can help in reducing the chances of complete blindness due to DR along with lowering the workload on ophthalmologists. For DR screening, development of low cost and versatile Computer Aided Diagnosis (CAD) systems which can be used in clinical environments, have drawn much more attention in recent years [6-13]. These systems as any machine vision systems include the lighting, the acquisition, the processing and the segmentation/classification steps. The objective of CAD systems mostly is to recognize DR and normal images in utilizing various eye features readable from fundus images like exudates (EXs), microaneurysms (MAs), veins, texture, hemorrhages (HMs), node points, and so forth [6, 7]. DR screening between two classes (DR and normal) was produced by Usher et al. [8], Aptel et al. [9], and Quellec et al. [10]. They utilized clinical components like EXs, veins, MA, Cotton Wool Spots (CWS), and HMs. Usher et al. segmented out dark lesions using moth operator and EXs were extricated using recursive region growing (RRGT) and adaptive intensity thresholding (AIT) [8]. Their methods obtained specificity of 46.3% and sensitivity of 95.1% [8]. Quellec et al. have applied optimal filters to extricate MAs [10]. The artificial neural network (ANN) [8] and Bayesian outline work [9] were used for classification.

Although CAD systems were developed before, but the graphic user interface for user is not developed for the ease of uses for everyone and not just limited to professional. So, in this project, a system is created in order to help the doctor to reduce their burden on the job daily and the false negative rate for the benefit of the patient. The input of the system is the Retinal fundus images (RFI) and the system was built with the ability to enhance and process the image for confirmation of DR. In addition, the system will help to extract out the important feature and classify it whether the patient is associated with the characteristics of DR. Also, the system will be easy to use to everyone as it will have its own graphic user interface to make it clear to everyone not just professionals so that the image from the RFI can be inserted and the result will come out in a short duration of time.

2. Material and Methods
There were several steps that need to be done in order to complete this project, as shown in Figure 1. After acquiring the fundus images, the images will undergo image processing step namely image enhancement and image segmentation. Image enhancement is performed to filter out the noises in the image and intensify the features of the image while image segmentation was performed to remove any irrelevant and unwanted parts. After that, the images were further analyzed by extracting the features, selecting the good features and classify the features selected. Feature extraction was performed using Gray-Level Co-Occurrence Matrix (GLCM) to measure the pixel of the image. Then, extracted features were selected so the dimensional of the image can be reduced to only a subset of image. Next, feature classification by using Neural Network took place where it can visualize, simulate and classify the output images that have been processed. Finally, CAD system was developed.

![Figure 1. Block diagram of CAD system for DR.](image-url)
2.1 Data Acquisition
In this study, the data were taken from the public database called Structured Analysis of the Retina (STARE). Images of retina are taken by a device called fundus camera. RFI is the name given to these images. This camera takes images of the internal surface of retina, posterior pole, macula, optic disc, and blood vessels. Figure 2 shows the example of the rgb images taken from STARE database.

![Figure 2. Example of Retinal fundus images (RFI).](image)

In RFI related to DR, most important feature that need to be focused on is the blood vessel from the eyeball as DR will cause the blood vessel to be grown on the back of the eye where the blood vessel is very weak and it might burst and bleed out on the other part of the eye. So as the blood vessel from the image come out as more black (lower intensity pixel value) than the surrounding eyeball, an image processing procedure is needed for better determination of the blood vessel. For this study, 40 images of normal eye and 40 images of DR eye were used.

2.2 Image Enhancement and Segmentation
Image enhancement is usually the first significant step for an image processing in order to create a good quality of imaging. Firstly, the rgb image was converted into grayscale image as the blood vessel in the grayscale image is darker than the other part. After that, the image is filtered with median filter of 3x3 neighborhood in order to clear up all the noises in the images as the median filter uses to make the edge of each pixel 0’s to clear up any blurring part in the image. In this study, few different filters were initially tested, but median filter was chosen in the end because it is the most effective than other filters with highest value of Peak Signal to Noise Ratio (PSNR) and lowest value of Mean Squared Error (MSE). Next, the image was darkened to make it more obvious. Subsequently, the image was complemented in order to inverse the image to make the blacker colored blood vessel to become white. Afterwards, in order to have a distinct of an image where the black and white are more intensified, the adjustment have been made to have the input contrast limit to become low and the output contrast limit to become high to make the image have larger difference. Thus, adaptive histogram equalization was used to focus on the part that wanted where it enhanced the contract of every tile to make the blood vessel more obvious.

Next, image segmentation was performed to the output image of adaptive histogram equalization step. In this part, the techniques that were taken into consideration were based on morphological processing where only the important regions were retrieved and selected out for the imaging process. A structuring element was used to sort and select the regions, thus removing those that were not needed. The structuring element always used with morphological open which is the function to remove the structure element that was selected before the function where it can remove the shape that was unwanted.

2.3 Feature Extraction, Selection and Classification
The feature extraction was performed using the Gray-Level Co-Occurrence Matrix (GLCM). GLCM is a texture filter where it can extract the pixel on the image and give out as a statistical data view for the user. In this study, there were four features of GLCM used such as Contrast, Correlation, Homogeneity and Energy. Contrast includes the calculation of the intensity contrast that relate to its nearest pixel it has for the whole image. Correlation is the calculation of the correlation in the image
with the neighboring pixels and relationship between the gray levels and the pixels. Energy on the other hand gives the total number of the square element in the GLCM properties. Lastly, homogeneity is the value that count the distribution of the pixel in one image to measure the elements of the GLCM.

Feature selection was performed using the Statistical Package for the Social Sciences (SPSS). For this study, one-way ANOVA was used. One-way ANOVA is one-way analysis of variance where it is one of the techniques that is used in comparing two or more groups of data or samples. The data that this project looking for is the p-values of the both set of normal eyes and DR eyes where the normal eyes result was stated as “1” and the DR eyes was set to “2”. The result in numbering that is closer to the “1” was set to be normal eyes and vice versa. P-value is the probability value that was needed to proof the data is sufficiently inconsistent to make sure that the data would not happen repetitively. When the p-value is less than 0.05%, it can be proven that the group of data were significantly different.

Feature classification is the process where the image is to be identified with various situations and whether the retina is contagious with the diabetic retinopathy disease. The supervised algorithm of Artificial Neural Network (ANN) was used where this ANN works with arrangement of simple and complex cell where these cells are arranged together to each layer to make sure the probability of an object is confirmed by each cell decision. Each layer is decided by the feature that has been selected through one-way ANOVA analysis previously so that the system would better distinguish between normal and diabetic retinopathy eyes. In this step, 80 images were used as training of ANN (40 images for each group of normal and DR), while 50 images were used as testing of ANN (25 images for each group of normal and DR).

2.4 Graphical User Interface (GUI) Development

The Graphic User Interface Development Environment (GUIDE) in the MATLAB system provides the controls and designing option for the user to enhance the coding performed in the MATLAB. The development of Graphic User Interface (GUI) may help users to perform the analysis faster.

3. Result and Discussion

This section includes the result of the image processing steps taken in order to observe the blood vessel of the eye.

3.1 Result of Image Processing

Figure 3 shows the result after the RGB image with DR was converted into grayscale and filtered using median filter. Based on the result, the blood vessel inside the retina can be seen where the pixels were darker rather than the other part. Figure 4 shows the result after the segmentation step using the morphological process. Based on the result, we can say that the output image can highlight the blood vessel better. While in Figure 5, the red circle shows that the patient suffers from diabetic retinopathy where the consecutively black dots shown that the blood vessel burst and spreading around the back of the eyes and this was the cause of vision impairments in DR patient.
3.2 Result of Feature Extraction

Figure 6 shows the mean result of the GLCM for each Contrast, Correlation, Energy and Homogeneity for both normal eye and DR eye. As can be seen in the Figure, Contrast has shown a distinguished result between normal and DR eye, followed by Energy, and Homogeneity. Correlation only shows slightest difference between the normal and DR eye.

![Figure 6. Result of GLCM for both normal eye and DR eye.](image)

3.3 Result of Feature Selection

Based on the statistical analysis using one-way ANOVA, two groups between normal eyes and diabetic retinopathy eyes were being compared and analyzed. According to the result, the p-value of only contrast and energy is 0.000 where it is <0.05 thus both of contrast and energy were used for the classification step using ANN. Homogeneity and Correlation features were excluded to be used for classification purposes.

3.4 Result of GUI Development

Figure 7 shows the complete GUI design for detection of DR that is easy to be used by any medical personnel. The read and process image button can be clicked by user to choose the image that the user wanted to be processed and the system will auto train the system and show the diagnosis result in the panel. If the value was less than 1.5, the image was diagnosed as normal eyes, while if the value was more than 1.5, the image was diagnosed as diabetic retinopathy eyes.

![Figure 7. Complete GUI design for detection of diabetic retinopathy.](image)

The accuracy of the system was further tested by using 50 images (25 images of normal eye and 25 images of DR eye). Table 1 shows the result of the accuracy testing. Out of 25 DR eye images, 22 of them were successfully tested as DR eye (true positive (TP)) while another 3 was wrongly tested as
normal eye (false negative (FN)). Based on 25 normal eye images, 20 of them were detected as normal (true negative (TN)), while 5 of them were falsely detected as DR eye (false positive (FP)). The sensitivity value of the system was calculated 88%, the specificity value of the system was 80%, and the accuracy value of the system was 84%.

### Table 1. The result of accuracy testing.

| Tested  | Actual DR eye | Normal eye |
|---------|---------------|------------|
| DR eye  | 22            | 5          |
| Normal eye | 3           | 20         |

4. **Conclusion**

As a brief conclusion, image processing steps including enhancement and segmentation have been successfully implemented, where the output images enable good features to be extracted from the images. The burst out of the blood vessel was clearly pointed out from the multiple image processing stages. With the aid of the GUI system, this system was able to be used at ease for users with quite decent accuracy. As recommendations, this developed system can be improved by collecting the image data personally with collaboration of hospital as the image intensity differs with each machine. With the image consistently produced, the feature can be easily extracted, and the neural network can perform better, thus higher accuracy of the system may be achieved.

**Acknowledgments**

The authors would like to thank the sponsor for this study. This study was funded by grant TIER 1 H223.

**References**

[1] Tarr J M, Kaul K, Chopra M, Kohner E M and Chibber R 2013 ISRN Ophthalmol. 1-13
[2] Amin J, Sharif M and Yasin M 2016 Hindawi Publishing Corporation Scientifica 1-20
[3] Kayal D and Banerjee S 2014 Proc. of the 1st Int. Conf. on Sig. Processing & Int. Networks 141–44
[4] Kertes P J and Johnson T M 2007 Lippincott Williams & Wilkins
[5] Meriaudeau F, Sidibé D, Adal K, Ali S, Giancardo L, Karnowski T P and Chaum E 2013 11th Int. Conf. on Quality Control by Artificial Vision 241-47
[6] Trucco E1, Ruggeri A, Karnowski T, Giancardo L, Chaum E, Hubschman JP, Al-Diri B, Cheung CY, Wong D, Abràmoff M, Lim G, Kumar D, Burlina P, Bressler NM, Jelinek HF, Meriaudeau F, Quellec G, Macgillivray T, Dhillon B 2013 Investigative Ophthalmology & Visual Science
[7] Chua K, Lim C M, Ng E Y K and Laude A 2013 Comp. in Biol. and Med. 43 12 2136–55
[8] Usher D, Dumskjy M, Himaga M, Williamson T H, Nussey S and Boyce J 2004 Diabetic Med. 21 1 84–90
[9] Aptel F, Denis P, Rouberol F and Thivolet C 2008 Diabetes & Metabolism 34 3 290-93
[10] Quellec G, Russell S R and Abramoff M D 2011 IEEE Trans on Medical Imaging 30 2 523–33
[11] Agurto C, Murray V, Yu H, Wigdahl J, Pattichis M, Nemeth S, Barriga E S and Soliz P 2014 IEEE Journal of Biomedical and Health Informatics 18 4 1328–36
[12] Aqeel A F and Ganesan S 2014 Proc. of IEEE Int. Conf. on Electro/Information Technology 206–15
[13] Rokade P M and Manza R R 2015 Int. J of App. or Innov in Eng. & Mgmt 4 5 402–10