Automatic Classification of Diabetic Retinopathy Stages

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November 7, 2019

Abstract

Diabetes Mellitus is one of the worlds most famous and dominant diseases that strike many people at a very early stage in life. This disease later on leads to another completely unforeseen chronic eye disease called Diabetic Retinopathy (DR). Diabetic Retinopathy is a retinal disease that usually leads to or can progress to irreversible vision loss (blindness). The main purpose of this research is the early detection of this very critical and perilous condition to try and avoid any serious complications in the future. Our system proposes reading a wide variety of retinal fundus images and deciding whether a person suers from Diabetic Retinopathy or not; If it appears that a person suers from (DR) the system then classies the level or stage of the Diabetic Retinopathy.

1 Introduction

1.1 Background

According to the world health organization(WHO)[1] around 422 million people worldwide have been diagnosed with Diabetes Mellitus, particularly in low-and middle-income countries, and these numbers are only expected to increase with time. And according to Lee's et al. [11] studies, one third of people suffering from Diabetes Mellitus are expected to also be diagnosed with eye diseases such as Diabetic Retinopathy, which means that around 147 million people are vulnerable. The relationship between Diabetes and retinal complications has been first discovered and introduced in 1856, but it was not until the second half of the 20th century that this work provided more evidence that suggested that Retinopathy really was a complication of diabetes. Diabetic Retinopathy is a disease that causes retina abnormality and in severe conditions can lead to total blindness. In this study we propose a classification method that reads an5d extracts features from retinal images and decides whether a person suffers from Diabetic Retinopathy (DR) or not, and what level or stage is he/she currently in. This study also focuses on detecting and recognizing the features and characteristics of (DR) for optimal accuracy during the classification method.

1.2 Motivation

More than 39 million people in the MENA region (Middle East and North Africa) suffer from Diabetes Mellitus as shown below in figure 1, and it is expected that by 2045 this number will rise to 67 million. What really encouraged and motivated us to pursue this specific topic is that out of this humongous number, 8.2 million cases were in Egypt in 2017 according to "International Diabetes Federation"[2] as shown below in figure 2. Which means that third of this number is usually bound to suffer from (DR). After researching the market we discovered that early stages of Diabetic Retinopathy and other eye diseases were not detected accurately manually, we also discovered two main drawbacks that were huge factors in accurately detecting (DR); The datasets used in the process were very small, which unsurprisingly led to the second drawback which is low recognition and classification rates. So based on this critical information we aim to elucidate a more effective means of classifying early stages of Diabetic Retinopathy for potential clinical benefits.

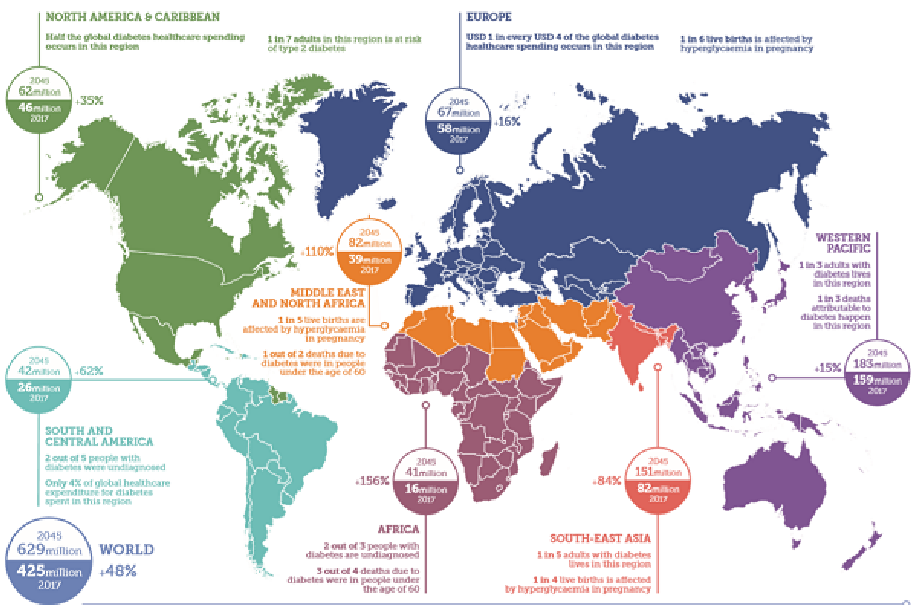

Figure 1: Diabetes Mellitus Rates World Wide .

Country summary table: estimates 2017

Country/territory	IDF Region	Adults with diabetes (20-79) in 1,000s	Diabetes age-adjusted (20-79) comparative prevalence (%)	Adults with Undiagnosed diabetes (20-79) in 1,000s	Mean diabetes-related expenditure per person (20-79) with diabetes (R=2, USD)	Diabetes related deaths (20-79 years)
Egypt	MENA	8,222.6	17.3%	4367.0	268.4	71,293

Figure 2: Country Summary Table: Estimates 2017 .

1.3 Problem Definitions

Our main goal in this research is early detection. Our aim is to be able to detect the early stages of Diabetic Retinopathy from retinal images before it evolves and leads to total blindness. We Chose The Deep Learning approach in order to use CNN (Convolutional Neural Network) and be able to work on huge datasets , along with the Tensor-flow library which makes the feature selection and extraction process easier. The System will take retinal images as Input, however some kind of data Pre-processing may be required, The System will then extract many different features from the image and classify each image into the appropriate class, Finally the output would tell us whether a person suffer from (DR) or not and the level of the disease in his body on a 4-stages scale. During this project we will mainly focus on three main aspects; Increasing the dataset number in order to be able to accurately detect and classify all the cases, Increasing the overall system recognition rate, and most importantly creating our very own architecture or model that would work perfectly on most datasets/inputs. This contribution will be extremely useful for future prognosis.

2 Project Description

Our System will detect the early stages of Diabetic Retinopathy in the body of a diabetic patient, and then classify the level of the disease in his/her body on a scale of 4 stages. Since we will work on a big number of dataset, and GPU (Graphics Processing Unit) has become an integral part in executing any Deep Learning algorithm, the System would preferably work on a super computer or machine to enhance the speed of computation and recognition.

2.1 Objective

Our Objective is to be able to develop our very own architecture or model that would work efficiently on most datasets/inputs, and using this architecture we would then be able to detect the early stages of Diabetic Retinopathy and classify the level of the disease in the patient's body on a scale of 4 stages. We also aim on using huge datasets for more accurate and precise recognition and classification, leading to increasing the overall system accuracy and recognition rate.

2.2 Scope

1- The System will be able to detect the presence of Diabetic Retinopathy.

2- The System will Classify the level of the (DR) disease on a scale of 4 stages, and produce the output to the patient, revealing whether or not he/she needs serious medical attention.

3- The System Works Using a Deep Learning approach, which greatly assists using big datasets.

4- The System will start applying different filters and convolutions on the input images.

5- The System is divided on Three main stages: First some Pre-processing on the retinal images will be required, Second is Detection and Classification of the input image, and finally the Output result to the patient.

2.3 Project Overview

- System Overview

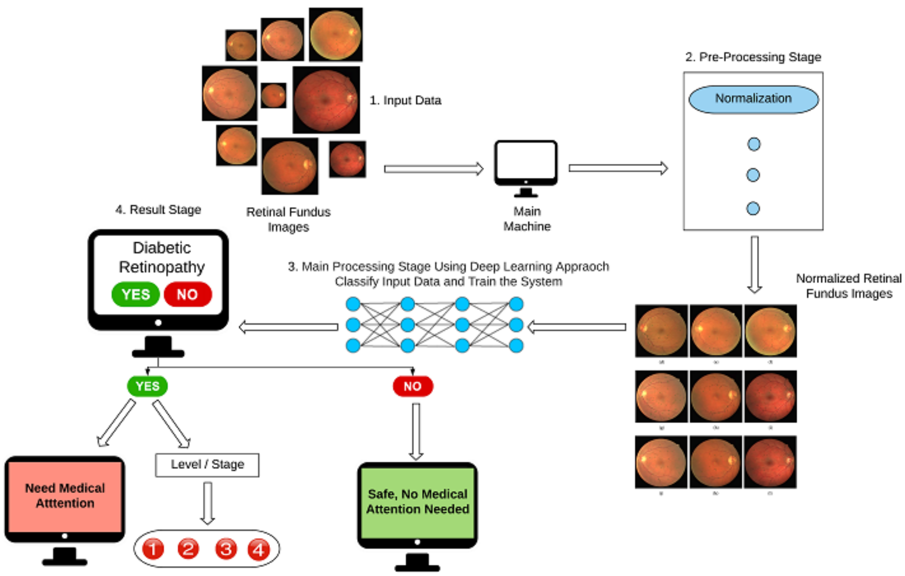

Figure 3: System Overview

- First, The Main Computer/Machine will collect the information from the Input Images, which are unnormalized Retinal Fundus Images with different sizes chosen from our dataset. The System will then apply some data pre-processing algorithms such as Normalization so that all the images are the same size and dimension. This will thoroughly help us in the main processing phase by simply reducing the complexity of the Input images. Then comes the Main Processing stage in which we test and train our system, We use a Convolutional Neural Network in which a group of connected nodes distributed on multiple layers enhance and strengthen each other along with the Tensor-flow library for feature extraction and classification of the Input images. The System will then proceed to the final stage, which is the Result stage; If the result turned out to be (YES), the System will show the Level/Stage of the disease on a scale of 4-stages, and finally propose that the patient needs medical attention right away. Else (NO) the System will propose that there is no need for medical attention.

2.3.1 Dataset

1- The Dataset we will start with in our project is called MESSIDOR[13]. MESSIDOR is composed of 546 images from DR level 0 (normal), 153 images form DR level 1 (mild), 247 images from DR level 2 (moderate), 254 images from DR level 3 (severe).

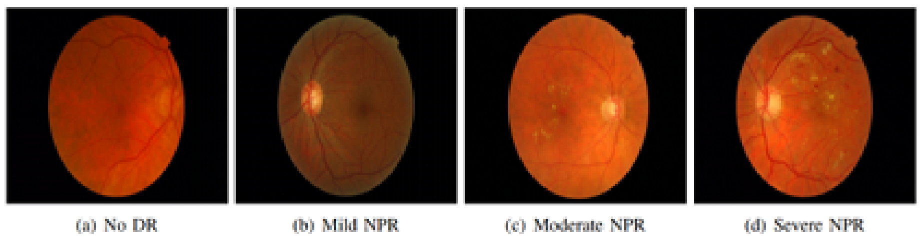

Figure 4: MESSIDOR Dataset

2 - The Dataset we intend to use in our project is called EyePacs Dataset [?]. The images are labeled in five stages: Normal (0), Mild (1), Moderate (2), Severe (3) and Proliferative DR (4) according to the severity of illness. In total, there are 88,702 images of left and right eyes.

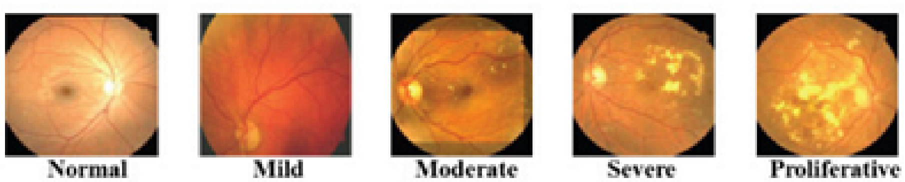

Figure 5: EyePacs Dataset

2.3.2 Input

- Our Input for the system will be through a Computer Interface/ Machine that takes the dataset unnormalized Retinal Fundus Images with different sizes.

2.3.3 Pre-Processing

- After the Images have been successfully read by the system, Pre-processing will be applied on them before proceeding to the main processing stage. The Images will be Normalized so that they all have the same dimensions.

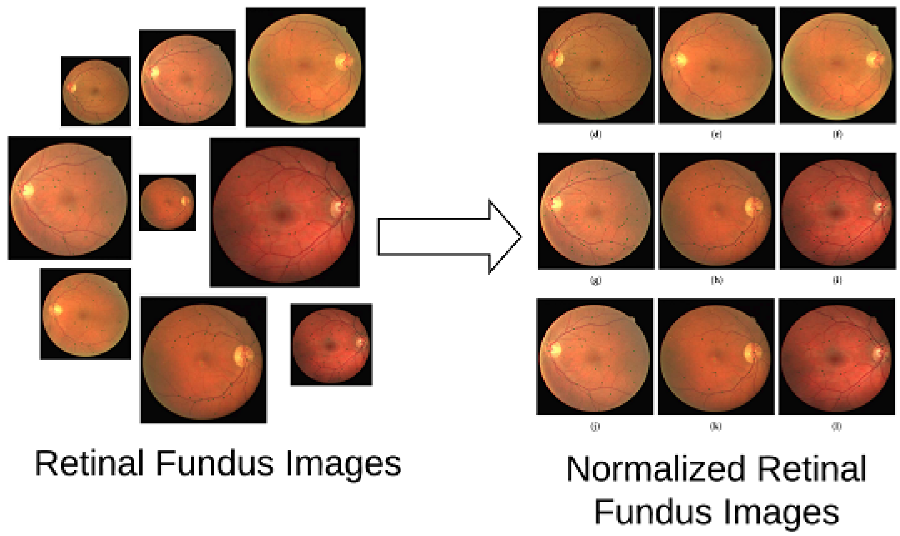

Figure 6: Dataset 2
a) Unnormalized input images with different sizes.
b) Normalized input images with same dimensions.

2.3.4 Main Processing

- After Data Pre-processing stage is completed, the system will then start the main processing phase, which involves using a Convolutional Neural Network (CNN) to train and test the system, along with the Tensor-flow library for feature extraction and classification into different levels and classes.

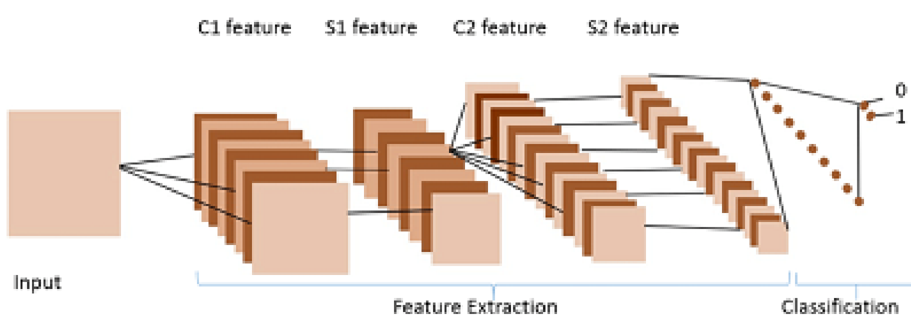

Figure 7: CNN Model

2.3.5 Output

- The Final Output of the System is divided into two scenarios:
A- There IS Diabetic Retinopathy (YES) - The System shows the level/stage of the disease on a scale of 4-stages, and signals the need for immediate medical attention.
B- No Diabetic Retinopathy (NO) - The System signals that the case is safe, and doesn't need any medical attention.

3 Similar System Information

Afrin et al. [3] proposed a robust system which detects retinal from retinal images and classifies the 5 stages of DR automatically. At first, blood vessels, Microaneurysms and exudates are detected by using image processing techniques. Next, blood vessels area, Microaneurysms count, exudates area, contrast and homogeneity are measured from the processed images as the retinal features. Then These features are fed to knowledge based fuzzy classifier for classifying normal, mild, moderate and severe NPDR. Dataset consisted of 400 retinal fundus images are collected from STARE, DIARETDB0 and DIARETDB1 databases and the images are classified with accuracy 95.63 % .

Carrera et al. [4] proposed a computer-assisted diagnosis based on the digital processing of the retinal images to classify the non-proliferative Diabetic Retinopathy grades of any image by using SVM and Decision Tree classifier . The system was tested on 400 retinal images which obtained 85% as an average accuracy of the classifier. This paper can help us in extracting more features mentioned in their future work to improve the system's accuracy and sensibility.

Carson et al.[5] demonstrated the use of convolutional neural networks (CNNs) on fundus images. They additionally explored multinomial classication models,they used EyePacs dataset of 88,702 images with 5-class labels (normal, mild, moderate, severe, end stage) and Messidor dataset of 1,200 color fundus images with 4-class labels (normal, mild, moderate, severe).the accuracy of tested models was between 57.2% and 74.5%.

Herliana et al.[6] applied particle swarm optimization (PSO) method to select the feature of Diabetic Retinopathy based on 1151 images . Then classified using classification method of neural network. the results by applying neural network based particle swarm optimization (PSO) is 76.11 % . also shown that there is an increase in classification 78.21 % by only applying neural network method.

Jain et al. [7] proposed an automated detection of Diabetic Retinopathy and evaluate the severity. Using of Convolutional Neural Network (CNN) Architectures on images from EyePacs dataset also using CNN for the classification of DR images after being subjected to many image processing techniques ,they classified into 5 classes using different models but the highest accuracy was 76.9 % .

Junjun et al. [8], they proposed automatic Diabetic Retinopathy (DR) detection method using deep convolutional neural networks (DCNNs). To identify the region of interests(ROIs), based on deep convolutional neural networks, which are trained only with image-level labels on a large scale DR dataset which is divided into 4 classes, not clear whether they added staging or not In experiments, around 30000 color retinal images were used to train the proposed model and around 5000 images are collected to evaluate its classication performance. The results show that accuracy is 78.4 %.

Kaur et al. [9] proposed an algorithm that will segment the retinal blood vessels with an accuracy of 96.17 %. This algorithm will extract the features from input images which was very small number of image 48 images only . They created only two stages and used for classification Naive Bayes Classifier.

Khan et al.[10] has implemented an automated tools by using CNN approach for the classification of DR images, also used pre-trained CNN models i.e. AlexNet, VGG-16 and SqueezeNet to detect Diabetic Retinopathy using images, the classification result accuracy between 91.82 % and 94.49 % on Messidor dataset . Also, they proposed a customized 5 layered CNN model that consists of 2 convolution layers and 3 fully connected neural layers, which shown promising result of sensitivity, specificity and accuracy with numbers between 97.87 % and 98.94 %.

Maya et al. [12] detect and classify the severity of DR. first is extraction Pre-process, by performing Green channel extraction, Blood vessel extraction and Optic Disc (OD)removal. Then Recognition of Diabetic features using recursive region growing segmentation (RRGS) algorithm at the end the extracted features are fed to CNN for classification purpose to classify into 5 classes. This method reducing the workload of an ophthalmologist with an accuracy of around 98 % on Messidor dataset but its disadvantage the consumption of time more than the other systems.

Sangwan et al. [14] proposed a system's main target is to study and extract features from fundus images given as an input and be able to segregate between Diabetic Retinopathy illness stages and a normal eye image. The main problem was to find the most suitable features to use in classification which might offer the highest accuracy. However, Area of on pixels, mean and area of exudates were the three features extracted and fed into the neural network along with applying SVM training. This resulted in getting an accuracy rate of 92.6 % when applied on 150 images as a dataset. This paper could be useful if using same features along with a simpler classifier to be able to increase the size of the dataset and get better results.

Suriyal et al. [15] focused on detection aspects of a mobile application. The application was powered by a tensor-flow deep neural network architecture that was trained and tested on 16,798 fundus images from Kaggle. These images are pre-processed to remove noise .After pre-processing the input dataset is fed into the neural network. The convolutional neural network model used in this project was MobileNets, neural network has 28 convolutional layers and after each layer there was batchnorm and ReLU nonlinear function except at the final layer. The output from last layer result either DR or no DR. The final accuracy of the model is 73.3 %.

3.1 Similar System Description

- The Similar System is called "Automated Detection of Diabetic Retinopathy using Deep Learning", The project's main goal and purpose is to implement an automatic DR grading system capable of classifying retinal fundus images, using pre-trained CNN models i.e. AlexNet and Inception (GoogleNet). The System performs a data Pre-Processing stage, such as input images normalization and uses both the CNN and the N-ary tree classifying algorithms. The System uses two datasets for training, the Messidor and EyePacs datasets and has 4 stages. However, The System has very low accuracy levels, which will be solved in our project.

3.2 Comparison with Proposed Project

Criteria	Classification Classes	Dataset Source	No. of Images used	Classifier	Accuracy
Afrin et al. [3]	5	STARE, DIARETDB0 and DIARETDB1	400	Fuzzy Classifier	95.63%
Carrera et al. [4]	5	Messidor Dataset	400	SVM	85%
Carson et al.[5]	5	EyePacs Dataset, Messidor Dataset	89,902	CNN, N-ary Tree	74.50%
Herliana et al.[6]	2	Diabetic Retinopathy Debrecen dataset	1,151	NN, SVM	76.11%
Jain et al. [7]	5	Kaggle Dataset	35,126	CNN	76.90%
Junjun et al. [8]	5	Kaggle Dataset	35,126	DCNN	78.40%
Kaur et al. [9]	2	Not Mentioned	48	Naïve Bayes Classifier	96.17%
Khan et al.[10]	Not Mentioned	Messidor Dataset	1,200	5 layered CNN	98.15%
Maya et al. [12]	5	Messidor Dataset	1,200	CNN	Not Mentioned
Sangwan et al. [13]	5	Two hospitals in Delhi	96	SVM	92.60%
Suriyal et al. [14]	2	Kaggle Dataset	16,798	DCNN	73.30%
Our proposed System	**5**	**EyePacs Dataset, Messidor Dataset**	**89,902**	**CNN**	**-**

Figure 8: Comparison Table

3.3 Screen Shots from previous systems

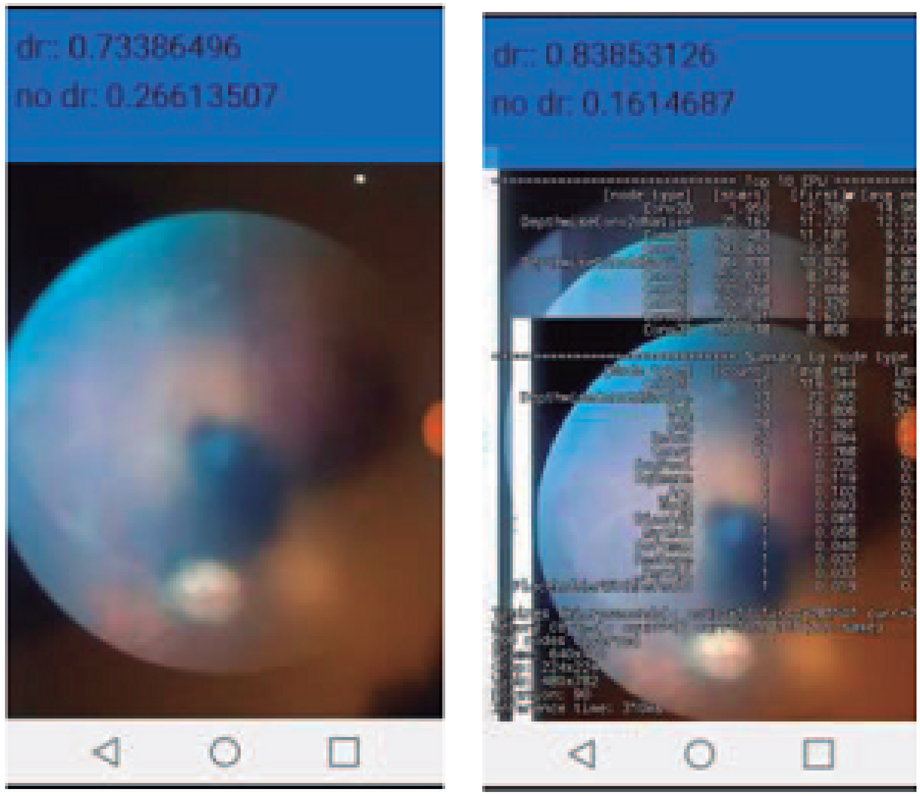

Figure 9: Mobile Screenshots

- The Output Screen for Mobile Assisted (DR) Detection, the final result is the percentage of of (DR) and (No-DR) for the case.

4 Project Management and Deliverables

4.1 Tasks and Time Plan

Task	Date	Deadline
Proposal Ideas	1 July 2019	15 July 2019
Announce Proposal For Students	16 July 2019	22 July 2019
Proposal Evaluation	First Week Of October	-
Submit Contribution Paper	First Semester	-
SRS Evaluation	Second Week Of December	-
4SDD Evaluation	Third Week Of February 2020	-
Prototype Evaluation	3 Days After Midterm Exam	-
Deliver Contribution Paper	Second Semester	-
Technical Evaluation	First Week Of May 2020	-
Final Thesis	Last 10 Days in June 2020	-
Ceremony	24 June 2020	-

4.2 Budget and Resource Costs

(No Enough Data to Complete in the Meantime).

4.3 Supportive Documents

Re: Diabetic Retinopathy project

DH

Dina Hossam <drdhossam@yahoo.com>

10/2/2019 9:45 PM

To: Mohamed Mohamed Alaa Eldine Hanafi Mohamed

Dear Mohamed

It is my pleasure supervising your valuable project and i am willing to provide you with any information needed about Diabetic Retinopathy, which is considered one of the most prevalent preventable eye diseases in Egypt and the middle east. The success of setting a comprehensive screening and management program for Diabetic Retinopathy in Egypt will definitely have an extremely positive impact on the rates of blindness among the Egyptian population.

Good luck in your project and best wishes.

Dr. Dina Hossam Hassanein, MD, FRCS
Assistant Professor of Ophthalmology
Cairo University

Figure 10: Dr. Dina's reply on our request to be our medical supervisor

5 References

References

[1] "Diabetes." [Online]. Available: http://www.who.int/health-topics/diabetes

[2] "Diabetes facts and figures," 2017. [Online]. Available: https://idf.org/aboutdiabetes/what-is-diabetes/facts-figures.html

[3] R. Afrin and P. C. Shill, "Automatic lesions detection and classification of diabetic retinopathy using fuzzy logic," in *2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST).* IEEE, 2019, pp. 527–532.

[4] E. V. Carrera, A. González, and R. Carrera, "Automated detection of diabetic retinopathy using svm," in *2017 IEEE XXIV International Conference on Electronics, Electrical Engineering and Computing (INTERCON).* IEEE, 2017, pp. 1–4.

[5] D. Y. Carson Lam, M. Guo, and T. Lindsey, "Automated detection of diabetic retinopathy using deep learning," *AMIA Summits on Translational Science Proceedings*, vol. 2018, p. 147, 2018.

[6] A. Herliana, T. Arifin, S. Susanti, and A. B. Hikmah, "Feature selection of diabetic retinopathy disease using particle swarm optimization and neural network," in *2018 6th International Conference on Cyber and IT Service Management (CITSM).* IEEE, 2018, pp. 1–4.

[7] A. Jain, A. Jalui, J. Jasani, Y. Lahoti, and R. Karani, "Deep learning for detection and severity classification of diabetic retinopathy," in *2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT).* IEEE, 2019, pp. 1–6.

[8] P. Junjun, Y. Zhifan, S. Dong, and Q. Hong, "Diabetic retinopathy detection based on deep convolutional neural networks for localization of discriminative regions," in *2018 International Conference on Virtual Reality and Visualization (ICVRV).* IEEE, 2018, pp. 46–52.

[9] S. Kaur and K. S. Mann, "Optimized technique for detection of diabetic retinopathy using segmented retinal blood vessels," in *2019 International Conference on Automation, Computational and Technology Management (ICACTM).* IEEE, 2019, pp. 79–83.

[10] S. H. Khan, Z. Abbas, S. D. Rizvi *et al.*, "Classification of diabetic retinopathy images based on customised cnn architecture," in *2019 Amity International Conference on Artificial Intelligence (AICAI).* IEEE, 2019, pp. 244–248.

[11] R. Lee, T. Y. Wong, and C. Sabanayagam, "Epidemiology of diabetic retinopathy, diabetic macular edema and related vision loss," *Eye and vision*, vol. 2, no. 1, p. 17, 2015.

[12] K. Maya and K. Adarsh, "Detection of retinal lesions based on deep learning for diabetic retinopathy," in *2019 Fifth International Conference on Electrical Energy Systems (ICEES)*. IEEE, 2019, pp. 1–5.

[13] G. PATRY, G. GAUTHIER, B. LAY, J. ROGER, D. ELIE, A. DONJON, and H. MAFFRE, "Messidor." [Online]. Available: http://www.adcis.net/en/third-party/messidor/

[14] S. Sangwan, V. Sharma, and M. Kakkar, "Identification of different stages of diabetic retinopathy," in *2015 International Conference on Computer and Computational Sciences (ICCCS)*. IEEE, 2015, pp. 232–237.

[15] S. Suriyal, C. Druzgalski, and K. Gautam, "Mobile assisted diabetic retinopathy detection using deep neural network," in *2018 Global Medical Engineering Physics Exchanges/Pan American Health Care Exchanges (GMEPE/PAHCE)*. IEEE, 2018, pp. 1–4.