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A Deep Learning Based Architecture to Diagnose Diabetes Using Retinal Images

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ABSTRACT

Diabetes is one of the leading fatal diseases globally, putting a huge burden on the global healthcare system. Early diagnosis of diabetes is hence, of utmost importance and could save many lives. However, current techniques to determine whether a person has diabetes or has the risk of developing diabetes are primarily reliant upon clinical biomarkers. In this article, we propose a novel deep learning architecture to predict if a person has diabetes or not from a photograph of his/her retina. Using a relatively small-sized dataset, we develop a multi-stage convolutional neural network (CNN)-based model DiaNet that can reach an accuracy level of over 84% on this task, and in doing so, successfully identifies the regions on the retina images that contribute to its decision-making process, as corroborated by the medical experts in the field. This is the first study that highlights the distinguishing capability of the retinal images for diabetes patients in the Qatari population to the best of our knowledge. Comparing the performance of DiaNet against the existing clinical data-based machine learning models, we conclude that the retinal images contain sufficient information to distinguish the Qatari diabetes cohort from the control group. In addition, our study reveals that retinal images may contain prognosis markers for diabetes and other comorbidities like hypertension and ischemic heart disease. The results led us to believe that the inclusion of retinal images into the clinical setup for the diagnosis of diabetes is warranted in the near future.

INDEX TERMS: Convolutional neural network, deep learning, diabetes, machine learning, Qatar, Qatar Bio bank (QBB), retina.

INTRODUCTION

Diabetes mellitus or diabetes is considered as a collection of metabolic conditions that can predominantly be described by hyperglycemia rising from the deficiency in insulin discharge [1]. The prolonged hyperglycemia of diabetes is correlated with long-term impairment and collapse of heart, kidneys, and micro vascular circulation of the retina [2]. Among the diabetic individuals in the USA, almost 30% of them have the tendency of growing diabetic retinopathy (DR), a common complication for diabetic patients which may lead to blindness.

Diabetes may adversely affect the vascular system of the retina causing structural change of it [2]. As the changes in vascular structure in retina can provide visual cues for diabetes, most of the clinical guidelines recommended annual retinal screen for the diabetic patients through retinal fundus images or dilated eye examinations.

Alternatively, these retinal images could be used to detect diabetes as well, but it requires subjective judgment from the ophthalmologist, and it might be time consuming as well. The human oriented subjective judgment could be avoided if we could implement the automation of retinal image-based diabetes diagnosis in clinical setup. Such automation could alleviate the workload of the ophthalmologist as well as screen a large number of patients objectively within a short amount of time [7].

LITERATURE SURVEY

[1] D. Mellitus, ‘‘Diagnosis and classification of diabetes mellitus,’’ Diabetes Care, vol. 37, no. 1, pp. S81–S90, 2014. [Online]. Available: https://care. diabetesjournals.org/content/37/Supplement_1/S81

Diabetes is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction, and failure of different organs, especially the eyes, kidneys, nerves, heart, and blood vessels. Several pathogenic processes are involved in the development of diabetes.

These range from autoimmune destruction of the -cells of the pancreas with consequent insulin deficiency to abnormalities that result in resistance to insulin action. The basis of the abnormalities in carbohydrate, fat, and protein metabolism in diabetes is deficient action of insulin on target tissues.

Deficient insulin action results from inadequate insulin secretion and/or diminished tissue responses to insulin at one or more points in the complex pathways of hormone action. Impairment of insulin secretion and defects in insulin action frequently coexist in the same patient, and it is often unclear which abnormality, if either alone, is the primary cause of the hyperglycemia.

Symptoms of marked hyperglycemia include polyuria, polydipsia, weight loss, sometimes with polyphagia, and blurred vision. Impairment of growth and susceptibility to certain infections may also accompany chronic hyperglycemia. Acute, life-threatening consequences of uncontrolled diabetes are hyperglycemia with ketoacidosis or the nonketotic hyperosmolar syndrome.

[2] E. S. Shin, C. M. Sorenson, and N. Sheibani, ‘‘Diabetes and retinal vascular dysfunction,’’ J. Ophthalmic Vis. Res., vol. 9, no. 3, pp. 362–373, Sep. 2014.

Diabetes predominantly affects the micro vascular circulation of the retina resulting in a range of structural changes unique to this tissue. These changes ultimately lead to altered permeability, hyper proliferation of endothelial cells and edema, and abnormal vascularization of the retina with resulting loss of vision. Enhanced production of inflammatory mediators and oxidative stress are primary insults with significant contribution to the pathogenesis of diabetic retinopathy (DR).

We have determined the identity of the retinal vascular cells affected by hyperglycemia, and have delineated the cell autonomous impact of high glucose on function of these cells. We discuss some of the high glucose specific changes in retinal vascular cells and their contribution to retinal vascular dysfunction. This knowledge provides novel insight into the molecular and cellular defects contributing to the development and progression of diabetic retinopathy, and will aid in the development of innovative, as well as target specific therapeutic approaches for prevention and treatment of DR.

[3] X. Zhang, J. B. Saaddine, C.-F. Chou, M. F. Cotch, Y. J. Cheng, L. S. Geiss, E. W. Gregg, A. L. Albright, B. E. K. Klein, and R. Klein, ‘‘Prevalence of diabetic retinopathy in the United States, 2005-2008,’’ JAMA, vol. 304, no. 6, pp. 649–656, Aug. 2010.

Diabetic Retinopathy Is The leading cause of new cases of legal blindness among adults aged 20 to 74 years in the United States.1 Vision loss due to diabetic retinopathy occurs through a variety of mechanisms, including retinal detachment, preretinal or vitreous hemorrhage, associated nonvascular glaucoma, and macular edema or capillary nonperfusion.2 The presence of diabetic retinopathy may indicate microcirculatory dysfunction in other organ systems.

Diabetes-related blindness is a personal catastrophe to the individual and costs the United States

approximately $500 million annually.5 However, risk of vision loss due to diabetic retinopathy can be reduced by effective control of serum glucose and blood pressure and by its early detection and timely treatment.

[4] J. Yau, S. Rogers, and R. Kawasaki, ''Global prevalence and major risk factors of diabetic retinopathy,'' Diabetes Care, vol. 35, no. 3, pp. 556–564, 2012.

Diabetic retinopathy (DR) is the leading cause of blindness among working aged adults around the world (1). Despite the significance of this problem, and the rising prevalence of diabetes notably in emerging Asian countries such as India and China (2,3), there are few precise contemporary estimates of the worldwide prevalence of DR, particularly severe vision-threatening stages of the disease, including proliferative DR (PDR) and diabetic macular edema (DME).

Previous individual studies have shown considerable variability in DR prevalence estimates among individuals with both diagnosed and undiagnosed diabetes, with rates ranging from 17.6% in a study in India (4) to 33.2% in a large U.S. study (5). Differences in study methodologies, population characteristics, and ascertainment and classification of DR have made direct comparisons between studies difficult.

Existing Method

There are many existing techniques used for diabetic retinopathy classification and found many limitations as well as complexity.

Machine learning is a branch of artificial intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy. IBM has a rich history with machine learning. One of its own, Arthur Samuel, is credited for coining the term, "machine learning" with his research (PDF, 481 KB) (link resides outside IBM) around the game of checkers. Robert Nealey, the self-proclaimed checkers master, played the game on an IBM 7094 computer in 1962, and he lost to the computer. Compared to what can be done today, this feat seems trivial, but it's considered a major milestone in the field of artificial intelligence.

Over the last couple of decades, the technological advances in storage and processing power have enabled some innovative products based on machine learning, such as Netflix's recommendation engine and self-driving cars. Machine learning is an important component of the growing field of data science. Through the use of statistical methods, algorithms are trained to make classifications or predictions, and to uncover key insights in data mining projects. These insights subsequently drive decision making within applications and businesses, ideally impacting key growth metrics. As big data continues to expand and grow, the market demand for data scientists will increase. They will be required to help identify the most relevant business questions and the data to answer them.

PROPOSED METHOD

In this section, we discuss in detail the process involved in the collection, curation, and pre-processing of the dataset as it pertains to this work and the development of our proposed solution for the problem at hand. Our proposed approach uses two datasets to achieve state-of-the-art in detecting diabetes from retinal images.

The larger of these datasets contains retinal images from patients with different stages of DR, while the other, smaller dataset, and contains retinal images from diabetic patients and a control group. We describe the smaller dataset first since it is more closely related to the goal of our work and is also one of the contributions of this paper.

This study was conducted under the regulation of the Ministry of Public Health, Qatar. All procedures were approved by the Institutional Review Board (IRB) of Hamad Medical Corporation, Qatar and only de-identified images were collected from QBB. The

dataset consists of retinal images from a diabetes cohort of size 246 and a control group of size 246.

The medical practitioners interviewed all the participants at QBB to collect their medical and family history, lifestyle, and their habitual factors. Then both the diabetes and the control groups were determined with the help of QBB medical practitioners and nurses.

RESULT

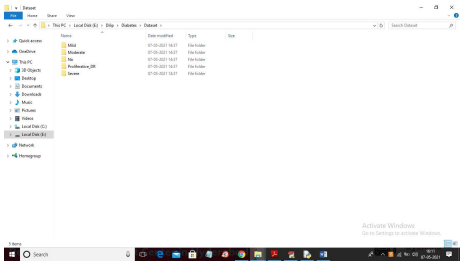
In this project we are detecting presents of diabetes and its stages and to implement this project we are using Convolution Neural Network (CNN) Algorithm). To train CNN we are using IDRID (Indian diabetes Retinopathy Diabetes) images which consists of 5 different types of diabetes disease images. Those 5 types of diseases are

Mild, Moderate, No (not presence of diabetes), Proliferative_DR and Severe

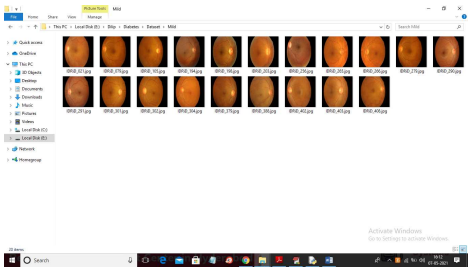
To implement this project we have designed following modules

1) Upload dataset: using this module we will upload diabetes dataset to application
2) Pre-process dataset: using this module we will read all images and then perform preprocessing such as resizing image, rotation and augmentation etc.
3) Train CNN: using this module we will apply CNN algorithm on diabetes dataset to build CNN model to predict disease
4) Upload Test Image & Predict Disease: using this module we will upload retina image and then CNN will predict presence of disease and its stage
5) Accuracy & Loss Graph: using this module we will plot CNN accuracy and loss graph. While training CNN we took 50 EPOCH/iterations and for each epoch we calculate CNN accuracy and loss.

Below screen shots showing dataset images

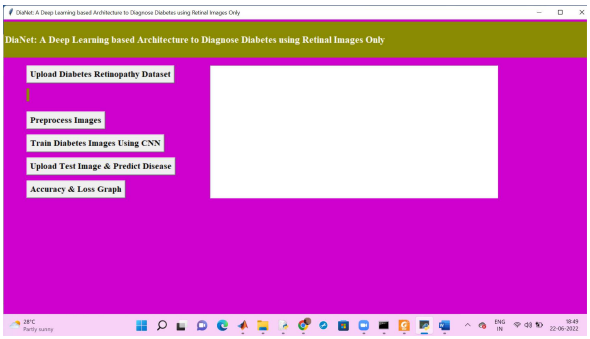


In above screen we have 5 folders and each folder contains retina diabetes disease image and you can go inside any folder to see that disease images. Below screen showing 'MILD' disease images

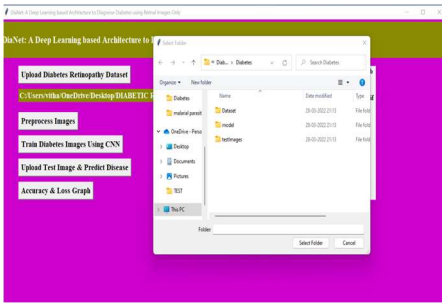


SCREEN SHOTS

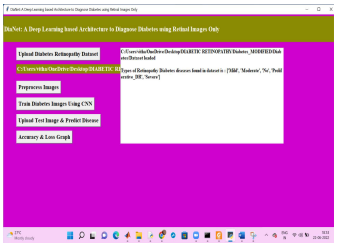
To run project double click on 'run.bat' file to get below screen



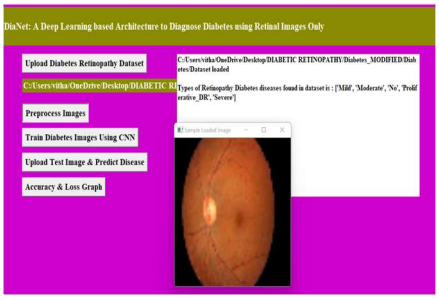
In above screen click on 'Upload Diabetes Retinopathy Dataset' button to upload dataset



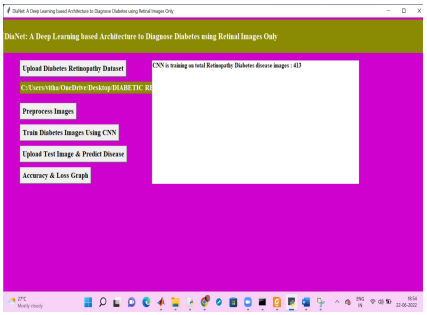
In above screen selecting and uploading 'Dataset' folder and then click on 'Select Folder' button to load dataset and to get below output



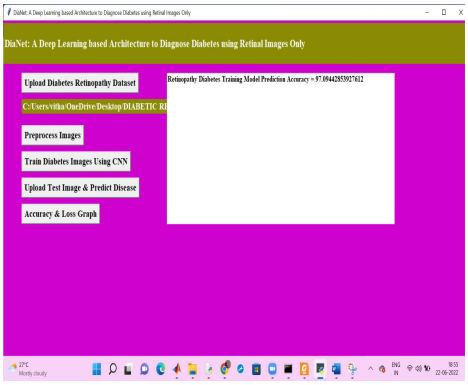
In above screen dataset loaded and in text area we can see names of different diabetes disease found in dataset and now click on 'Preprocess Images' button to read all images and then resize to CNN compatible size



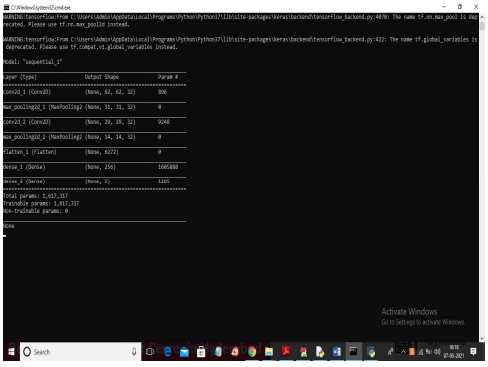
In above screen all images are resize to 64 X 64 and in above screen we can see one sample image from dataset and now close above image to get below screen



In above screen all images are processed and dataset contains total 413 image and now click on 'Train Diabetes Images Using CNN' button to train CNN on above dataset

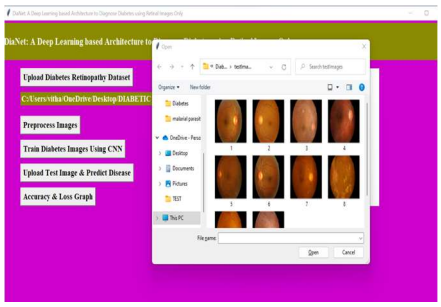


In above screen CNN model is generated and we got CNN accuracy on retina images as 97% and in below console we can see CNN layers and architecture details

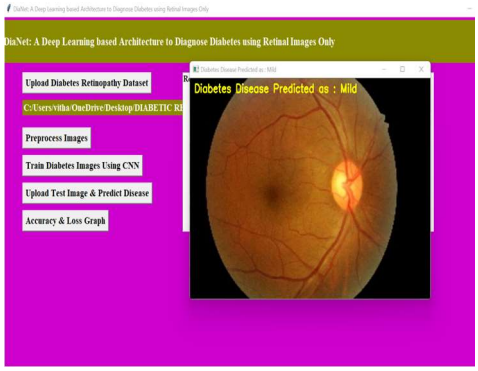


In above screen we build multi layers CNN model where first layer filter image using 62 X 62 image pixels and second layer filter with 31 X 31 and goes on. Now model is ready and now click on 'Upload

Test Image & Predict Disease' button to upload test image and then CNN will predict disease

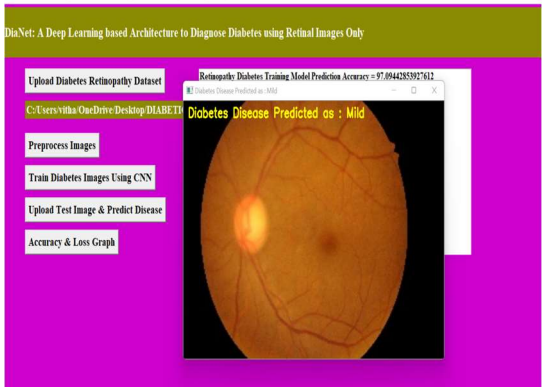


In above screen selecting and uploading '6.jpg' file and then click on 'Open' button to get below result

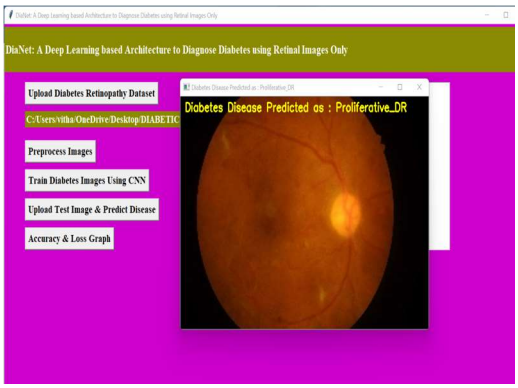


In above screen we got prediction result as 'No' which means disease is not present and now test other image

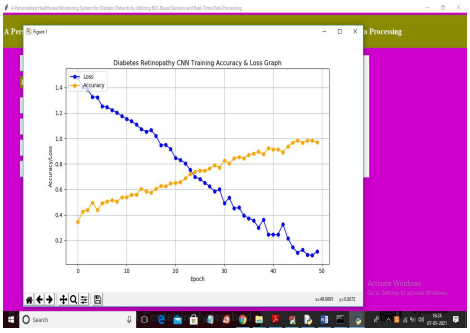
In above screen 2.jpg is uploading and below is the result



In above screen Mild disease is predicted



Similarly you can upload other images and test the prediction result. Now click on 'Accuracy & Loss Graph' button to get below graph



In above screen x-axis represents Epoch and y-axis represents accuracy/loss values and in above graph blue line represents LOSS and orange line represents ACCURACY and in above graph we can see with each increasing epoch accuracy is getting increase and loss getting decrease which means accurate CNN model is building.

CONCLUSION

In this work, we proposed DiaNet, a novel deep learning-based model to distinguish diabetes from the control group using QBB retinal photography. Our model, based on retinal images, achieved over 84% accuracy to classify the diabetes group from the control group achieving a higher level of accuracy than what we achieved using clinical dataset only, for the same purpose. As per our best knowledge, our study is the first, which predicts diabetes considering only retinal

images. So, we believe the retinal images can be used in clinical setup to diagnose diabetes and incorporate more images the model could perform at a higher level than what we achieved.

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