Diabetic Retinopathy Dectector Web App

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Abstract

In this project, I developed a web application that allows the user to upload a retinal image of the eye that is then ingested into a neural network for detection of an eye disease called diabetic retinopathy. The prediction is then sent to the UI, along with a response from the GPT 3.0 language model. The model acts as if it is your eye doctor, while conveying the results from "examing" their retinal eye image. This web app was coded in JavaScript, and using development technologies such as React, GraphQL, Node.js, Express, and webpack. The neural network was coded and trained in Python in Google Colab.

1 Introduction

The Diabetic Retinopathy Detector app was created as a means to practice my software development and machine learning skills rather than for practical usage. However, there are already neural networks designed for disease detection that are currently used within the medical field. As artificial intelligence continues to improve, disease detection technologies accompanied with language models will begin to work as doctor assistants. As you will see from the model performance and the response from GPT 3.0 language model (in which I will refer to as the AI doctor), it is clear that it is only a matter of time until AI will play a significant role in disease diagnosis. Of course, the intent of these technologies is to assist rather than replace our doctors. I believe that AI, if properly regulated and aligned with human goals, will save countless lives.

In this report I will go over the neural network model created, the dataset used to train the model, the image processing techniques used to preprocess the retinal images, and then give an overview the web application.

2 What is Diabetic Retinopathy?

Diabetic retinopathy is a complication of diabetes that affects the blood vessels in the retina, the light-sensitive tissue located at the back of the eye. The retina is responsible for converting light into electrical signals that are sent to the brain, enabling us to see.[1]

Diabetic retinopathy occurs when high blood sugar levels damage the tiny blood vessels in the retina, causing them to leak or swell, or even close off completely. In some cases, abnormal new blood vessels can grow on the surface of the retina. These changes can lead to vision loss, and if left untreated, may result in blindness.[1]

There are two main stages of diabetic retinopathy non-proliferative diabetic retinopathy (NPDR) and proliferate diabetic retinopathy (PDR). This is the early stage, characterized by weakened blood vessels in the retina that may leak blood or fluid. This can cause the retina to swell or form deposits called hard exudates. NPDR can be further divided into mild, moderate, and severe, depending on the extent of the damage.[1]

PDR is the more advanced stage, marked by the growth of abnormal new blood vessels on the surface of the retina. These vessels are fragile and prone to bleeding, which can lead to the formation of scar tissue and, in severe cases, retinal detachment. PDR can also cause a condition called neovascular glaucoma, where the new blood vessels interfere with the normal flow of fluid in the eye, leading to increased eye pressure and damage to the optic nerve.[1]

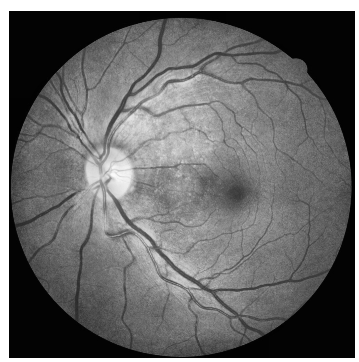
3 Importing and Preprocessing the Eyepacs Dataset

The dataset used to train the neural network model is called the Eyepacs DR dataset from Kaggle.[2] This dataset consists of 35,000 retinal images, each rated 0-4 based on the severity of the diabetic retinopathy detected. 0 means that no DR was detected. 1 means a mild case of DR was detected. 2 means a moderate case of DR was detected. 3 means a severe case of DR was detected. 4 means that a proliferate case of DR was detected.

I first had to download the Eyepacs dataset, upload it to google drive, then extract each image into my colab environment. Along with the image dataset, is a CSV file that labels each image with it's corresponding DR severity, 0-4. Then each image needed to be preprocessed effectively so the neural network can be trained to learn patterns within each image. Firstly, each image was normalized, meaning each pixel value was divided by 255 to make each new pixel value in the range [0,1]. The green channel is then extracted from the image. This is typically done when one wants to extract the blood vessels from each image. In the case, blood vessel abnormality is a good indication of diabetic retinopathy. We then apply the Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm to the extracted green channel of each image to enhance contrast. The color channels are then merged back together and converted to grayscale. Then we apply a morphological operator called opening, with a kernal of size (1,1) to get rid of the isolated pixels within the image. This will help get rid of the noise within the image. Then another image processing algorithm called adaptive thresholding is applied to make all of the blood vessels white, and the rest of the image black. Finally, to clean the image further, another morphological opening operation is applied with a kernel of size (2,2) and the color channels are stacked back together.

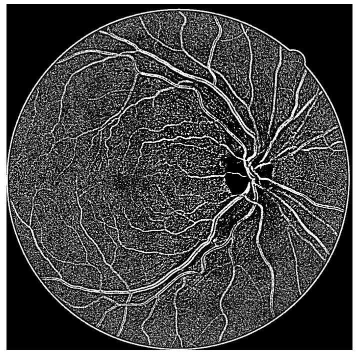
(a) Original retinal image

(b) After applying CLACHE

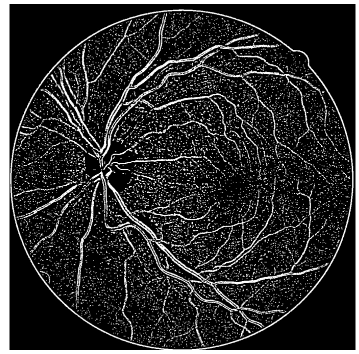


(c) After applying grayscale

(d) After first morphological opening



(e) After applying adaptive thesholding



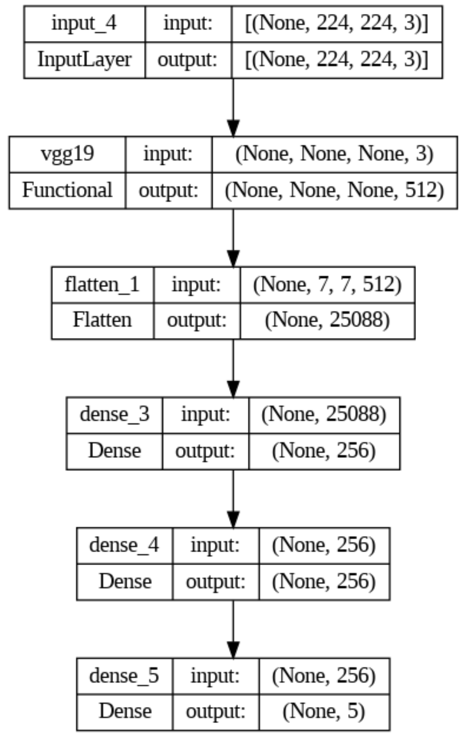
(f) After applying second morphological opening

Before training the neural network with the preprocessed images, the dataset had to be split into training and validation sets. In machine learning, the training set is used to train the neural network. Then after each training epoch, the model is evaluated with the validation set. This gives us developers a sense of whether the neural network is effectively converging to a generalized solution, rather than over-fitting to the testing data or running into the exploding gradient problem.

4 Building the ML Model

We need a model that can detect patterns and features within images, so it makes sense to use a pre-trained model such as VGGNET. VGGNET is convolutional neural network that is trained on the ImageNet dataset. The ImageNet dataset consists of over 14 million images and 22,000 images classes. Since VGGNET is trained on such a large, generalized image dataset, it is a great option to train for more focused image recognition tasks.

Before we can start training the model, we must fine-tune the model for the task of interest. In our case, we keep the base model and weights to start off. The input tensor is then set to take in images of the shape (224,224,3). The output layer of the VGGNET is flattened and connected to dense layer with 256 output nodes and the relu activation function. This dense layer is set to a dropout rate of 0.5 to prevent the neural network from over-fitting to the training data. Then one more dense layer with 5 output node corresponding to the predicted diabetic retinopathy severity is added. The model is then compiled to used the ADAM optimizer with gradient clipping to prevent exploding gradients and the loss function is set to categorical crossentropy. Below is an image of what the model looks like:



5 Training the ML Model

Training and improving the model is usually a non-eventful endeavor. It includes waiting 2-3 hours, evaluating results, tweaking hyperparameters, adding or removing layers, and repeat until the desired results are achieved. Training the model with 6 epochs and a batch size of 32 yielded the best results which will be covered in the next section.

Preventing the model from predicting no diabetic retinopathy every time was tricky. 73.49% of the dataset are images labeled as no diabetic retinopathy. This was avoided by keeping the batch size low and a carefully evaluating the training and validation loss values. The following is the output from training the model:

Epoch 1/5
1098/1098 [==============================] - 1150s 1s/step - loss: 0.8998 - accuracy: 0.7301 - val_loss: 0.8376 - val_accuracy: 0.7349
Epoch 2/5
1098/1098 [==============================] - 1069s 974ms/step - loss: 0.8216 - accuracy: 0.7360 - val_loss: 0.7931 - val_accuracy: 0.7381
Epoch 3/5
1098/1098 [==============================] - 1084s 988ms/step - loss: 0.8053 - accuracy: 0.7368 - val_loss: 0.7950 - val_accuracy: 0.7382
Epoch 4/5

1098/1098 [==============================] - 1074s 978ms/step - loss: 0.7928 - accuracy: 0.7362 - val_loss: 0.7935 - val_accuracy: 0.7386
Epoch 5/5
1098/1098 [==============================] - 1053s 960ms/step - loss: 0.7821 - accuracy: 0.7368 - val_loss: 0.7491 - val_accuracy: 0.7422
Training complete!
1098/1098 [==============================] - 527s 480ms/step - loss: 0.7491 - accuracy: 0.7422

6 Model Results

Upon evaluating the models predictions over the entire dataset, the results were decent. This model achieved 74.2% accuracy with a loss of 0.749. Since such a large percentage of the images with no diabetic retinopathy, the predictions scew heavily toward such prediction.

7 Web App Results

The web app I developed provides an easy to use user interface that allows the user to upload retinal images of the eye. Upon submission, it gives a prediction of the diabetic retinopathy condition and a response from the AI doctor. This process is straight forward and doesn't need much explanation so I will give a brief overview of the output for each condition.

The model detects no diabetic retinopathy:

Prediction: No Diabetic Retinopathy

AI Doctor: Thank you for coming in today. After carefully examining your retinal images, I am pleased to tell you that they show no signs of diabetic retinopathy. This means that your eyes have not been affected by any long-term damage due to diabetes. However, it is still important to get your eyes checked regularly to make sure there are no changes. If you have any questions or concerns, please do not hesitate to ask.

The model detects mild diabetic retinopathy:

Prediction: No Diabetic Retinopathy

AI Doctor: Thank you for coming in today. I have looked at your retinal images and I am pleased to tell you that they show no signs of Diabetic Retinopathy. This is very good news, as it means that your eyes are healthy and that there is no damage to your retinas. I recommend that you continue to follow the advice of your doctor to keep your diabetes under control, as this will help you to prevent any future damage. If you have any concerns or questions, please do not hesitate to contact me.

The model detects moderate diabetic retinopathy:

Prediction: Moderate Diabetic Retinopathy

AI Doctor: Thank you for coming in today. After reviewing your retinal imaging, I have determined that you have a moderate case of diabetic retinopathy. This is a condition in which the blood vessels in the back of your eye become weakened and can leak fluid or blood, leading to vision problems. It is a common complication of diabetes, and the good news is that it can usually be treated if it is caught early. The next step is to monitor your condition closely to make sure that it does not worsen. I will need to see you for regular check-ups every 6-12 months, as well as doing regular retinal imaging, to make sure that the condition is not progressing. I may also recommend that you make lifestyle changes, such as controlling your blood sugar, to help slow the progression of the condition. If the condition does progress, there are treatments that can help to stabilize or even improve your vision. These include laser treatments and injections, which can help to reduce fluid or blood leakage and improve vision. I would recommend that you make an appointment with your primary care physician to discuss ways to better control your diabetes, and to make sure you keep up with your regular check-ups with me. Together, we can

The model detects severe diabetic retinopathy:

Prediction: Severe Diabetic Retinopathy

AI Doctor: I am sorry to tell you that the retinal images that we took indicate that you have a severe case of Diabetic Retinopathy. This is a complication of diabetes that affects the eyes and can lead to vision loss if left untreated. The good news is that with treatment, we can often slow down or even reverse some of the damage caused by this condition. We will need to start you on a course of treatment right away in order to prevent the condition from getting worse.

The model detects proliferate diabetic retinopathy:

Prediction: Proliferate Diabetic Retinopathy

AI Doctor: Thank you for coming in today. I have reviewed your retinal images and they have indicated that you have a proliferative case of diabetic retinopathy. This is a condition that can cause vision problems in people with diabetes. It is caused by changes in the blood vessels in the retina, the light-sensitive layer at the back of the eye. The most common symptom of this condition is blurred vision, but it can also cause more serious vision problems, such as vision loss and blindness. Your retinal images show that the condition is quite advanced, so it's important that you take steps to manage it. This includes controlling your blood sugar levels, eating a healthy diet, and exercising regularly. You may also need to take certain medications to control your diabetes. I recommend that you follow up with your primary care physician and a retinal specialist to discuss further treatment options. In the meantime, it's important that you have your eyes checked regularly to monitor the progression of the condition.

As you can see, the language model responds as if it an actual eye doctor according to the specific results the model predicts. Keep in mind that the language model produces it's reply in real-time, it is not predefined. This means that the AI doctor will not output the same message for corresponding predictions.

8 Conclusion

All in all, although the model performance is by no means perfect, I believe tools AI tools like these will revolutionize the medical industry. I was able to create good performing diabetic retinopathy detector with limited resources. Imagine what can be done with a team of developers, machine learning engineers, and a large budget. Continued innovation in machine learning and natural language processing will make this inevitable. Hopefully, as my career progresses, I can be a part of driving this progress.

References

[1] C. Koetting. "The four stages of diabetic retinopathy." Accessed: 2023-04-25. (2019), [Online]. Available: `https://modernod.com/articles/2019-june/standard-tools-and-tests-fordiagnosing-diabetic-retinopathy?c4src=article:infinite-scroll`.

[2] M. Herreot. "Kaggle dr dataset (eyepacs)." Accessed: 2023-03-25. (2022), [Online]. Available: `https://www.kaggle.com/datasets/mariaherrerot/eyepacspreprocess?select=eyepacs_preprocess`.