“Diabetic Retinopathy Detection using eye images”

A Project Report Submitted to
Gujarat Technological University in Fulfillment of the Requirements for the Degree of Bachelor of Engineering
In
Information Technology

B. E. IV, Semester –VIII

By

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We appreciate the **GTU** for giving us a platform which can transform our idea into a design or any product which can help people in their day to day life.

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This is to certify that the project entitled "**DIABETIC RETINOPATHY DETECTION USING EYE IMAGES**" has been carried out by VATSAL PATEL (150110116062), MEET K PATEL (150110116033) and DEEP KAKADIA (150110116012) under my guidance in fulfillment for the degree of Bachelor of Engineering in Information Technology (8th Semester) of Gujarat Technological University, Ahmedabad during the academic year 2018-19

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ABSTRACT

Diabetic Retinopathy (DR) is the most common cause of blindness in individuals from ages 25-65. Nearly 93 million people suffer from diabetic retinopathy. DR is an eye disease that damages retina of the eye and may eventually lead to complete blindness. The goal of this project is to design an automated way of detecting the disease in a manner which is efficient and reliable enough to be used in practice, and hence stem DR progress in the early stages. The current practice is manual detection which requires a lot of time and efforts. In this project we have implemented machine learning algorithms to classify the severity of DR from a given set of retina images. By using Convolutional Neural Networks in our research we hoped to find a more efficient way to solve the problem.

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"DIABETIC RETINOPATHY DETECTION USING EYE IMAGES"

A Project Report

Submitted By

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Meet Patel	Enrollment No. - 150110116033
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In fulfilment for the award of the degree

Of

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CHAPTER: 1

INTRODUCTION

1.1 Aim and objective

The main objective of this project is to find an automated, efficient and reliable way to detect the stage of diabetic retinopathy by applying machine learning algorithms and image processing to retina images.

1.2 Motivation

Diabetic Retinopathy is a disease which is the result of unregulated diabetes. Over 80 percent of population which suffers from diabetes for more than 10 years has developed DR to some extent, also the longer a person is in this disease higher the chances are of their having DR. Research demonstrates that it contributes around 5% of all the instances of visual impairment. As per 'WHO' estimation 347 million of total populace is suffers from diabetes and around 40-45% of them have some phase of the ailment. By analyzing retina images, we can spot contrasts between picture of ordinary eye and DR eye. There are different elements influencing the disease like period of diabetes, poor control, pregnancy, however Research demonstrates that progress of vision deterioration can be moderated or turned away if DR is identified in beginning period of the sickness. While a huge no. of population experiences DR, yet at the same time testing is done physically via prepared experts. This extensive process is in actuality lengthy, prone to miscommunication, requires expert's time and deferred results in the long run prompt to postponed treatment to stem the disease progress.

1.3 Problem specification

By using color fundus photography as input (provided by EYEPACS), the goal of this project is to push an automated detection system to the limit of what is possible – ideally resulting in models with realistic clinical potential. The input images have to be classified into 5 different classes each specifying different stage of DR progression.

CHAPTER: 2

LITRATURE SURVEY

- **Systems and methods for automated interest region detection in retinal images by Kaushal Mohanlal Solanki, Chaithanya Amai Ramachandra, Eyenuk inc., 2013, US8879813B1.** [1]

Embodiments disclose systems and methods that aid in screening, diagnosis and/or monitoring of medical conditions. The systems and methods may allow, for example, for automated identification and localization of lesions and other anatomical structures from medical data obtained from medical imaging devices, computation of image-based biomarkers including quantification of dynamics of lesions, and/or integration with telemedicine services, programs, or software. The computing system may include one or more hardware computer processors; and one or more storage devices configured to store software instructions configured for execution by the one or more hardware computer processors in order to cause the computing system to: access a medial retinal image for enhancement, the medical retinal image related to a subject; compute a median filtered image Is with a median computed over a geometric shape, at single or multiple scales; determine whether intensity at a first pixel location in the medical retinal image I(x,y) is lower than intensity at a same position in the median filtered image Is(x,y); if the intensities at the first pixel location is lower, then set a value at the first pixel location in an enhanced image to half of a maximum possible intensity value for the medical retinal image C. Scaled by a ratio of intensity at medical retinal image to intensity in the median filtered image is expressed using various equations.

- **Systems and methods for feature detection in retinal images by Meindert Niemeijer, Ryan Amelon, Warrent Claride, IDx, 2016, US20160292856A1** [2]

Provide are systems methods and devices for diagnosing disease in medical images. In certain aspects, disclosed is a method for training a neural network to detect features in a retinal image including the steps of: a) extracting one or more features images from a Train_0 set, a Test_0 set, a Train_1 set and a Test_1 set; b) combining and randomizing the feature images from Train_0 and Train_1 into a Training data set; c) combining and randomizing the feature images from Test_0 and Test_1 into a testing dataset; d) training a plurality of neural networks having different architectures using a subset of the training dataset while testing on a subset of the testing dataset; e) identifying the best neural network based on each of the plurality of neural networks performance on the testing data set; f) inputting images from Test_0, Train_1, Train_0 and Test_1 to the best neural network and identifying a limited number of false positives and false negative and adding the false positives and false negatives to the training dataset and testing dataset; and g) repeating steps d)-g) until an objective performance threshold is reached. user, and further configured to extract image features from the retinal image, which can be a multilevel neural network or a classic feature extractor; b) a multilevel neural network, trained according to the training methods disclosed herein and configured to receive image features from the feature extractor, and further configured to output scalar image features; and c) a machine learning program, configured to receive Scalar image features from the neural network and further configured to output disease diagnosis. In certain aspects, the image features are spatial distributions of image features. In further aspects, spatial distributions are heat maps. According to still further aspects, the spatial distributions are point-wise outputs. [2].

- **A Novel method for blood vessel detection from retinal images by Lili Xu and Shuqian Luo, licensee BioMed Central Ltd, BioMedical Engineering OnLine, 2010 [3]**

The morphological changes of the retinal blood vessels in retinal images are important indicators for diseases like diabetes, hypertension and glaucoma. Thus, the accurate segmentation of blood vessel is of diagnostic value. In this paper, they present a novel method to segment retinal blood vessels to overcome the variations in contrast of large and thin vessels. This method uses adaptive local thresholding to produce a binary image then extract large connected components as large vessels. The residual fragments in the binary image including some thin vessel segments (or pixels), are classified by Support Vector Machine (SVM). The tracking growth is applied to the thin vessel segments to form the whole vascular network. The proposed algorithm is tested on DRIVE database, and the average sensitivity is over 77% while the average accuracy reaches 93.2%.In this paper, they distinguish large vessels by adaptive local thresholding for their good contrast. Then identify some thin vessel segments with bad contrast by SVM, which can be lengthened by tracking. This proposed method can avoid heavy computation and manual intervention. [3]

- **Methods and systems for detection of retinal changes by Joo Paulo da Silva Pinto, Frederico Teles de Campos, Critical Health SA, 2011, US8041091B2** **[4]**

An image analysis system allows users to import digital color fundus images over time, and group such images for processing so as to generate analyses. Analyses are information modules based on a selected group of images and, optionally, related information. An analysis tool allows users to view and manipulate the analyses via a graphical user interface for aid in identifying and classifying microaneurysms and other symptoms related to retinopathy and, more generally, to allow for the detection of retinal changes over time. In order to address the above-described problems, systems and methods for the display and analysis of digital color fundus images to aid in the diagnosis of diabetic retinopathy and other pathologies are provided. In one embodiment, the system includes a record module configured to permit digital color fundus images taken at different times to be imported; an image set module configured to group two or more of said images (e.g., on an eye-by-eye and/or patient-by-patient basis) as part of an analysis; a processing module configured to generate analyses results for selected groups of said images; and an analysis tool set configured to permit viewing of the analysis results, as well as the images, on a eye-by-eye basis and to collect inputs and instructions relating to said analyses and images from a user. In various instantiations of the invention, the record mod ule allows each image to be associated with various informa tion, including some or all of the following indicators: a date on which the respective image was captured, whether the image is of a right or left eye, the kind of equipment used to capture the image, the field and angle of acquisition, and whether or not mydriasis was used at the time the image was acquired. The image set module is adapted to group selected images either manually (the system automatically disposes them in a chronological manner), or with one image being selected as a reference and images within a designated time interval being grouped with respect to that reference auto matically.

- **Apparatus and method for spectrally measuring fundus by Toshifumi Mihashi, Yoko Hirohara, Topcon Corporation, May 2016. US7568800B2 [5]**

To provide a spectroscopic fundus measuring apparatus capable of identifying each part in spectral fundus images easily and accurately based on its spectral characteristic and a measuring method therefor. A spectral fundus image measuring apparatus 1 of the present invention includes: an illumination optical system 10; a light receiving optical system 20 for photographing a series of spectral fundus images of different wavelengths; an image processing section 7 for processing the spectral fundus images; a storage section 7A; and a display section 7B. The image processing section 7 has a position correcting section 72 for correcting the series of spectral fundus images to match the positions of the same parts therein, and an image analyzing section 73 for calculating the spectral characteristic of each part in the spectral fundus images based on the series of spectral fundus images corrected in the position correcting section 72. The storage section 7A stores the spectral characteristics of the parts together with standard spectral characteristics of specific parts. The image processing section 7 has a first grouping section 74A for comparing the spectral characteristic of each part with the standard spectral characteristics of the specific parts to divide the parts into groups corresponding to the specific parts.

- **Diabetic Retinopathy Detection Using Machine Learning by Maisha Maliha, Ahmed Tareque, Sourav Saha Roy, BRAC University, 2018. [6]**

Diabetic Retinopathy (DR) is human eye disease among people with diabetics which causes damage to retina of eye and may eventually lead to complete blindness. Detection of diabetic retinopathy in early stage is essential to avoid complete blindness. Effective treatments for DR are available though it requires early diagnosis and the continuous monitoring of diabetic patients. Also many physical tests like visual acuity test, pupil dilation, and optical coherence tomography can be used to detect diabetic retinopathy but are time consuming. The objective of our thesis is to give decision about the presence of diabetic retinopathy by applying ensemble of machine learning classifying algorithms on features extracted from output of different retinal image. It will give us accuracy of which algorithm will be suitable and more accurate for prediction of the disease. Decision making for predicting the presence of diabetic retinopathy is performed using K-Nearest Neighbor, Random Forest, Support Vector Machine and Neural Networks.

CHAPTER: 3

DESIGN ENGINEERING CANVAS

3.1 AEIOU Summary:

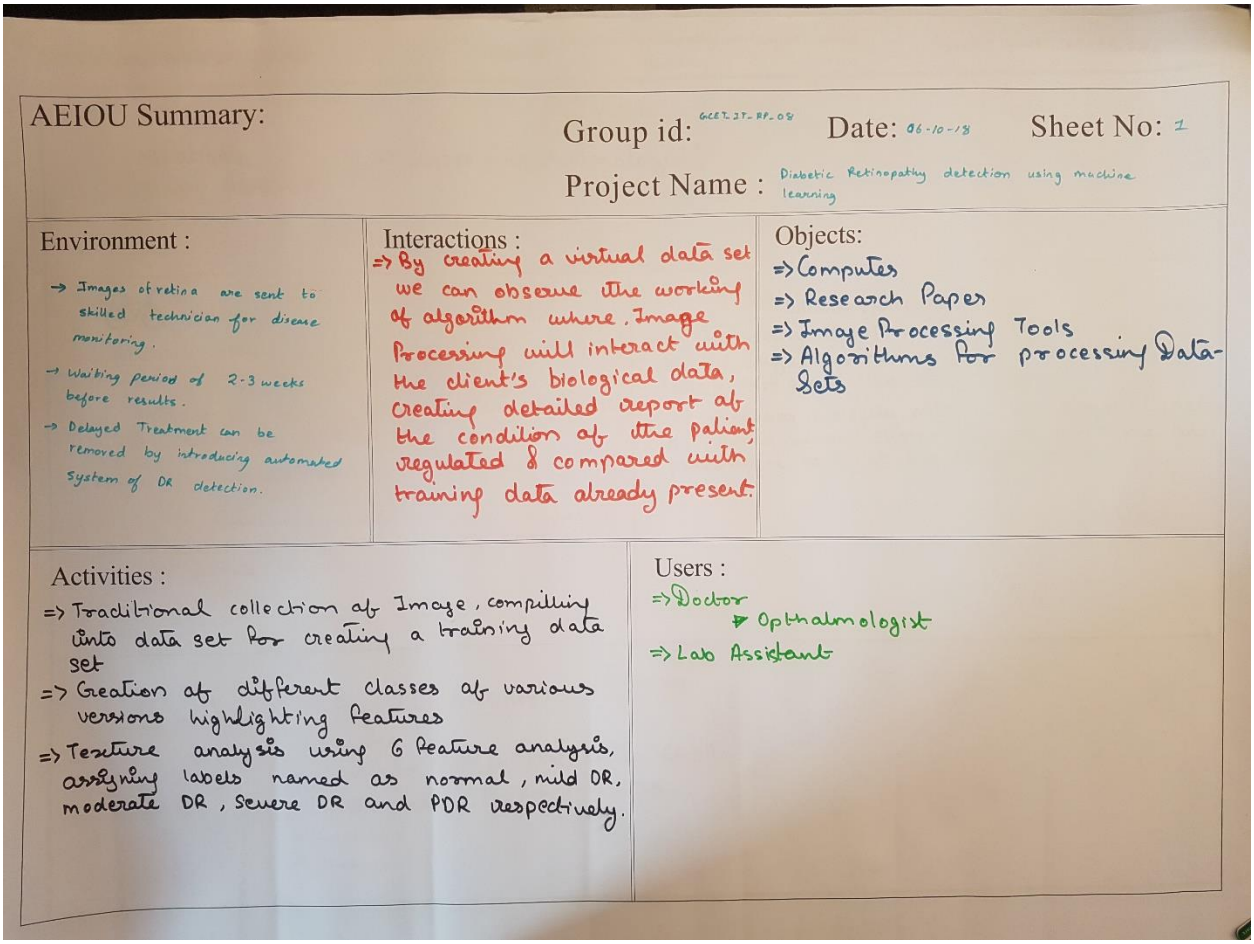

Figure 3.1 AEIOU Summary

The above canvas is an AEIOU Summary about the Activities, Environment, Interactions, Objects and Users. Based on the observations done we were able to draft this summary which includes the situations and the major/minor factors that are responsible for the inactions.

3.2 **Product Development Canvas:**

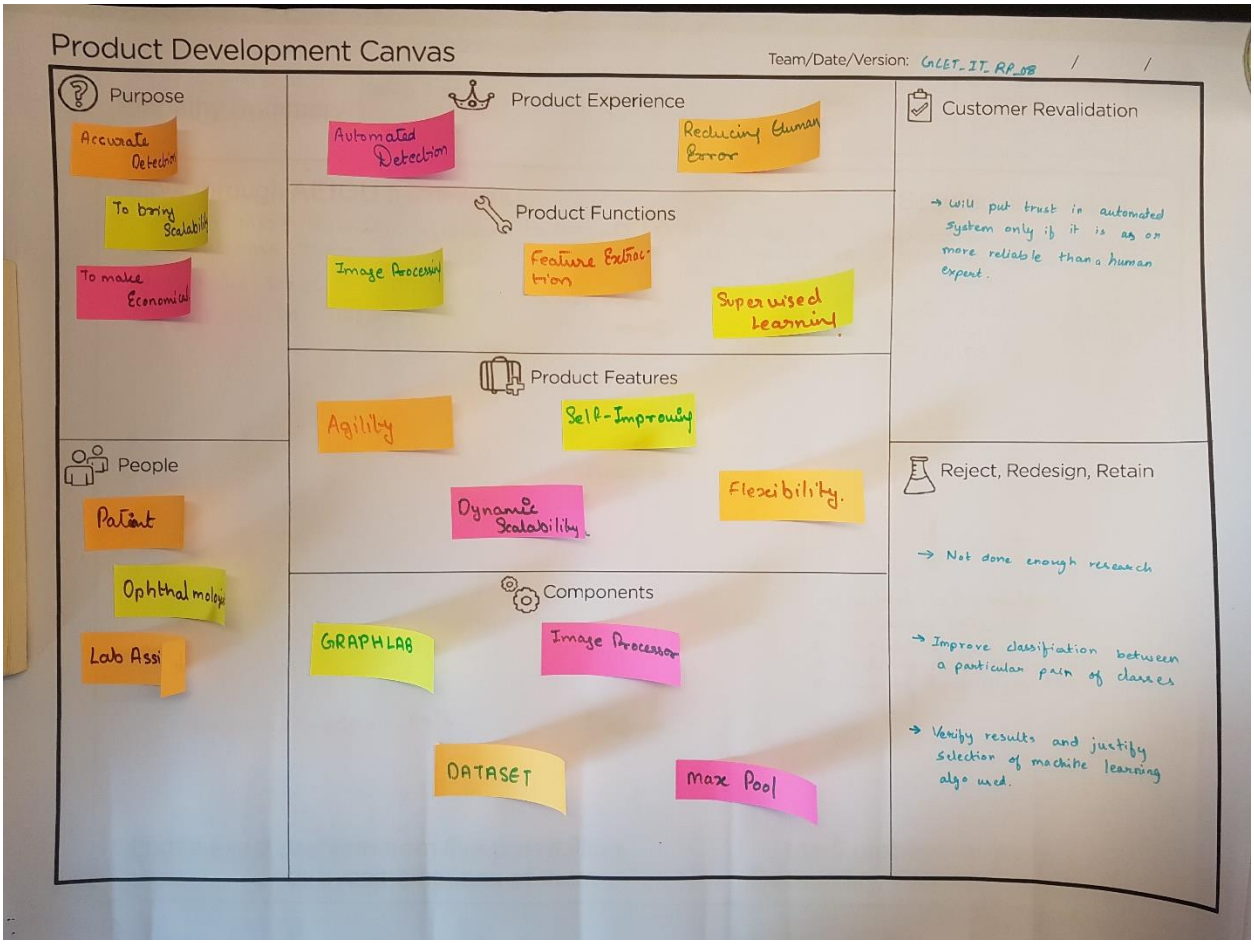

Figure 3.2 Product Development Canvas

Based on the observation in the previous AEIOU summary a particular Ideation can be derived which results into the Ideation Canvas above. This canvas shows the initial idea about the formation of the product and shows that how a particular product should be designed. The factors that will be affecting the development of the product are also included in this canvas.

3.3 Empathy Mapping:

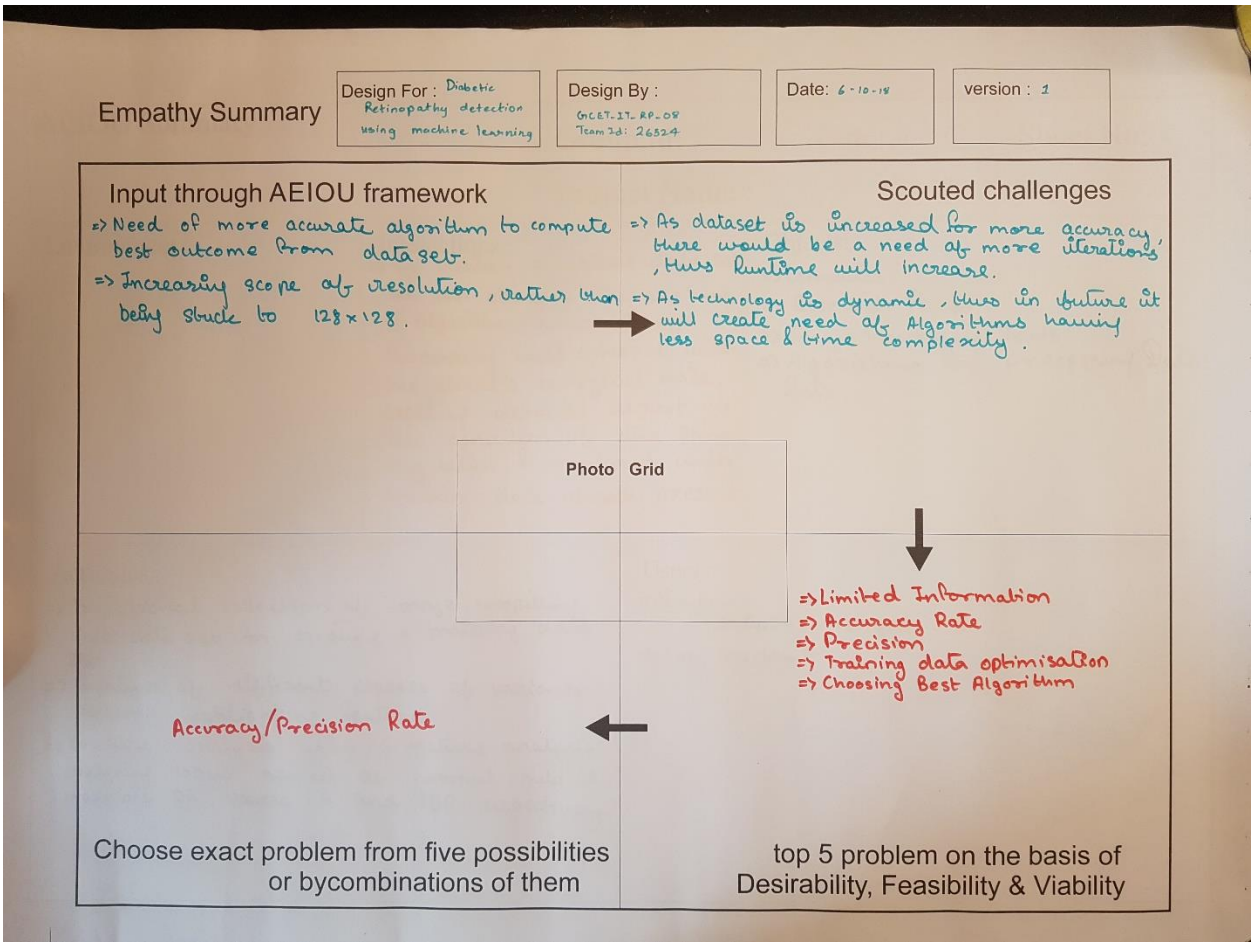

Figure 3.3 Empathy Mapping Summary Canvas

The above canvas shows the empathy part included behind the creation of the project. The canvas includes some short stories that depict the actual case scenarios of the use and need of the product. The scenarios are best show cased using two happy and two sad stories.

3.4 Ideation Canvas:

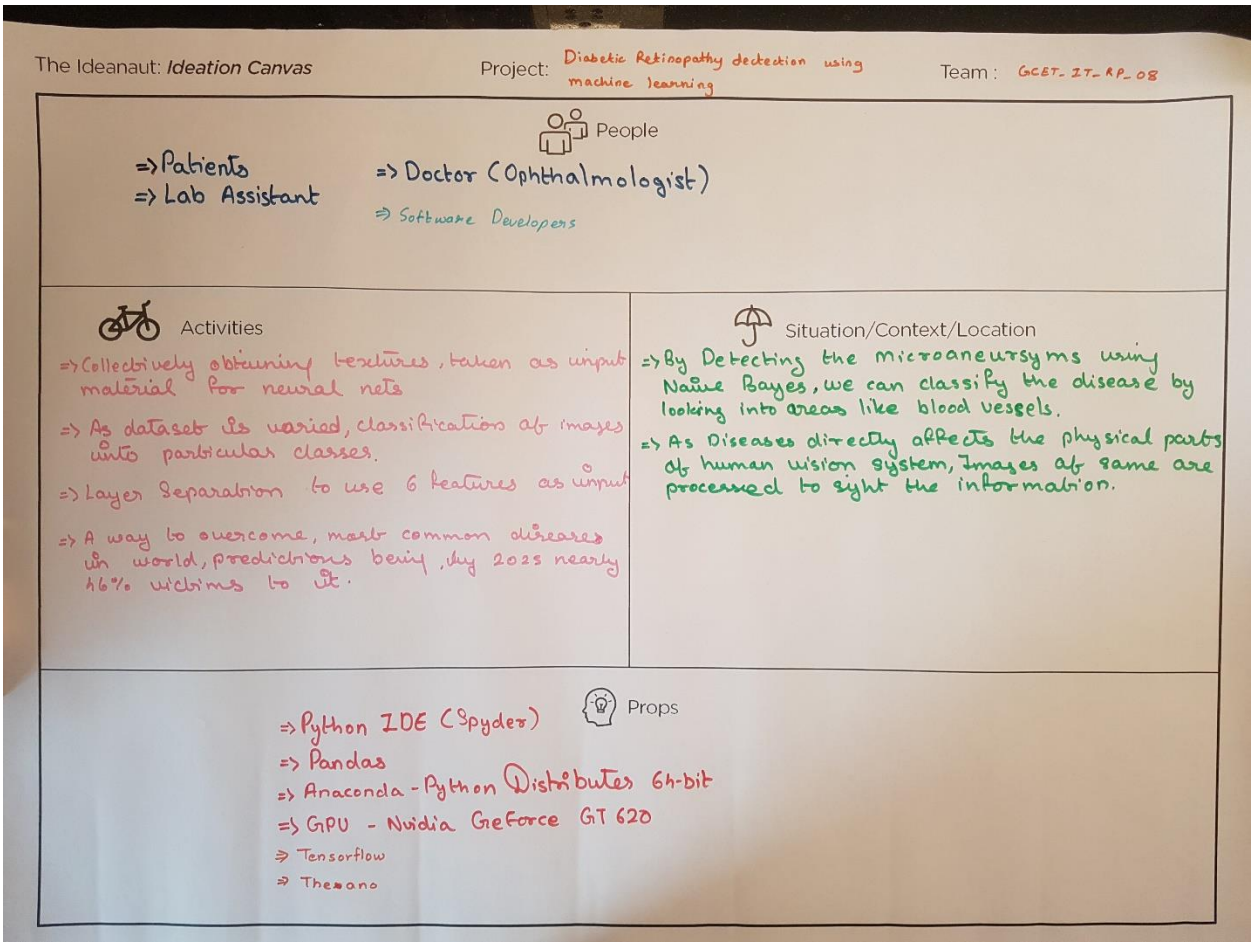

Figure 3.4 Ideation Canvas

After understanding the ideal stage of the product and going through the empathy part of the product it is time to design the final product definition, users, features, functions and components. This canvas will let us know exactly the amount of efforts and the clear idea that is to be put into this project. After that, the Customer revalidation part shows us how true we were in idealizing and creating a solution for the user. After that according to the Validations it is up to us that we reject, redesign and retain the function and features according to the feedback from the customer.

3.5 Business Model Canvas:

Business Model Canvas has been introduced to make a good product out of the student's final year project to help the society & increase manufacturing industries in India. One can also make a patent from their project.

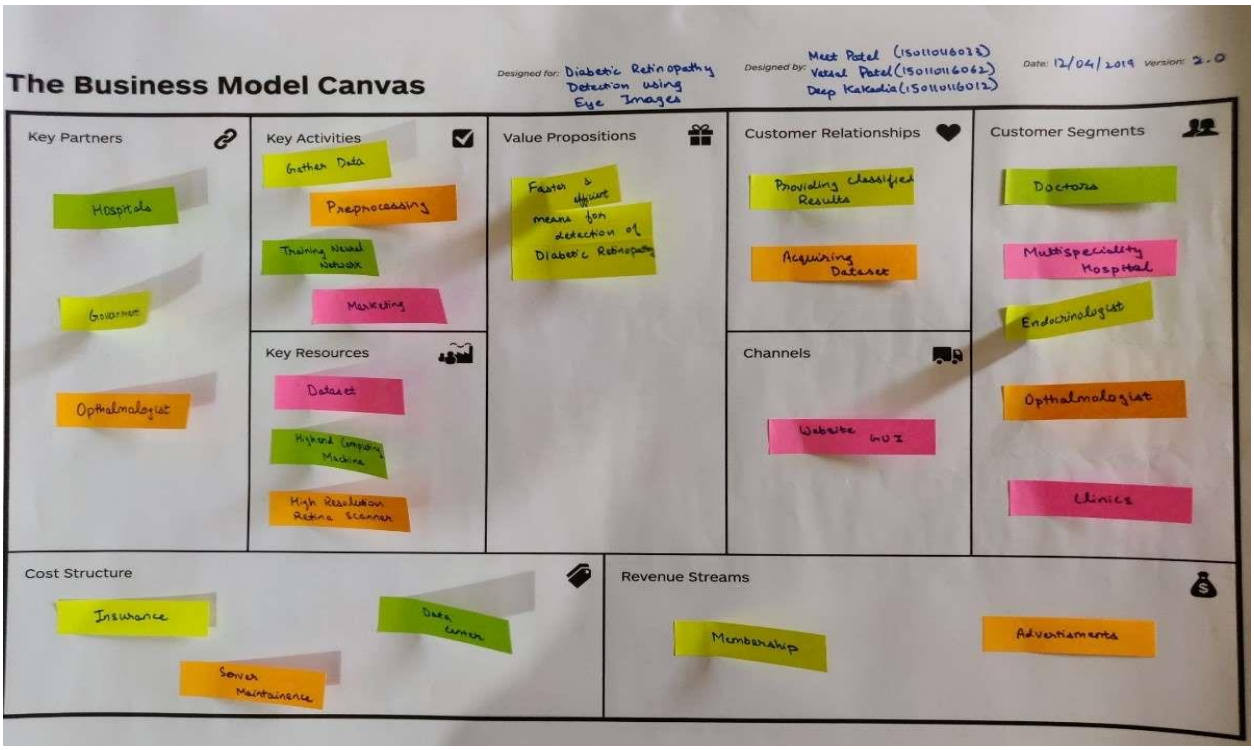

Figure 3.5 Business Model Canvas

3.5.1 Business Model Canvas Report

- **WHAT**

  - **Value Proposition**
    - **Faster and Efficient means** – This provides a faster and efficient means of Diabetic Retinopathy Detection reducing the human efforts and errors.

- **WHO**
  - **Customer Segments**
    - Doctors
    - Multispecialty Hospitals
    - Clinics
    - Ophthalmologist
    - Endocrinologist

  - **Customer Relationships**
    - Acquiring Dataset via upload link.
    - Providing classified results via website GUI.

  - **Channels**
    - Website GUI will be providing the interface for uploading the data or dataset and classified results will be displayed by training the same on the neural network.

- **HOW**

  - **Key Partners**

    - Doctors: Doctors who are working in a hospital or clinics for detecting this disease will be one of the key partners.
    - Government: The same model can be implemented in government hospitals for efficient results thus making it one of the key partners.
    - Ophthalmologist: The eye specialist will be the main partner in this case.

  - **Key Activities**

    - Gathering Data: The primary task is to acquire data or dataset.
    - Pre-processing: Secondly, the same data will be pre-processed for redundant and faulty images.
    - Training the Neural Network: Then, the neural network will be trained to classify the images according to their severity.
    - Marketing: The advertisement and marketing of the same will be the last activity.

  - **Key Resources**

    - Dataset
    - High end Computing Machine
    - High Resolution Retina Scanner

      .

- **HOW MUCH?**

    - **Revenue Streams**
        - Revenue is generated from advertisements given through the web application in terms of product promotion.
        - Monthly and yearly Membership plans will be created for the customers who are going to use the product.

    - **Cost Structure**
        - Server Maintenance
        - Data Center
        - Insurance

CHAPTER: 4

METHODOLOGY

4.1 System Architecture

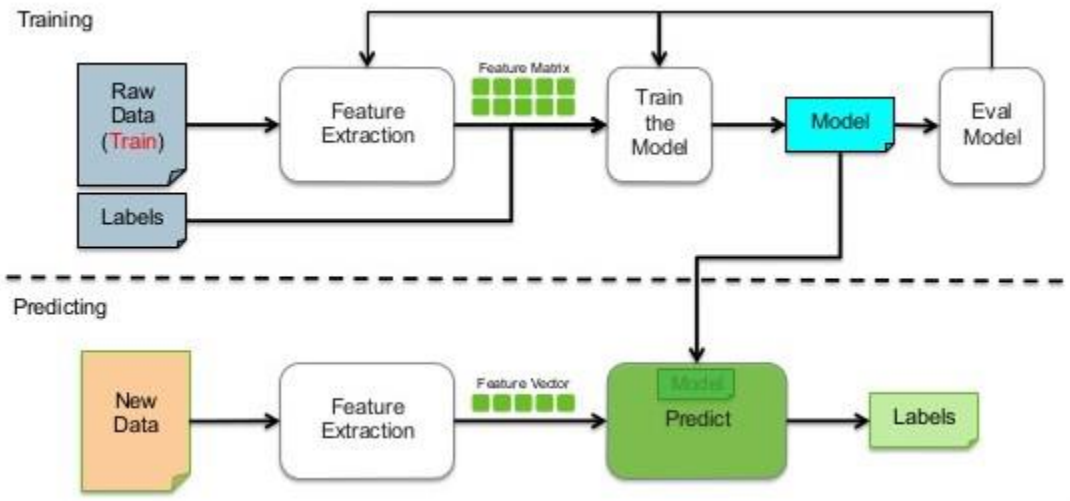

Figure 4.1 System architecture

4.2 Use Case Diagram

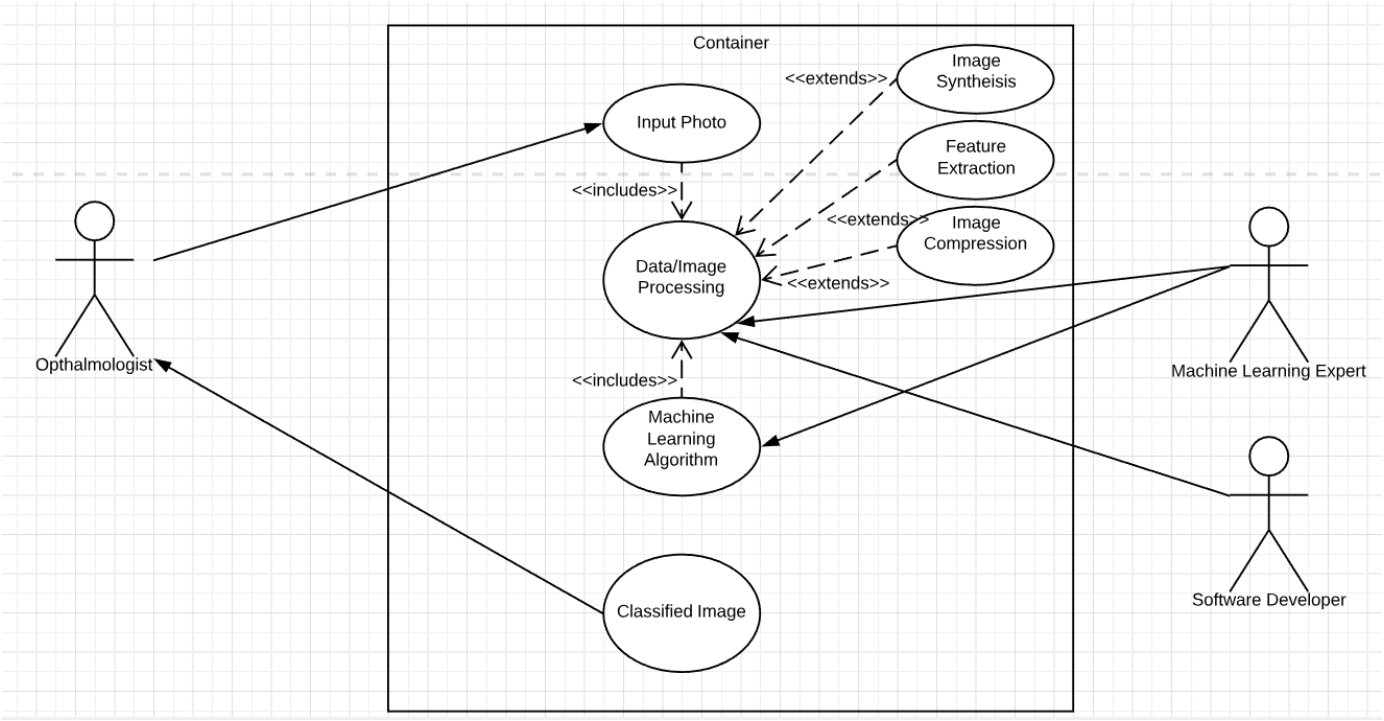

FIGURE 4.2 Use case diagram

4.3 System Flow Diagram

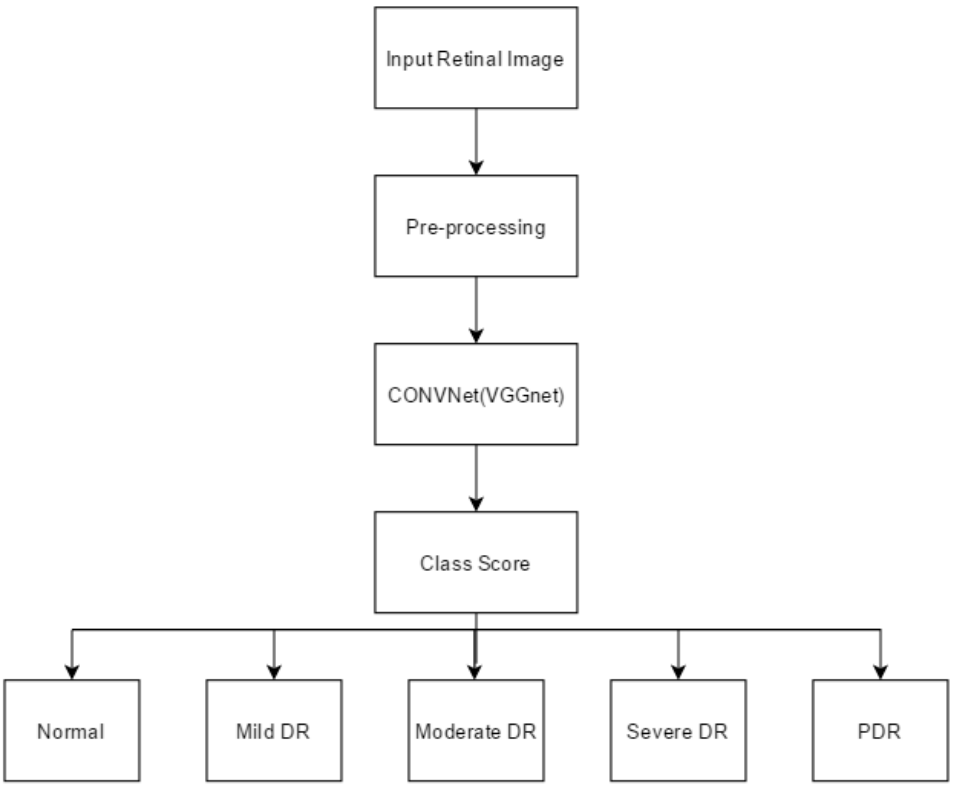

Figure 4.3 System Flow Diagram

4.4 Activity Diagram

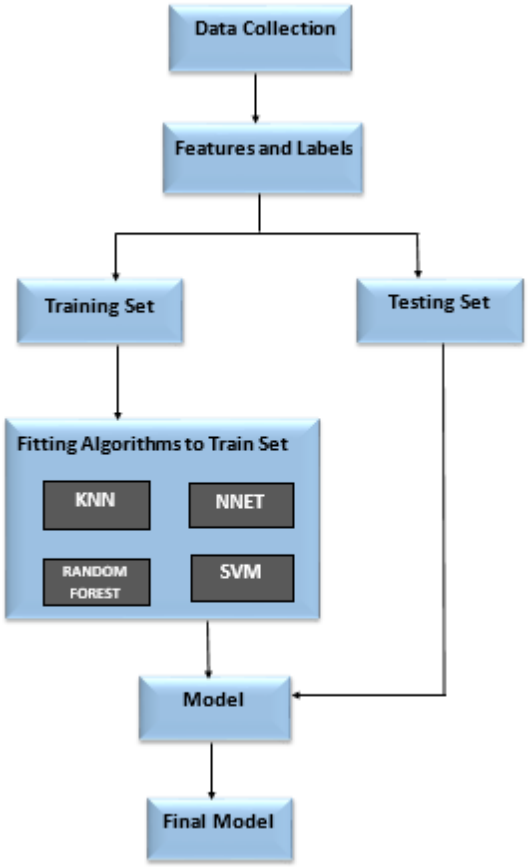

Figure 4.4 Activity Diagram

CHAPTER: 5

APPLICATION

5.1 Dataset

This is an ongoing problem on Kaggle.com[1] which tries to develop a model for DR detection. Dataset consists of high-resolution eye images and graded by trained professionals in 5 classes (0-4). The following table and graph will show the number of images and their percentages. Our dataset contains images which are taken at various lighting condition. There are five training labels [0,1,2,3,4] where the labels are named as normal, mild DR, moderate DR, severe DR and PDR respectively and for each patient there are two images of both right and left eye naming “right” and “left” and for each patient, which has a unique patient id. This dataset that we are using is taken from a competition which took place in kaggle.com.

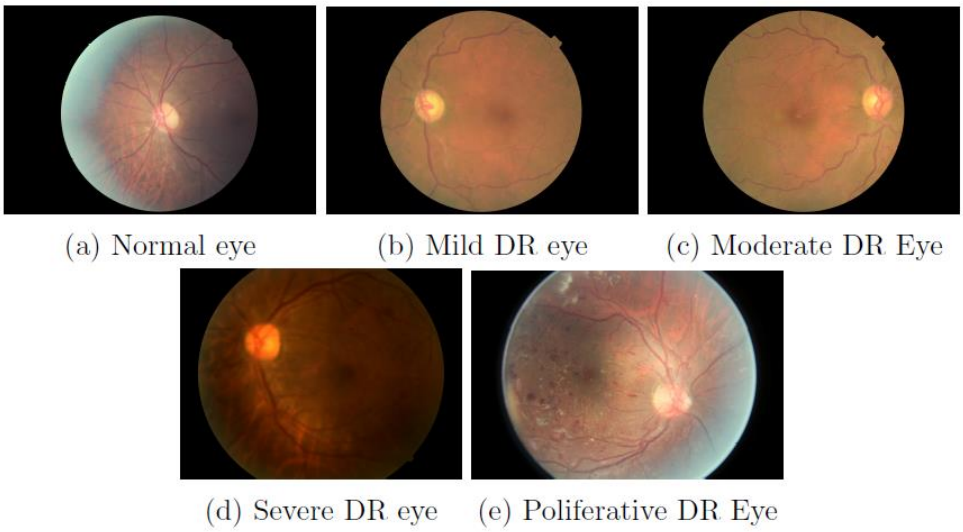

Figure 5.1 Data Classes

5.2 Data Preprocessing

The very first item analyzed was the training labels. While there are five categories to predict against, the plot below shows the severe class imbalance in the original dataset.

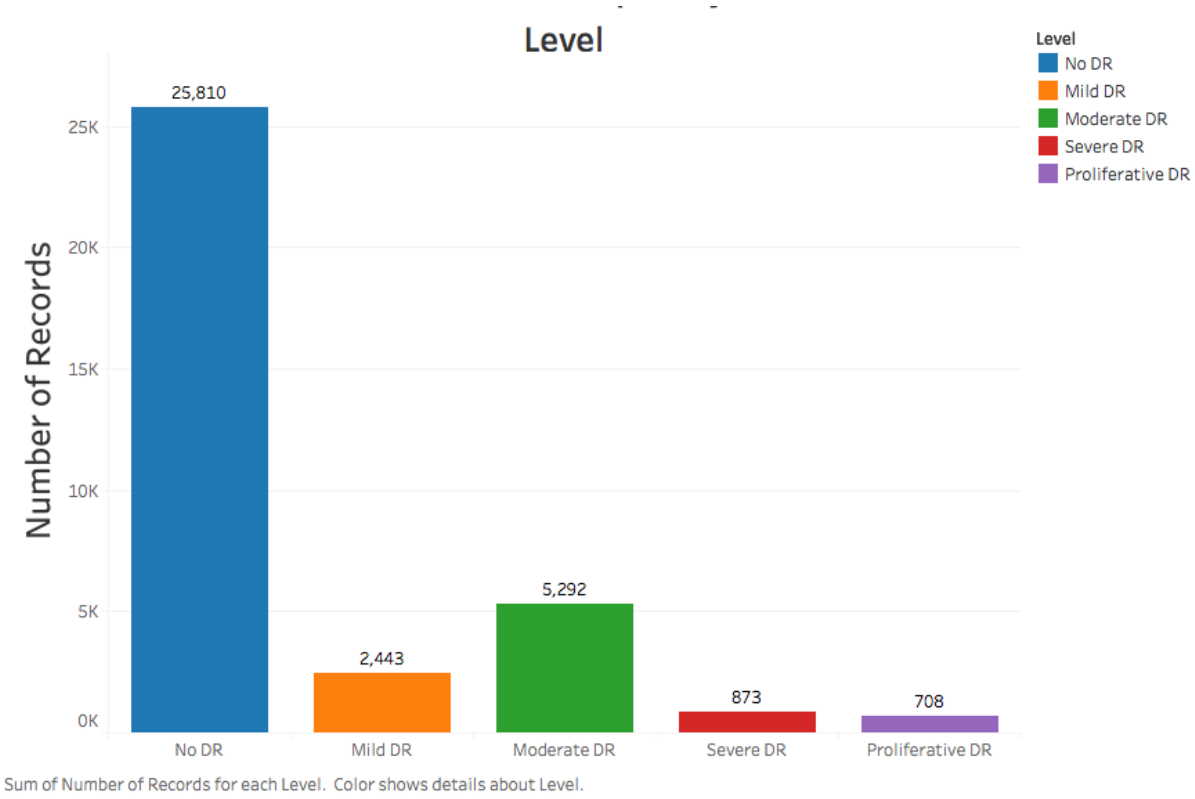

Table 5.1 Data Analysis

Of the original training data, 25,810 images are classified as not having retinopathy, while 9,316 are classified as having retinopathy. Due to the class imbalance, steps taken during preprocessing in order to rectify the imbalance, and when training the model. Furthermore, the variance between images of the eyes is extremely high.

The preprocessing steps taken are as follows:

1. **Crop and Resize All Images**

   All images were scaled down to 256 by 256. Despite taking longer to train, the detail present in photos of this size is much greater then at 128 by 128. Additionally, 403 images were dropped from the training set. Scikit-Image raised multiple warnings during resizing, due to these images having no color space. Because of this, any images that were completely black were removed from the training data.

2. **Rotate and Mirror All Images**

All images were rotated and mirrored. Images without retinopathy were mirrored; images that had retinopathy were mirrored, and rotated 90, 120, 180, and 270 degrees. The first images show two pairs of eyes, along with the black borders. Notice in the cropping and rotations how the majority of noise is removed. After rotations and mirroring, the class imbalance is rectified, with a few thousand more images having retinopathy.

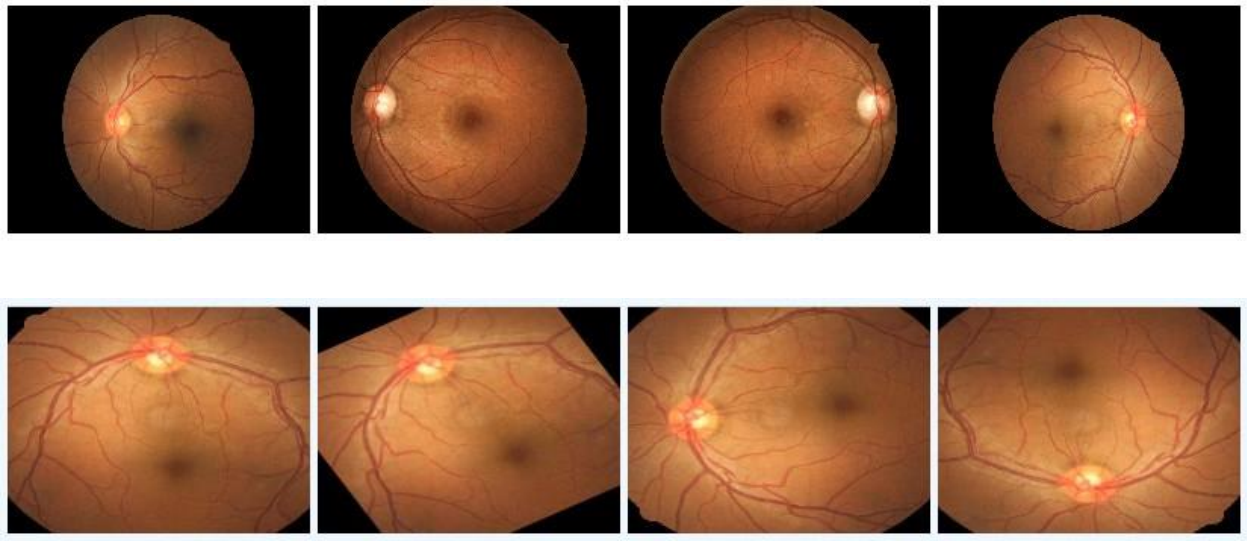

Figure 5.2 Preprocessed Images

5.3 Training

Two things can be done for training. Either Transfer Learning or training from scratch can be done here. We used Pre-trained model called ResNet50 from Keras. By using a pre-trained model we saved time as someone else has already spent the time and compute resources to learn a lot of features and this model benefits from it. We can use the neural network to extract these feature vectors for new images even if the network hasn't seen them before. The feature vectors, or deep features can then be used to classify the images. This is the basis of transfer learning and is much faster than training a deep convolutional neural network from scratch.

This is the last part of the whole process. Here I have used deep neural nets with 3 convolution layers. In this part image pool is given as input in neural nets along with labels. This on output gives predicted labels. In this step I have used deep neural net library provided by Keras and used github code [2] as base.

	class 0	**class 1**	**class 2**	**class 3**	**class 4**
class 0	170	53	20	14	0
class 1	41	69	14	6	1
class 2	18	26	25	4	0
Class 4	3	8	5	8	1
Class 5	0	2	6	2	4
	232	158	70	34	6

Table 5.2 Confusion Matrix

5.4 Deploying the Model

We used a customizable web app to deploy your DL model with ease. The web-app code was taken from a github repository. The web-app was uses Flask.

We inserted our own model and edited the output format to match the results we wanted to receive (ie. between 5 classes or 2 classes) when an image was uploaded onto the webpage. It is a very neat implementation which is enough for our research presentation purposes.

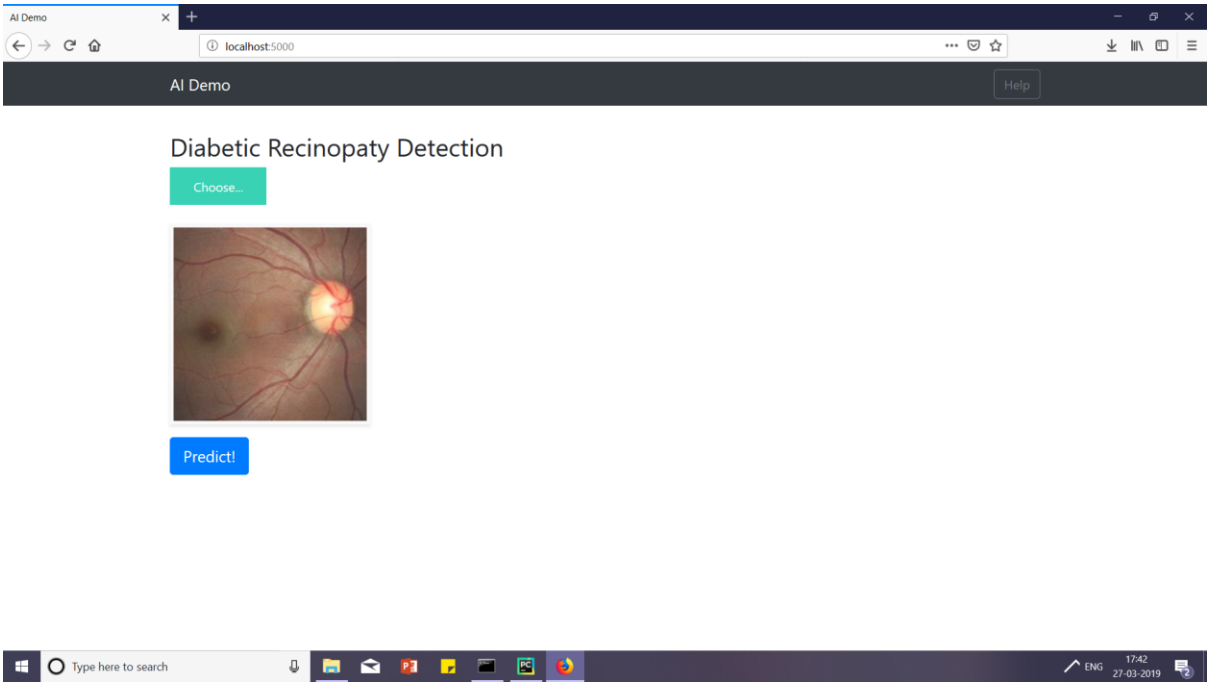

Figure 5.3 Webapp

CHAPTER: 6

RESULTS

In experimental result, we observe that the accuracy of the both training and testing set is quite similar and for both training and testing dataset. The implementation of transfer learning and layers added by us give an accuracy rate of only 51% for 5 classes. However the same CNN algorithm is giving higher accuracy rate of around 70% when trained for only 2 classes – DR and No DR. So, we can say that this algorithm will give us more accurate prediction about the disease. There have been very low implementations of using transfer learning along with an efficient, low resource requirement methods.

```
[ ]  model.fit(X_train, Y_train, epochs=5, validation_data=(X_valid, Y_valid), verbose=1)

     WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/ops/math_ops.py:3066: to_int32 (from tensorflo
     Instructions for updating:
     Use tf.cast instead.
     Train on 790 samples, validate on 88 samples
     Epoch 1/5
     790/790 [==============================] - 42s 53ms/step - loss: 7.6608 - acc: 0.4949 - val_loss: 8.6085 - val_acc: 0.4659
     Epoch 2/5
     790/790 [==============================] - 26s 33ms/step - loss: 7.8550 - acc: 0.5127 - val_loss: 8.6085 - val_acc: 0.4659
     Epoch 3/5
     790/790 [==============================] - 26s 33ms/step - loss: 7.8550 - acc: 0.5127 - val_loss: 8.6085 - val_acc: 0.4659
     Epoch 4/5
     790/790 [==============================] - 26s 33ms/step - loss: 7.8550 - acc: 0.5127 - val_loss: 8.6085 - val_acc: 0.4659
     Epoch 5/5
     790/790 [==============================] - 26s 33ms/step - loss: 7.8550 - acc: 0.5127 - val_loss: 8.6085 - val_acc: 0.4659
     <keras.callbacks.History at 0x7f1403e095c0>
```

Figure 6.1 Accuracy (5 Classes)

CHAPTER: 7

SUMMARY & FUTURE SCOPE

7.1 Innovation:

- Eliminates human efforts & errors
- Drastically reduces time required for diagnosis
- Frees up skilled experts to do other work

7.2 Future scope:

- Improve accuracy after having narrowed down the appropriate algorithm to be used.
- This can be incorporated into a user-friendly software.

7.3 Tools and technologies Required

- Advanced Statistics knowledge
- Python
- Pandas, Numpy, Matplotlib
- Keras
- Flask, Javascript, CSS, HTML
- Tensorflow / Theano
- Pycharm
- Google Colaboratory / Computer with GPU

7.4 Summary

In our paper, we proposed a system which will be able to detect diabetic retinopathy from the image of an eye of a patient. With our proposed system, the doctors can however spend less time on the overall detection process and can take more care of his/her patient. We have narrowed down to the algorithm we find most suitable for the task, and will work on improving its performance in the future. This overall work is very important because early detection is very important for a patient with diabetic retinopathy because without that the patient can go blind in extreme cases. So hopefully, if we can integrate this system with medical science then many doctors will be able to save the vision of their patients.

CHAPTER: 8

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Chapter: 9

Appendix

9.1 Periodic Progress Reports (PPR)

- **Periodic Progress Report - 1 (PPR-1)**

PPR Details

Periodic Progress Report : First PPR

Project : Diabetic Retinopathy Detection Using Eye Images

Status : Submitted

1. What Progress you have made in the Project ?

Analysed the data-set according to the given classes, and found huge data imbalance between class 0 and class 1 through 4 combined. Took the data-set and derived a subset from it, to be able to train a neural network in an environment with a relatively small amount of resources.

2. What challenge you have faced ?

The orginal data-set was of 85 GB and consisted of high resolution medical images from a variety of sources, hence there was high variance in images of the same data-set. This made finding an appropriate subset difficult.

3. What support you need ?

Finding the right size of subset to use, and suggestions to get rid of data imbalance.

4. Which literature you have referred ?

Literature referred included Matplotlib tutorials found at : https://matplotlib.org/tutorials/index.html

Document : Download

Comments

Comment by Internal Guide :

None

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

- **Periodic Progress Report - 2 (PPR-2)**

PPR Details

Periodic Progress Report : Second PPR

Project : Diabetic Retinopathy Detection Using Eye Images

Status : Submitted

1. What Progress you have made on the Project ?

- Applied data preprocessing methods decided upon in the previous sem: 1• Resize images to 256*256 2• Crop area which didnt contain retina, (noise reduction) 3• Mirror, Rotate images by 90, 120, 150, 260 and create separate copies of each iteration for images of class 1-4, to reduce data imbalance.

2. What challenge you have faced ?

- To find a way to solve problem of having right and left eye images.

3. What support you need ?

- Appropriate python libraries to manipulate a large amount of images.

4. Which literature you have referred ?

OpenCV tutorials : http://docs.opencv.org/master/d9/df8/tutorial_root.html

Document : Download

Comments

Comment by Internal Guide :

None

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

- **Periodic Progress Report - 3 (PPR-3)**

PPR Details

Periodic Progress Report : Third PPR

Project : Diabetic Retinopathy Detection Using Eye Images

Status : Submitted

1. What Progress you have made in the Project ?

- Imported ResNet50, a pretrained Keras model. - Added extra layers to make it suitable for two class classification of retina images. - Trained model on personal laptop. - Found 60% accuracy for two classes (Class 0 and Class 1-4)

2. What challenge you have faced ?

- not able to assign proper weights to neural network.

3. What support you need ?

- to learn and practice more about building neural nets in keras.

4. Which literature you have referred ?

https://machinelearningmastery.com/tutorial-first-neural-network-python-keras/

Document : Download

Comments

Comment by Internal Guide :

None

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

- **Periodic Progress Report - 4 (PPR-4)**

PPR Details

Periodic Progess Report : Forth PPR

Project : Diabetic Retinopathy Detection Using Eye Images

Status : Submitted

1. What Progress you have made in the Project ?

- Improve existing neural network with reference from another github code. - Converted CNN to classify into 5 different classes. (49% accuracy) - Trained the model on google colaboratory with more data. - Implemented a flask web-server to be able to deploy .h5 model and us it through a web page.

2. What challenge you have faced ?

- Finding more features. - Improving accuracy on 2 class and 5 class classifier. - Installing all correct version of libraries onto personal machine.

3. What support you need ?

- Help setting up a google colaboratory notebook. - Better feature extraction with more preprocessing steps. - Properly modify a neural network and using transfer learning.

4. Which literature you have referred ?

- https://github.com/sthorn/retinopathy - https://towardsdatascience.com/develop-a-nlp-model-in-python-deploy-it-with-flask-step-by-step-744f3bdd7776 - https://colab.research.google.com/

Document : Download

Comments

Comment by Internal Guide :

None

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None