A Project Report

on

DIABETIC RETINOPATHY

Submitted for partial fulfilment for the award of the

Bachelor of Technology

In

Information Technology

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Certificate

This is to certify that the project entitled **"AUTOMATIC DETECTION AND ESTIMATION OF THE LEVELS OF SEVERITY IN DIABETIC RETINOPATHY"** in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology from National Institute of Technology, Raipur is the record of the candidate own work carried out by **ABHIJIT SINHA, KAVETI RAVI TEJA, NITIN BHOJWANI AND SAGAR SAHU** under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree.

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Abstract

Diabetic retinopathy (DR) is one of the leading disabling chronic diseases, and one of the leading causes of preventable blindness in the world. Early diagnosis of diabetic retinopathy enables timely treatment and in order to achieve it a major effort will have to be invested into screening programs and especially into automated screening programs. Through advanced image analysis techniques, retinal images are analysed for abnormalities that define and correlate with the severity of DR. For this purpose, features from the retinal images used are Blood Vessels, Exudates and Optic Disc. A through study is done in this area in recent days and based on that we had plotted many hypotheses. On the basis of hypothesis and the research happened on Diabetic retinopathy we had started designing the image processing model and the statistical model for the prediction model that is going to determine the severity of Diabetic retinopathy. In this duration we have been able to develop and estimate the data model for the blood vessel, optic disc and exudates features. The Designed system is open sourced and will be released to public domain under any open sourced licence so that our efforts are not limited to us. This makes development as well as maintenance of this system inexpensive and we will be able to provide user something valuable.

1. INTRODUCTION

1.1. DIABETIC RETINOPATHY

The effect of diabetes on the eye is called Diabetic Retinopathy (DR) which can cause partial or even complete loss of vision if not detected and taken corrective measures at the early stage. Diabetic Retinopathy is effecting the young age population of developing as well as developed countries. It is found that diabetes affects 4 per cent of the world's population. Also, every patient, who has diabetes for more than 10 years, has about 80 per cent chances of this disorder. [**1**] In India itself, as reported by the World Health Organization (WHO), the diabetic patients are increasing drastically, so the diabetic retinopathy has become one of the most possible causes of visual disability.

Diabetic Retinopathy is caused because of changes in the blood vessels of the eye. It is caused by high blood sugar levels damaging the network of tiny blood vessels that supply blood to retina. It usually affects both eyes. Typically, it has no symptoms during the early stages. Many times, when symptoms become noticeable the condition is often at an advanced stage. Sometimes, the only detectable symptom is a sudden and may be nearly complete loss of vision.

According to a study conducted by the Chennai Urban Rural Epidemiology, higher frequency of all the grades of retinopathy was observed in known diabetic subjects compared to newly detected cases. [**2**]

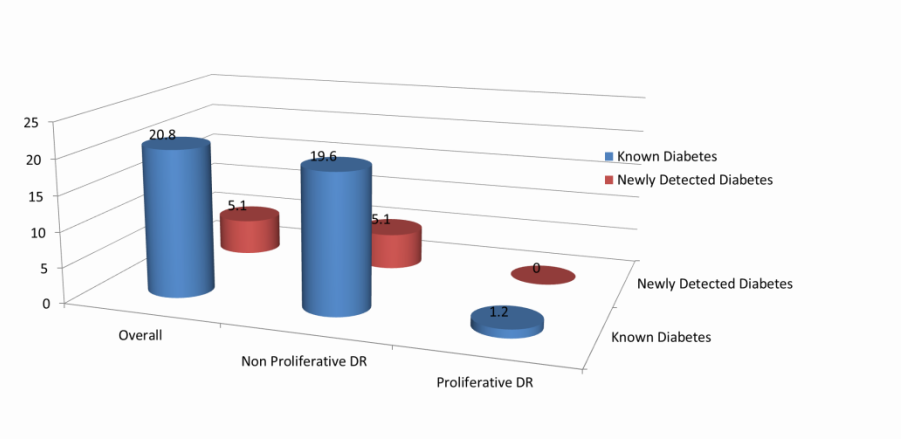

Figure 1 Diabetic retinopathy in India [3**]**

1.2. THE HUMAN EYE

Eye is an organ associated with vision. It is housed in socket of bone called orbit and is protected from the external air by the eyelids. [**4**] The cross section of the eye is as shown in Figure 2 while that of retina is as shown in Figure 3 below

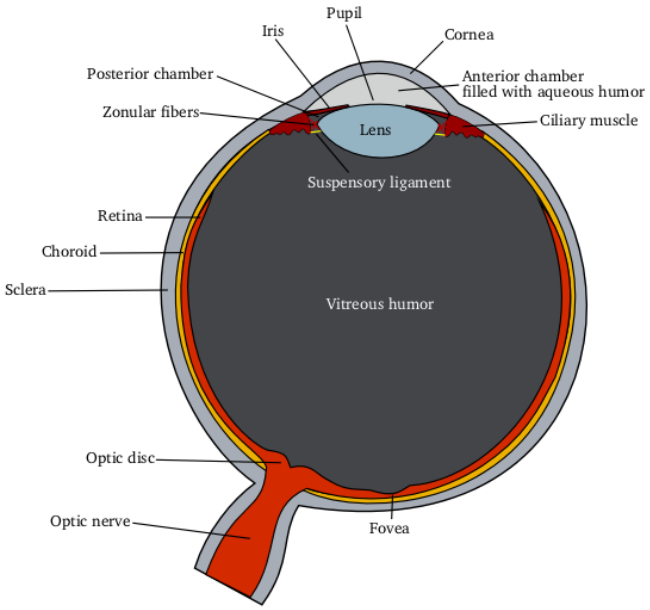

Figure 2 Structure of eye

1.2.1. Functions of various parts:

- **Iris**: The iris (plural: **irides** or **irises**) is a thin, circular structure in the eye, responsible for controlling the diameter and size of the pupil and thus the amount of light reaching the retina.
- **Pupil**: The pupil is a hole located in the center of the iris of the eye that allows light to enter the retina.
- **Cornea**: The clear, transparent front portion of the fibrous coat of the eye; functions as an important refractive medium.
- **Retina**: Light-sensitive tissue at the back of the eye which transmits visual impulses via the optic nerve to the brain.
- **Choroid**: Blood vessel-rich tissue behind the retina that is responsible for its nourishment.

- **Sclera**: The tough white protective coat of the eye. The portion of the sclera that surrounds the cornea is covered by the conjunctiva.
- **Optic Disc**: The main function of the optical disk is to act as an entry point for the main blood vessels that supply blood to the retina.
- **Optic Nerves**: The nerve at the back of the eye that carries visual impulses from the retina to the brain. The area at which the optic nerve connects with the retina is known as the optic disc.
- **Fovea**: The Fovea is located in center of the macula of the retina. It's responsible for sharpening the central vision. Because of this humans are able to see directly in front of them to do things such as read and drive.
- **Vitreous Humor**: Transparent, colorless mass of soft, gelatinous material that fills the center of the eye behind the lens.
- **Aqueous Humor:** Watery liquid that flows between the lens and the cornea and nourishes them.
- **Lens:** The transparent tissue behind the iris that bends light rays and focuses them on the retina.
- **Cilliary Muscle:** The function of the Cilliary muscle is to accommodate the eye when viewing objects at different distances.

1.2.2. How Eye Works?

Light enters the eye through the pupil and is focused on the retina. The lens assists in focusing images from different distance. The amount of light entering the eye is controlled by the iris, by closing when light is bright and opens when light is dim. To the outside of the eye is a transparent white sheet called conjunctiva. Cilliary muscles in Cilliary body control the focusing of lens automatically. Choroids form the vascular layer of the eye supplying nutrition to the eye structures. Image formed on the retina is transmitted to brain by optic nerve.

Optic disk is brighter than any part of the retina image and is normally circular is shape. It is also the entry and exist point for nerves entering and leaving the retina to and from the brain. Near to the centre of the retina is an oval shape object called macula. The fovea is near the centre of the macula and it contains packed cone cells.

Due to high amount of light sensitive cells, the fovea is responsible for the most accurate vision. [**4**]

1.2.3. Cross Section of Retina

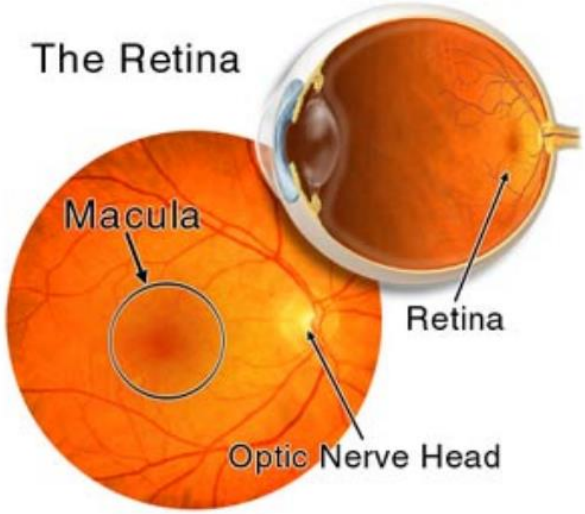

Figure 3 Cross Section of Human Retina [4]

The retina is a multi-layered sensory tissue that lines the back of the eye. It contains millions of photoreceptors that capture light rays and convert them into electrical impulses. These impulses travel along the optic nerve to the brain where they are turned into images. There are two types of photoreceptors in the retina: rods and cones. The retina contains approximately 6 million cones. The cones are contained in the macula, the portion of the retina responsible for central vision. They are most densely packed within the fovea, the very centre portion of the macula. Cones function best in bright light and allow us to appreciate colour. [**4**]

1.2.4. Abnormalities associated with the eye

Diabetic Retinopathy is caused when retina of eye is affected due to diabetes. Early treatment is necessary to avoid loss of vision. [**5**] DR is classified into different types according to occurrence of various lesions i.e. Micro aneurysms, Haemorrhages, Hard Exudates, Soft Exudates, and Neovascularisation etc. These are explained below:

- **Micro-aneurysms:** A retinal micro aneurysm is a tiny area of blood protruding from an artery or vein in back of the eye. These protrusions may open and leak blood into the retinal tissue surrounding it. Their size ranges from 10-100 microns i.e. less than 1/12th diameter of an average optic disc and is circular in shape.

- **Hemorrhages:** Occurs in the deeper layers of the retina and are often called 'blot' hemorrhages because of their round shape.
- **Hard Exudates:** Hard exudates are yellow spots seen in the retina, usually in the posterior pole near the macula. They are lipid break-down products that are left behind after localized edema resolves. [**5**]
- **Soft Exudates:** Superficial white, pale yellow-white or greyish-white areas with ill-defined (feathery) edges, frequently showing striations parallel to the nerve fibre layer are the lesions included. [**6**]
- **Optic Disc:** That location of eye, where all the optic nerves enter into the eye. It is also known as Blind Spot. The optic disc (OD) is considered one of the main features of a retinal fundus image.

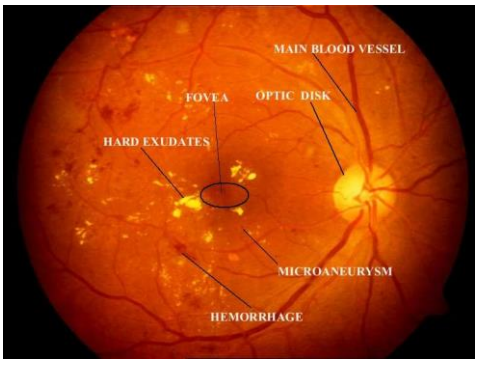

Figure 4 Features in Diabetic Eye

1.3. STAGES OF DIABETIC RETINOPATHY

Diabetic Retinopathy has mainly four stages, based on the progress in the disorder:

1.3.1. Mild Non-Proliferative Retinopathy- At this early stage, micro aneurysms may occur in the retinas tiny blood vessels. These manifestations of the disease are small areas of balloon-like swelling. Approximately 40 percent of people with diabetes have at least mild signs of DR. [**7**]

1.3.2. Moderate Non-Proliferative Retinopathy- As the disease progresses, some blood vessels that nourish the retina are blocked. Cotton wool spots and limited amount of venous bleeding can be seen. Generally 16 percent of patient with moderate NPDR will develop PDR within one year. [**7**]

1.3.3. Severe Non-Proliferative Retinopathy- Many more blood vessels are blocked, depriving several areas of the retina with their blood supply. These areas of the retina send signals to the body to grow new blood vessels for nourishment. [**7**]

1.3.4. Proliferative Retinopathy-This is the advanced stage, the signals send by the retina for nourishment triggers the growth of new blood vessels. These new blood vessels are abnormal. They grow along the retina and along the surface of the clear, vitreous gel that fills the inside of the eye. But these blood vessels do not cause symptoms or vision loss. However, they have thin, fragile walls. If they leak blood, severe vision loss and even blindness can result. About 3 percent of people in this condition may suffer severe visual loss. [**7**]

1.4. NEED FOR AUTOMATION OF DIABETIC RETINOPATHY DETECTION

Diabetic retinopathy is one of the leading disabling chronic diseases, and one of the leading causes of preventable blindness in the world. It was found to be the fourth most frequently managed chronic disease in general practice in 2009, and the projections go as high as the second most frequent disease by the year 2030.

Diabetic retinopathy cannot be cured but effective treatments have been established that preserve vision and reduce the risk of vision loss. But, treatment is successful only if the disorder is detected in earlier stages. And to check whether there is any abnormality or the disorder, the person suffering from diabetes, needs to visit the eye clinic regularly in the interval of 6 to 12 months.

Now, to avoid such a tedious job, consuming patient's much time and money, there is an urgent need of the automatic detection techniques. That is the reason for which efforts that has been undertaken in last few years in developing tools to assist the automatic diagnosis of diabetic retinopathy. Also, the image processing techniques can reduce the work of ophthalmologists and the tools used automatically may detect its severity.

1.5. DIABETIC RETINOPATHY SEVERITY LEVEL

Table 1 Diabetic Retinopathy- Clinical Signs and the Severity Level [8**]**

S.no.	Clinical Signs	Severity Level	Outcome
1.	No abnormalities within 2 DD of centre of macula	No Retinopathy	Screen again in 12 months
2.	< 5 micro aneurysms and/or dot haemorrhages	Minimal	Screen again in 12 months
3.	> 4 micro aneurysms and/or dot haemorrhages and/or exudates > 2 DD from centre of macula	Mild	Screen again in 6 months
4.	Up to 3 quadrants of blot or larger haemorrhages and/or Up to 1 quadrant of venous bleeding	Moderate	Refer to ophthalmologist within 6 weeks
5.	Definite IRMA and/or 2 quadrants or more of venous bleeding and/or 4 quadrants of blot or larger haemorrhages	Severe	Urgent referral to ophthalmologist within 4 weeks

1.6. OBJECTIVE

The objective of this study is to develop an automate system for the detection and estimation of the severity of the diabetic levels of any person. The estimation of the severity is based on various features of eyes which are determined by the various image processing techniques that will be discussed later in this report. These features will be further analysed and quantified by the statistical learning algorithm that will put the statistical model for the estimation of the severity levels of Diabetic Retinopathy.

2. LITERATURE

2.1. LITERATURE SURVEY

Sinthaniyothin uses maximum variance to obtain the optic disk centre and a region growing segmentation method to obtain the exudates. Tracks the optic disk through a pyramidal decomposition and obtains disk localization from a template-based matching that uses the Hausdorff distance measure on the binary edge image. However, the above methods will fail if exudates similar in bright-ness and size to the optic disk are present. It combines matched-filter responses, confidence measures and vessel boundary measures to obtain blood vessels robustly.

But the paper doesn't extend it to identify diabetic retinopathy in images [**9**]. It has used blood vessel intersection property to obtain the optic disc. However, they use the whole blood vessel network which can lead to wrong or inconclusive results because of noise from the fringe blood vessels. The optic disc is localized exploiting its high grey level variation. This approach has been shown to work well, if there are no or only few pathologies like exudates that also appear very bright and are also well contrasted. No method is proposed for the detection of the contours. In contrast, we use only the main blood vessels, which is more robust. Statistical classification techniques have been very popular lately for the problem of severity classification. An area threshold is used to localize the optic disc.

The contours are detected by means of the Hough transform, i.e., the gradient of the image is calculated, and the best fitting circle is determined. This approach is quite time consuming and it relies on conditions about the shape of the optic disc that are not always met. Sometimes, the optic disc is even not visible entirely in the image plane, and so the shape is far from being circular or even elliptic. Exudates have color properties similar to the optic disk while Micro aneurysms are difficult to segment due to their similarity in color and proximity with blood vessels.

In order to classify detected features, typically, candidate regions are detected using color/morphological techniques and then classification is done on these regions

using some classifier. Many classifiers have been tried including Neural Networks, PCA, Fuzzy C-means clustering, Support Vector Machines, and simple Bayesian classification. STARE is a complete system for various retinal diseases. The optic disk is detected using blood vessel convergence and high intensity property.

Recently, many studies have been conducted on automated detection of DR. Kugo et al. proposed a method for the detection of micro aneurysms by using a watershed transform on fluorescein angiograms. Akita et al. proposed a method for detecting micro aneurysms by the region growing technique in order to analyse fluorescein angiograms. Other groups have investigated methods that use regular retinal fundus images captured without using the contrast medium.

Usher et al. reported a method for detecting haemorrhages, micro aneurysms, and exudates by using adaptive intensity thresholding combined with an edge enhancement operation. Niemeyer et al. proposed a method for the detection of red regions by pixel classification and feature analysis. The sensitivity and specificity of their method were 100% and 87%, respectively. Nagayoshi et al. reported a method that included normalization processes in addition to Usher's method. Grisan et al. proposed a method for detecting the dark lesions on the basis of local thresholding and pixel density. [**10**]

2.2. IMAGE PROCESSING TECHNIQUES

2.2.1. Color Space

In digital image processing, images are either indexed images or RGB (Red, Green, and Blue) images. An RGB image is an M x N x 3 array of colour pixels, where each colour pixel is a triplet corresponding to red, green and blue components of RGB image at specified special location. The range of value of an RGB is determined by its class. An RGB image of class double, has value in the range of [0 1], while class of uint8 is [0 255], similarly for the range [0, 65535] is called class uint16.

There exist other colour spaces or models in some applications other than the two models mentioned above, these include NTSC (luminance(Y), hue(I), saturation(Q) colour model), HIS (luminance(H), hue(I), saturation (S)) colour model), YC_bC_r

(luminance(Y), hue(I), saturation (Q)) colour model), HSV (hue(H), saturation(S), Value(V)) colour model), CMY(cyan(C), Magenta(M), Yellow (Y) colour model) and CMYK(cyan(C), Magenta(M), Yellow (Y), black(K)) colour model. [**11**]

2.2.2. Image Filtering

Filtering is used to suppress the unwanted noise which gets added into the fundus image. Here Averages, Gaussian etc. filtering are used as it is very robust and has the capability to filter any sort of noise. [**11**]

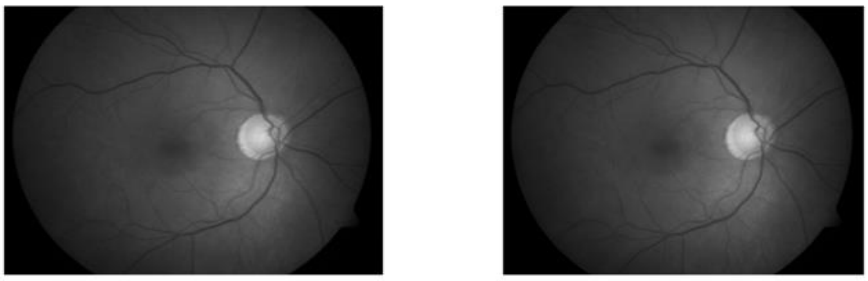

Figure 5 Image Filtering Process: a) Input b) Output

2.2.3. Histogram Equalization

Histogram equalization is performed to enhance the image quality. Histogram equalization is nothing but finding of cumulative distribution function for a given probability density function. After the transformation, the image will have an increased dynamic range, high contrast and probability density function of the output will be uniform. Instead of using normal histogram equalization, adaptive histogram equalization is used as it operates on small regions in the image which are called tiles. Adaptive histogram combines neighbouring tiles using bilinear interpolation to eliminate artificially induced boundaries. [**11**]

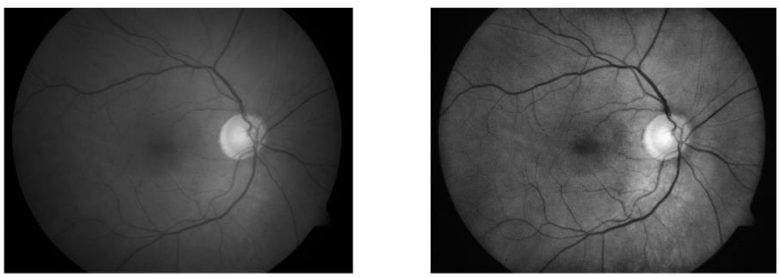

Figure 6 Histogram Equalization

2.2.4. Segmentation

The main objective of segmentation is to group the image into regions with same characteristics. The goal of the segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyse. Image segmentation is typically used to locate objects and boundaries (lines, curves etc.) in the images. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. [**11**]

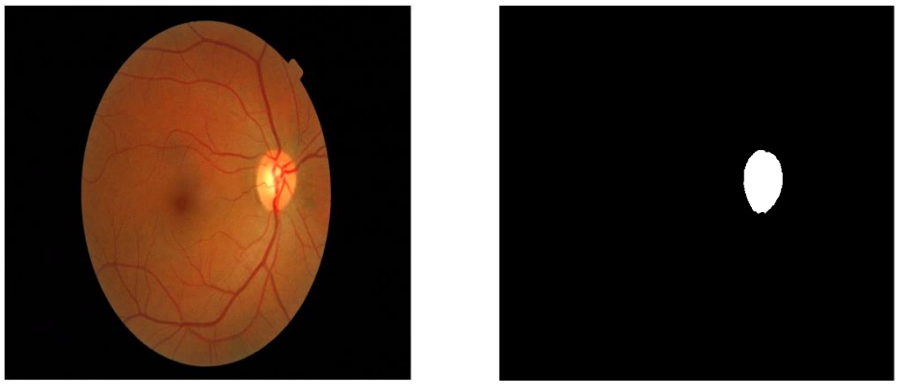

Figure 7 Image Segmentation: a) input b) Output

2.2.5. Thresholding

Simple thresholding is a simple method and highly intuitive method of segmenting image based on the pixel intensity value. It is based on the assumption that the intensity value of the image can be group into two non-overlapping groups namely object and background of the image.

Suppose the intensity of an object is denoted by f (t, u). Any pixel with value below this threshold, i.e. f(x, y) < T into a class called Background Information and any pixel with intensity value greater than T i.e. f(x, y) > T into another class called Object. In the segmented binary image, background pixels have value of zero while object pixels have value 1.

$$g(x,y) = \begin{Bmatrix} 1, if \;\; f(x,y) > T \\ 0, if \;\; f(x,y) < T \end{Bmatrix}$$

In our application we had used multiple thresholding i.e. using different RGB or HSI color intensity range for different features. When a pixel is fall in a range it is highlighted else not. [**11**]

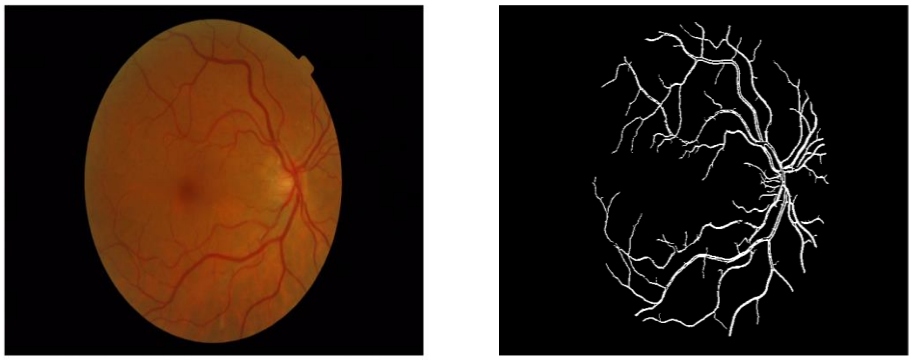

Figure 8 Image Thresholding: a) Input b) Output

2.2.6. Median Filtering

The median filter is a nonlinear filter, which can reduce impulsive distortions in an image and without too much distortion to the edges of such an image. It is an effective method that of suppressing isolated noise without blurring sharp edges. Median filtering operation replaces a pixel by the median of all pixels in the neighbourhood of small sliding window.

The advantage of a median filter is that it is very robust and has the capability to filter only outliers and is thus an excellent choice for the removal of especially salt and pepper noise and horizontal scanning artefacts. [**11**]

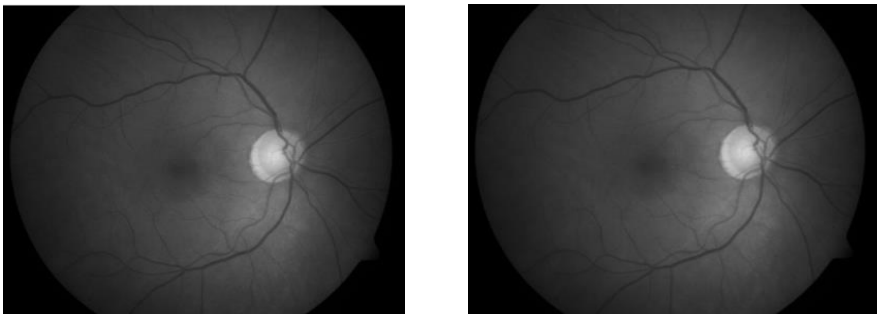

Figure 9 Median Filtering a) Input b) Output

2.2.7. Morphological Operations

Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image. According to Wikipedia, morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. Morphological techniques probe an image with a small shape or template called a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighbourhood of pixels. The morphological operations include dilation, erosion, opening, closing and skeletonization etc. [**11**]

2.2.7.1. Dilation

Dilation is a process that thickens objects in a binary image. The extent of this thickening is controlled by the Structuring Element (SE) which is represented by a matrix of 0s and 1s. Mathematically, dilation operation can be written in terms of set notation as below:

$$A \oplus A_s = \left\{ z \mid \left(A_s^{'} \right)_z \cap A \neq \phi \right\}$$

Where Φ is an empty element and as is the structuring element. The dilation of A by A_s is the set consisting of all structuring element origin locations where the reflected and transmitted A_s overlaps at least some portions of A. Dilation operation is commutative and associative. [**11**]

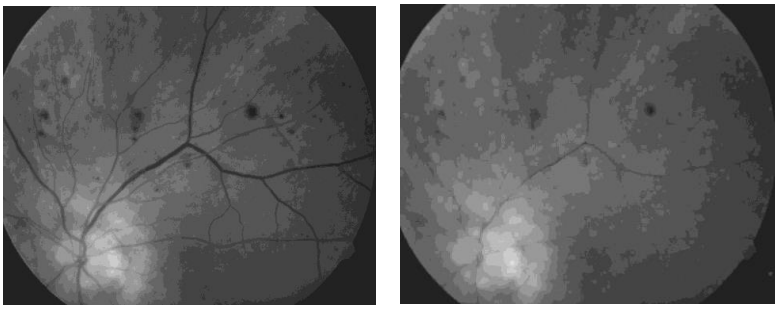

Figure 10 Dilation Process a) Input b) Output

2.2.7.2. Erosion

Erosion is one of the two basic operators in the area of mathematical morphology, the other being dilation. It is typically applied to binary images. The basic effect of erosion operator on binary image is to erode away boundaries of region of foreground pixels (i.e. white pixels typically).Thus area of foreground pixels shrink in size, and holes within those areas become larger. [**11**]

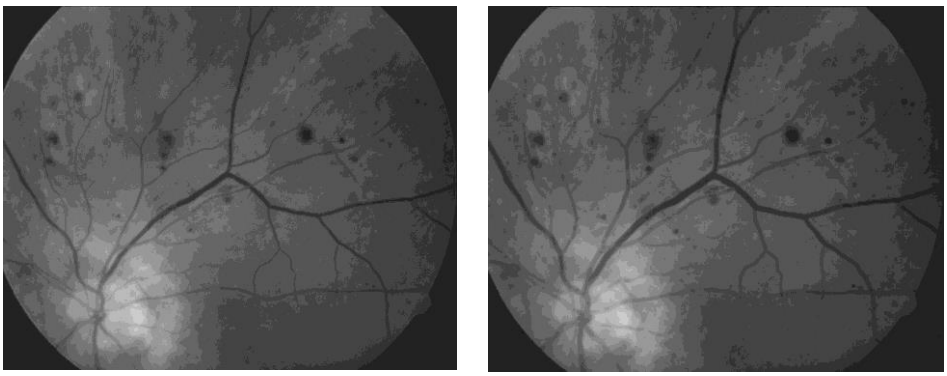

Figure 11 Erosion Process a) Input b) Output

2.2.7.3. Opening and Closing

In image processing, dilation and erosion are used most often and in various combinations. An image may be subjected to series of dilations and or erosions using the same or different SE. The combination of this two principles leads to morphological image opening and morphological image closing. Morphological opening can be described as an erosion operation followed by a dilation operation. Morphological opening of image X by Y is denoted by XOY, which is erosion of X by Y followed by dilation of the result obtained by Y closing and opening.

$$X \, o Y = \left(X \oplus Y \right) \Theta \, Y$$

Morphological closing can also be described as dilation operation followed by erosion operation. Morphological Closing of Image X by Y is denoted by X●Y, which is dilation of X by Y followed by erosion of the result obtained by Y.

$$X \bullet Y = \left(X \, \Theta Y \right) \oplus Y$$

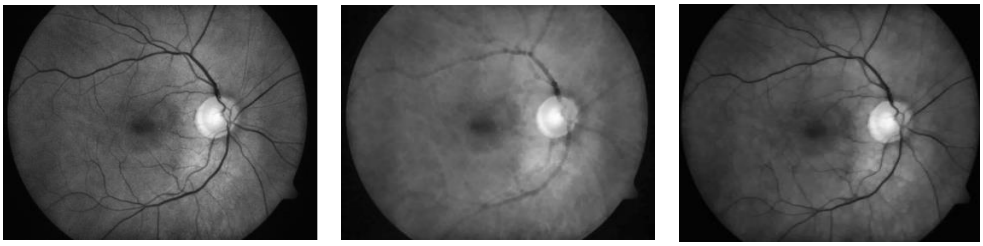

Figure 12 a) Input image b) Image after Close operation c) Image after Open operation

2.3. DATA ANALYSIS TECHNIQUE

2.3.1. KNN Classifier

KNN as the name suggests is K Nearest Neighbour Classification algorithm. It is very versatile and its applications range from vision to proteins to computational geometry to graphs and so on. KNN is one of the top data mining algorithms.

KNN is a non-parametric lazy learning algorithm. It means that KNN technique does not make any assumptions on the underlying data distribution. This makes it useful in practical world data. It is also a lazy algorithm which means it does not use any training data points to do any generalization. Lack of generalization means that KNN keeps all the training data. More exactly, all the training data is needed during the testing phase.

2.3.1.1. Assumptions in KNN

KNN assumes that the data is in a *feature space*. More exactly, the data points are in a metric space. The data can be scalars or possibly even multidimensional vectors. Since the points are in feature space, they have a notion of distance – which can be Euclidean distance, Minkowski distance, Mahalanobis distance.

Euclidean Distance between 2 points P (x, y) and Q (a, b) is given as

$$Distance\ (P, Q) = \sqrt{(x-a)^2 + (y-b)^2}$$

Each of the training data consists of a set of vectors and class label associated with each vector. In the simplest case, it will be either + or – (for positive or negative classes). But KNN, can work equally well with arbitrary number of classes.

We are also given a single number "k". This number decides how many neighbours (where neighbours are defined based on the distance metric) influence the classification. This is usually an odd number if the number of classes is 2. If k=1, then the algorithm is simply called the nearest neighbour algorithm.

2.3.1.2. How KNN Classifier Works?

The input to KNN consists of Training Data **(T)**, Number of neighbours **(N)** and Input tuple to classify **(t)**.The output consists of Class **(c)** to which t is assigned. The steps of algorithm are:

1. Find the set of neighbours N for t using Euclidean distance.
2. For each neighbour d ∈ D do

   If (|N| <= K)

   Then

   Do N=N ∪ d;

   Else

   If ∋ u ∈ N such that sim (t, u) >= sim (t, d) then

   Begin

   N = N-u;

   N = N ∪ d;

   End
3. Find Class for classification c to which most of u ∈ N are classified.

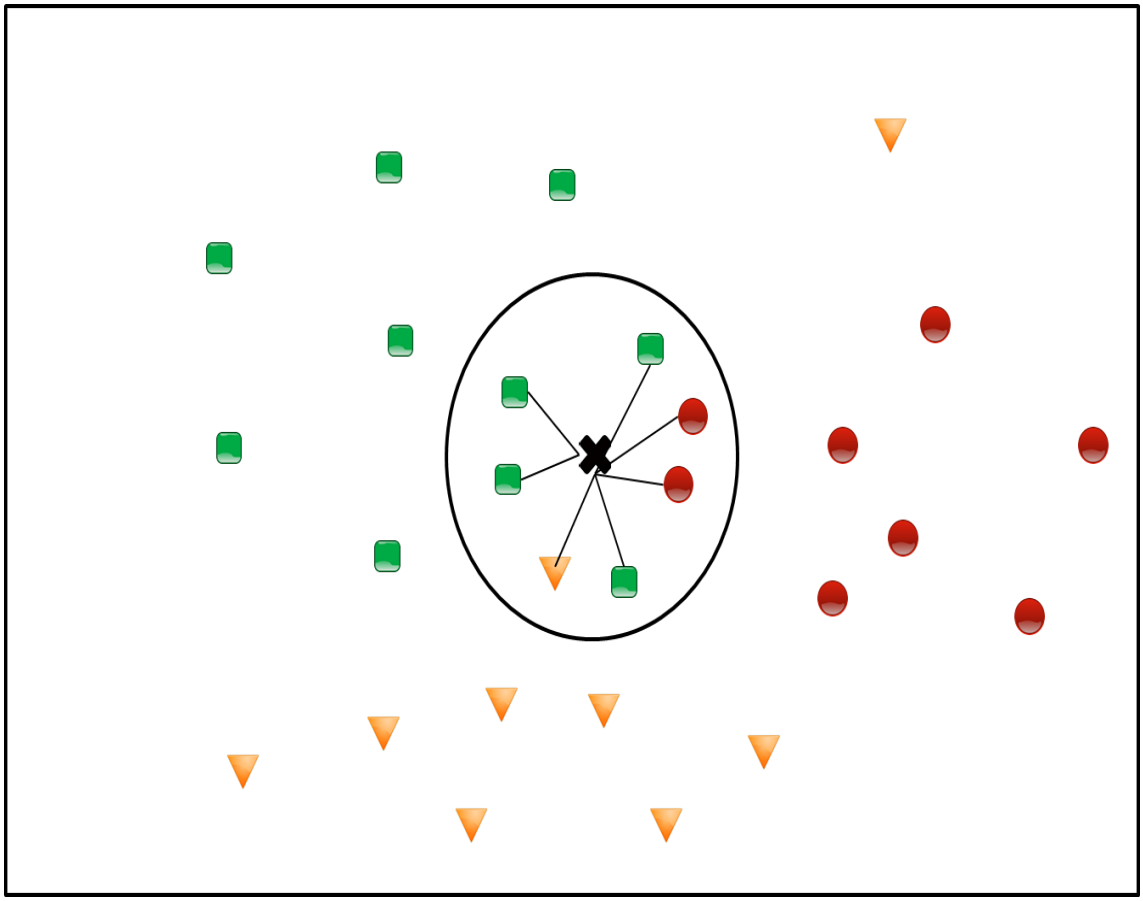

Figure 13 kNN Classification

In this diagram, there are three classes are there green red and green and we had to classify test data class represented by black cross. We first calculate the Euclidean distance and draw a decision boundary around 7 nearest neighbours. Now we can see green points are more in number in a given 7 neighbours and so the test data will be put in the green class. And in this way the classification of data takes place in kNN classification.

3. WORKING ARCHITECTURE

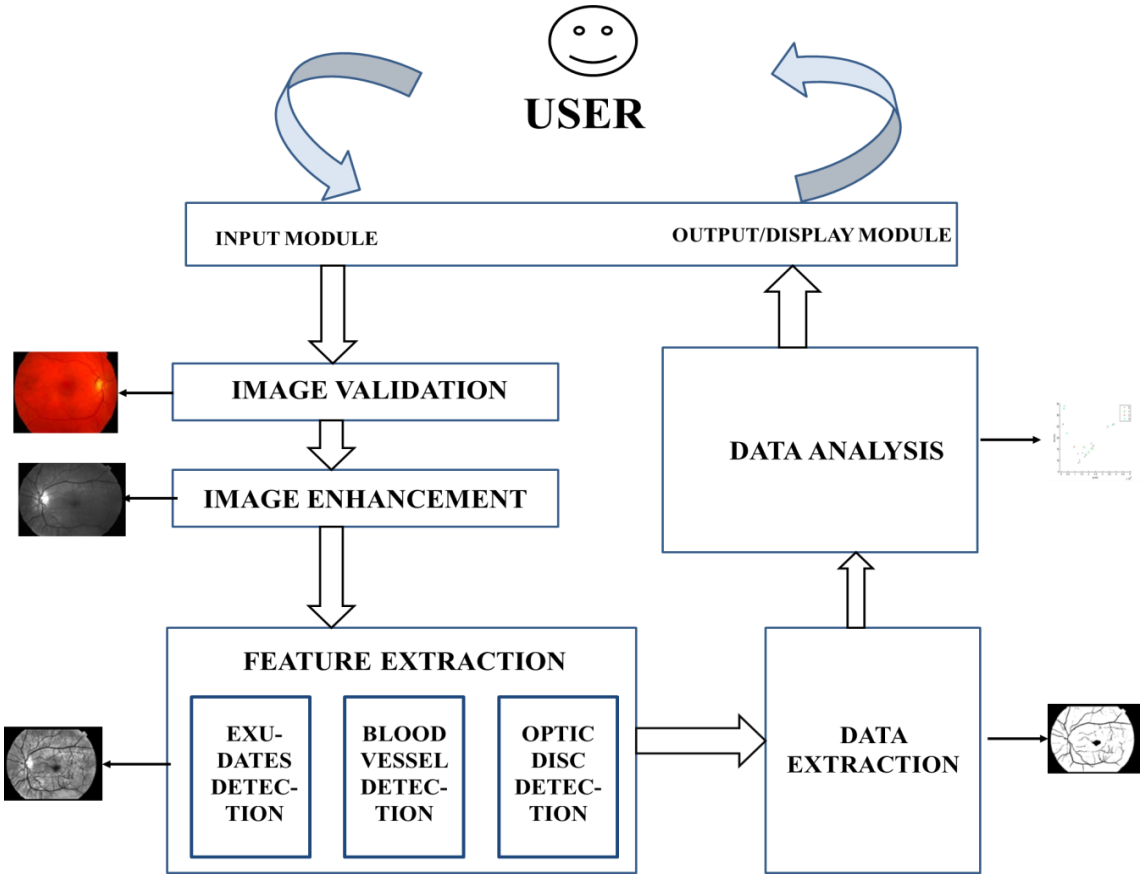

Figure 14 Working Architecture

3.1. INPUT EYE IMAGE

The user inputs an eye's fundus image. This image includes the interior surface of the eye (fundus) with Optic disc. Medical signs that can be detected from observation of eye fundus are haemorrhages, exudates, cotton wool spots, blood vessel abnormalities and pigmentation. [**1**]

3.2. IMAGE VALIDATION

In this process, the input eye image is validated to be an eye image. For this, the circular mask is used to confirm that the image is an eye image. This mask is centred at the fovea i.e. the centre of the eye fundus image.

3.3. IMAGE ENHANCEMENT

Digitized images usually suffer from poor image quality, particularly lack of contrast and presence of shading and artefacts, due to the deficiencies in focusing, lighting, specimen staining and other factors. Because some features are hardly detectable by eye in an image, we often transform images before display Image enhancement is a digital processing method which does its best to improve image vision and makes the image adapt to be processed by computer.

As well, the need for contrast enhancement also arises from the fact that current softcopy display devices are incapable of displaying as many different discernible levels of luminance as can be recorded in a digital image. It really enhances some information inside the image selectively and restrains the other ones. In this way, it is easy to detect and recognize useful information. It generally yields satisfactory results if the proper technique is selected for a given application along with the proper processing parameters.

Principle objective of Image enhancement is to process an image so that result is more suitable than original image for specific application. The process of improving the quality of the stored image by manipulating it is the Image Enhancement. Other problems corrected by this process include the enhancement of the contrast between the exudates and vein network and the background to aid in segmentation and detection of the abnormalities. Process involves in this stage include Color Space Conversion, Gray Level Slicing, Intensity and Threshold Transformations, various Filtering and Adaptive Histogram Equalization.

3.4. FEATURE EXTRACTION

Automated detection of certain features in retinal images can assist in early diagnosis and screening of Diabetic Retinopathy. A robust and computationally efficient approach for the localization of the different features in a fundus retinal image is used. Since many features have common intensity properties, geometric features and correlations are used to distinguish between them.

We propose a new constraint for optic disk detection where we first detect the major blood vessels first and use the intersection of these to find the approximate location of the optic disk. This is further localized using color properties. We also show that many of the features such as the blood vessels, exudates and optic disc can be detected quite accurately using different morphological operations applied appropriately. The detailed description of the methods applied, is given in the Experiment section. [**6**]

3.5. DATA EXTRACTION

Data Extraction is the process of retrieving useful data out of the source data (image here). In this process, we have generated the numerical values out of the features extracted, based upon the shape, size, intensity levels and other morphological structures, using the density-model, area-model, pixels count etc.

3.6. DATA ANALYSIS

In this phase, data extracted is analysed to train the system and the patterns are extracted. Data analysis is a body of methods that help to describe facts, detect patterns, develop explanations, and test hypotheses. It focuses on application of statistical or structural models for predictive forecasting or classification. In this process data is modelled and rather than just describing, it also emphasize on the predictive purposes.

3.7. WEB PORTAL

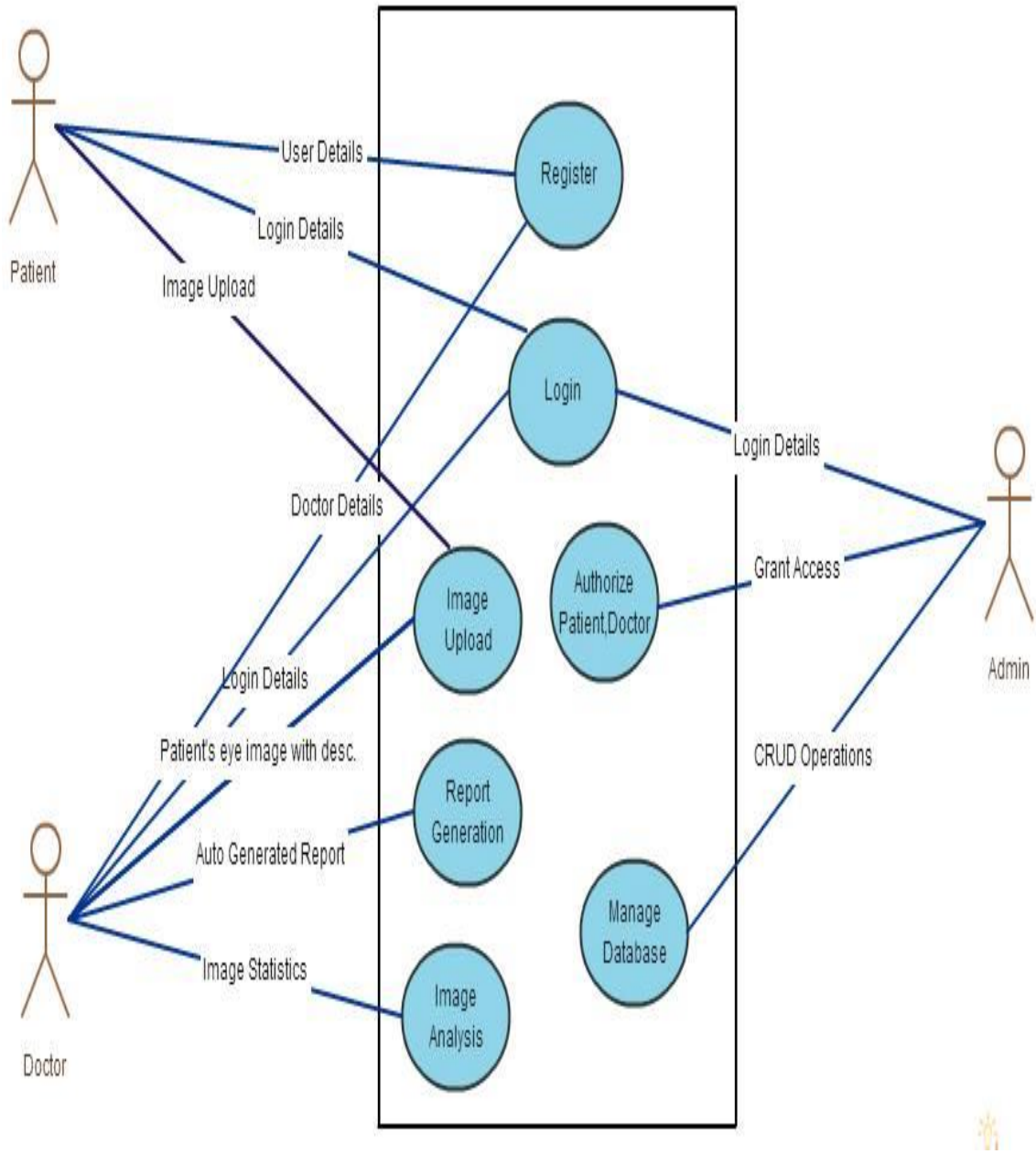

Figure 15 Use Case Diagram for Web Portal

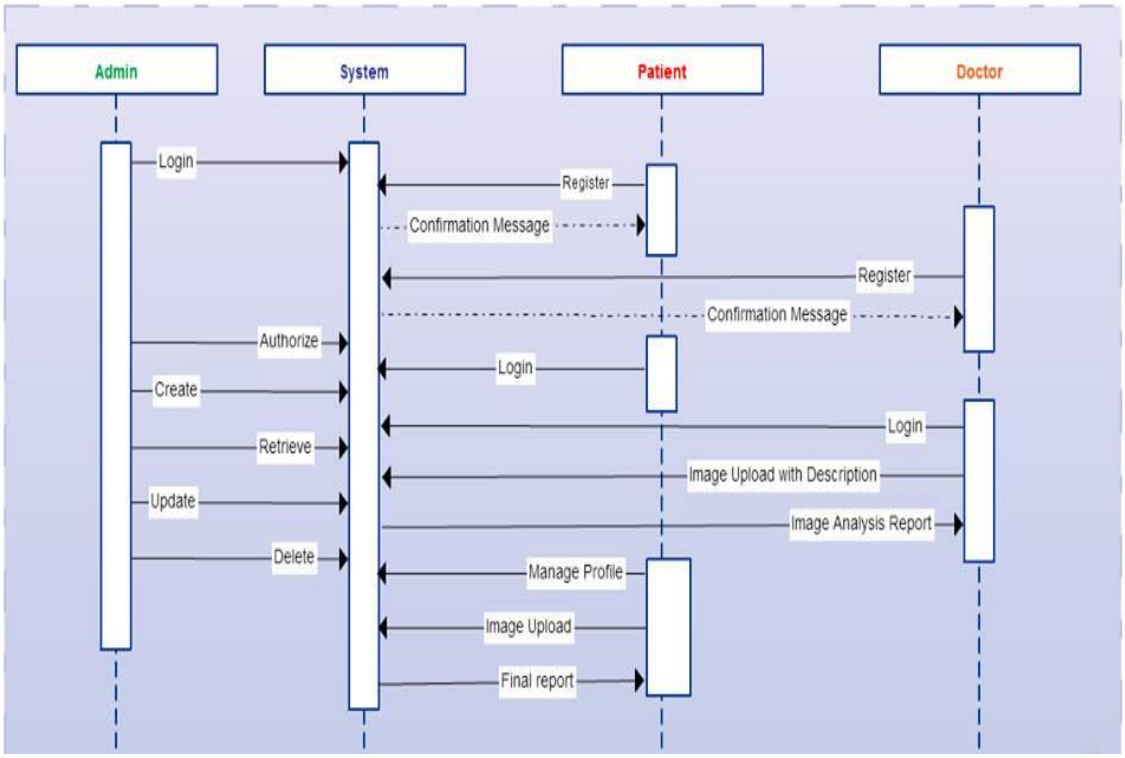

Figure 16 Sequence Diagram for Web Portal

Detail explanation of each actor/use-cases

1. Register: Users i.e. both Patient and Doctor Need to register themselves in order to use the services. They provide various personal details like Name, Address, Phone No., Photo, etc. which will be verified by Admin before their registration is finalized. Once the admin confirms the registration an email will be sent to the respective user as confirmation for Successful Registration. Now, they can activate their account by clicking the link sent in the email. After this they can login and use services whenever they want.

2. Login: To login the user i.e. both Patient and Doctor needs to provide corresponding user id and password. This will be, then, checked through queries whether the user is already registered with the same user id and password. If yes, then, they will be redirected to their home page else an error message will be displayed and redirected to login page.

3. Image Upload and Description: Once the user, especially, doctor logs in, he will upload his corresponding patients' retinal images. These images are then stored into database on the respective doctor's account. Along with the image uploading, doctor also provides various details related to the image like Patient's name, age, etc. Patients can also upload their retinal images. But, these images are not stored into the database and just, process image and provide the result whether the eyes is diseased or not.

4. Report generation and image analysis: After uploading the image the image processing service will run and process the image and then extract the various features of image and finally generate report which will be shown to doctor.

5. Database management: Database management is done by the Administrator of our website. Main operations of database manager is create, update, delete, retrieve of different information of our website users(Patient or Doctor) like managing of their profile information or deleting a particular user account etc.

4. HARDWARE AND SOFTWARE REQUIREMENTS

4.1. HARDWARE

- Any x86 or x86_64 based Architecture such as Intel Duo Core or Later
- 2 GB or more RAM
- 50 GB or more Hard Disk space
- Graphics Card for faster Graphic processing (optional)

4.2. SOFTWARE

- Operating System: Windows Vista or Later, Linux (at least Kernel ver. 2.6)
- Matlab (at least 2010a)
- Java 6
- Webserver: Apache, Microsoft IIS
- Database: MySQL, MariaDB, Oracle etc.
- Web browser: Google Chrome, Firefox (for testing)

4.3. MATLAB

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and FORTRAN. The MATLAB application is built around the MATLAB language, and most use of MATLAB involves typing MATLAB code into the Command Window (as an interactive mathematical shell), or executing text files containing MATLAB code, including scripts and/or functions.

Image Processing Toolbox™ provides a comprehensive set of algorithms, functions for image processing, analysis, visualization, and algorithm development. We can do image analysis, image segmentation, image enhancement, noise reduction, geometric transformations, and image registration. Many toolbox functions support multicore processors, GPUs, and C-code generation. Image Processing Toolbox

supports a diverse set of image types, including high dynamic range, gigapixel resolution, embedded ICC profile, and tomographic.

4.4. APACHE SERVER

A web server's job is accepted requests from client side, process and sends responses to those requests back to client. A web server gets a URL, translates it to a webpage name (for static requests), and sends that file back over the internet from the local disk, or it translates it to a program name (for dynamic requests), executes it, and then sends the output of that program back over the internet to the requesting client. If the web server was not able to process and complete the request, it instead returns an error message.

Apache is the most popular web available. The reasons behind its popularity, to name a few, are:

1. It is free to download and install.

2. It is open source: the source code is visible to anyone and everyone, which basically enables anyone (who can rise up to the challenge) to adjust the code, optimize it, and fix errors and security holes. People can add new features and write new modules.

3. It suits all needs: Apache can be used for small websites of one or two pages, or huge websites of hundreds and thousands of pages, serving millions of regular visitors each month. It can serve both static and dynamic content.

4.5. MYSQL

MySQL is a fast, easy-to-use RDBMS. MySQL is developed, promoted and supported by MySQL AB. MySQL is released under an open-source license and so free to use. It handles a large subset of the functionality of the most expensive and powerful database packages. It uses a standard form of the well-known SQL data language. It is cross platform and so works on many operating systems and with many languages including PHP, PERL, C, C++, JAVA, etc. It supports large databases, up to 50 million rows or more in a table.

5. EXPERIMENT

This section deals with the detection of all the features of diabetic retinopathy. Here the feature extraction like blood vessel, optic disc and exudates and estimation of severity based on following features are defined.

5.1. BLOOD VESSEL DETECTION AND ESTIMATION OF SEVERITY

Ocular fundus images give us the information about retinal, ophthalmic and diseases such as diabetes, hypertension etc. Blood vessels form a central feature in detection of such complications and thus a need for large population in the world. Automated detection of blood vessel is difficult thing as the diameter of blood vessel can vary from very small to large and thus a difficult task.

Most blood vessel detection algorithms are window based and emphasis the surrounding window around a given pixel that matches with a predefined model. The current stated implementation of detection of blood vessels using Gabor filters and scheme production. [**12**]The proposed method is beneficiary for both detection of large and small vessels but also good for removing noise and enhancement of responses of line filters. The stated method involves the following steps:

5.1.1. Inverted Green Channel

The analysis of RGB components of fundus images show that Green channel has best background contrast whereas Blue and Red Channel are very noisy. Therefore the input image to our system has green channel extracted only.

An iterative algorithm proposed in is used to remove the strong contrast between the retinal fundus and image outside the aperture.

5.1.2. Gabor Wavelet Transform

The continuous wavelet transform is defined as follows:

$$T_{\varphi}(b,\theta,a) = C_{\varphi}^{-1/2} a^{-1} \int \varphi^{*}\left(a^{-1} r_{-\theta}(X-b)\right) f(X) d^{2}X$$

Here f denoted the input image and ψ be the analyzing wavelet. C_ψ, ψ, b, θ and a denote the normalizing constant, analyzing wavelet, the displacement vector, the rotation angle and the dilation parameter (also known as scale) respectively. The ψ* denotes the complex conjugate of ψ. [**12**] The wavelet transform can be easily implemented using the fast Fourier transform algorithm and the equivalent Fourier definition of the wavelet transform:

$$T_\varphi(b,\theta,a) = C_\varphi^{-1/2} a \int \exp(jkb)\hat{\varphi}^*(ar_{-\Theta}k) f(k) d^2k$$

2-D Gabor wavelet has directional selectiveness capability of detecting oriented features and fine tuning to specific frequencies. This property is especially important in filtering out the background noise of the fundus images.
The 2-D Gabor wavelet is defined as

$$\varphi_G(X) = \exp(jk_0X)\exp(\frac{-1}{2}|AX|^2)$$

The Gabor wavelet is actually a complex exponential modulated Gaussian, where k_0 is a vector that defines the frequency of the complex exponential. [**12**] The θ is varied from 0^0 to 179^0 for all pixels at specified scale and the response of Gabor Filter is required.

5.1.3. Line Operators

We are focused on calculating two features at each pixel of image using orthogonal line operators. The first feature includes calculation of difference S= L – N where L denotes the maximum gray level obtained when the line operator is convoluted up to 360^0 for each pixel and N denotes average gray level. S is calculated for squared window centred on each pixel. [**13**]

The second feature of line operator is evaluated along gray level of line orthogonal to the first feature. This line has three pixels length centred at the midpoint of the basic line operator and perpendicular to it. Its average value is denoted by L_0 and its strength is obtained by S_0= L_0-N. In fact for a Pixel on vessel this value must be relatively large. This L_0 separates the pixels of thin vessels as it would be very low and pixels in background will have high L_0 value.

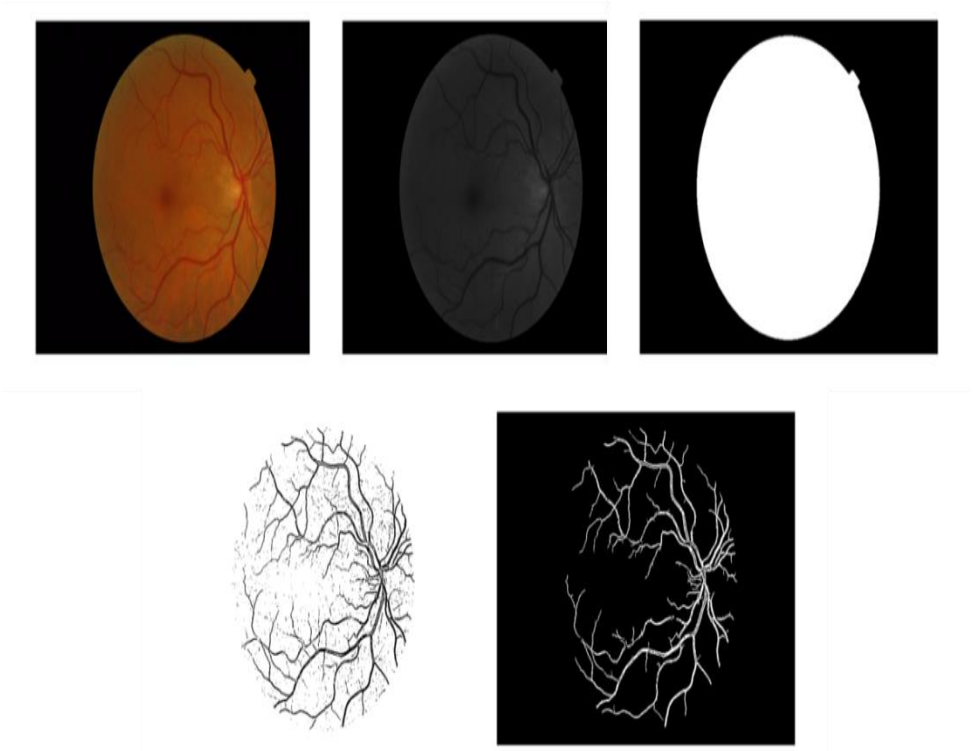

Figure 17 Blood Vessel Detection: a)Input Image b)Green channel of Image c)Mask eye of image d)Blood vessel after Gabor Filter e)Final Output Image

5.1.4. Estimation of Severity based of Blood vessel

We know that the blood vessel of eye started to grow with the level of diabetes and so the above concept is used as a base for the data model for the estimation of the severity level of diabetes. On the basis of the pixel density of blood vessel to the pixel density of the is used to estimate level of diabetes (normal, mild, moderate and severe). [**14**]

In this case number of pixels occupied by the Blood Vessel is calculated and then the number of pixels in eye of the fundus image is calculated. After that a ratio of blood vessel by eye pixels count is obtained and store in a text file as ‘data.txt’ which is going to be used as training data. Now training data is used to train kNN classifier. So any image feature value stored in ‘sample.txt’ is now compared with training set and the kNN classifier will determine the severity of diabetes level based on nearest neighbours severity.

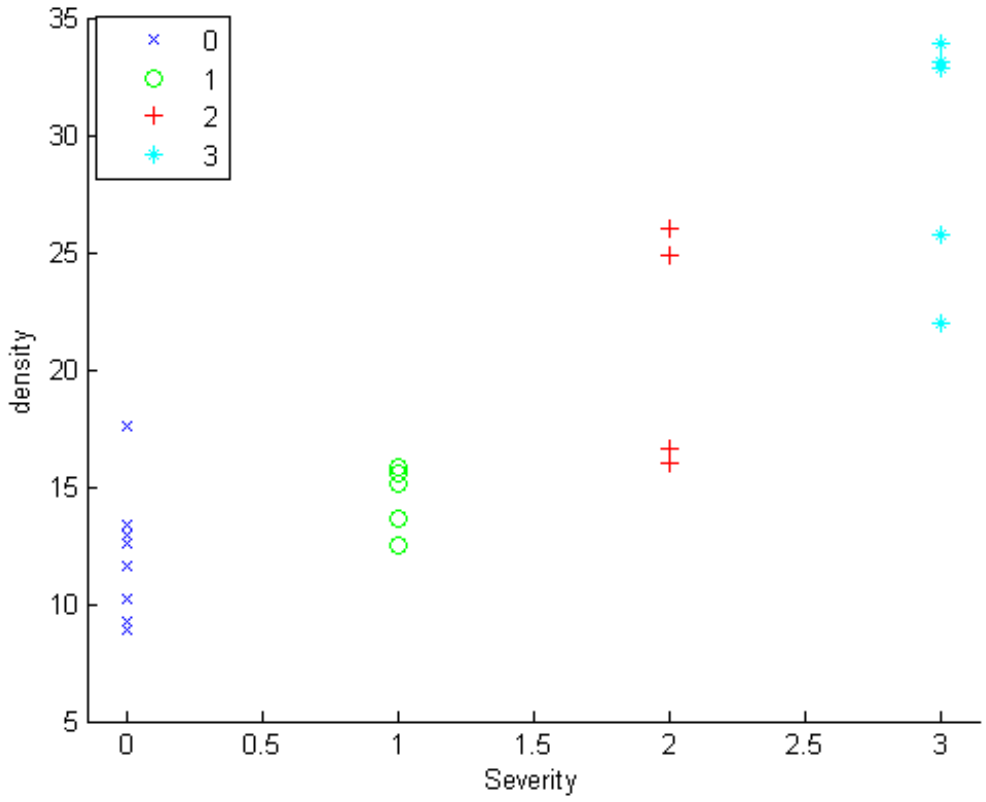

Figure 18 Estimation of Severity level of DR

5.2. DETECTION AND ESTIMATION OF OPTIC DISC

5.2.1. Detection of Optic Disc

Optic Disc is the brightest area in the eye image and carries the highest intensity levels. It is mostly circular or elliptical in shape and its color is bright yellowish or white. Its intensity range lie in red color range hence it is good to do analysis on red channel. [**9**]

On the red channel of image median filter is applied so that some image noise is reduced and image is smoothened. The filtered image now undergoes image enhancement so that the pixels of the image become more saturated to the surrounding pixels and the features and the background will be more easily differentiated by applying adaptive histogram on the red channel of image as shown in figure b).

The output image is a brighter and contains blood vessel and exudates that has to be removed. It is done by applying closing morphological operation so that the blood vessel is removed from the image. [**15**]

Closing operation is combination of erosion and dilation of image. The erosion operation narrows and remove blood vessel while the dilation operation restore the image without blood vessel as shown in figure c). There is a built in method imclose in Matlab which is fast and better compared to other implementation, it takes disk type structural element as parameter. After that image undergoes segmentation process and so for automatic determining the threshold value for the segmentation Otsu Algorithm is used.

Otsu shows that minimizing the intra-class variance is the same as maximizing inter-class variance between a segmented foreground object and background:

$$\sigma_b^2(t) = \sigma^2 - \sigma_\omega^2(t) = \omega_1(t)\omega_2(t)\left[\mu_1(t) - \mu_2(t)\right]^2$$

Which is expressed in terms of class probabilities ω_i and class means. μ_i The class probability $\omega_1(t)$ is computed from the histogram as t:

$$\omega_1(t) = \sum_0^t p(i)$$

While the class mean $\mu_1(t)$ is:

$$\mu_1(t) = \left[\sum_0^t p(i)\, x(i)\right] / \omega_1$$

Where $x(i)$ is the value at the centre of the i^{th} histogram bin . Similarly, you can compute $\omega_2(t)$ and $\mu_2(t)$ on the right-hand side of the histogram for bins greater than t .The class probabilities and class means can be computed iteratively. This idea yields an effective algorithm. So we pass image to Otsu Algorithm based graythresh built-in method in Matlab to get the automatic threshold value. And then apply segmentation on image based on threshold value obtained from Otsu algorithm.

Now the image as shown in figure d) consists of small bright spots that are mostly exudates or fats etc. Such small bright spots (that covers less than 1% pixels of image) are removed from the image by bwareaopen built-in method in Matlab as shown in figure e). And finally a binary image consist of the desired optic disc image is obtained. Then this binary image is used to map the optic disc back to original image. This is done by highlighting the pixels of the original image that are bright in the binary image and hence in this way the optic disc is mapped back to original image. [**6**]

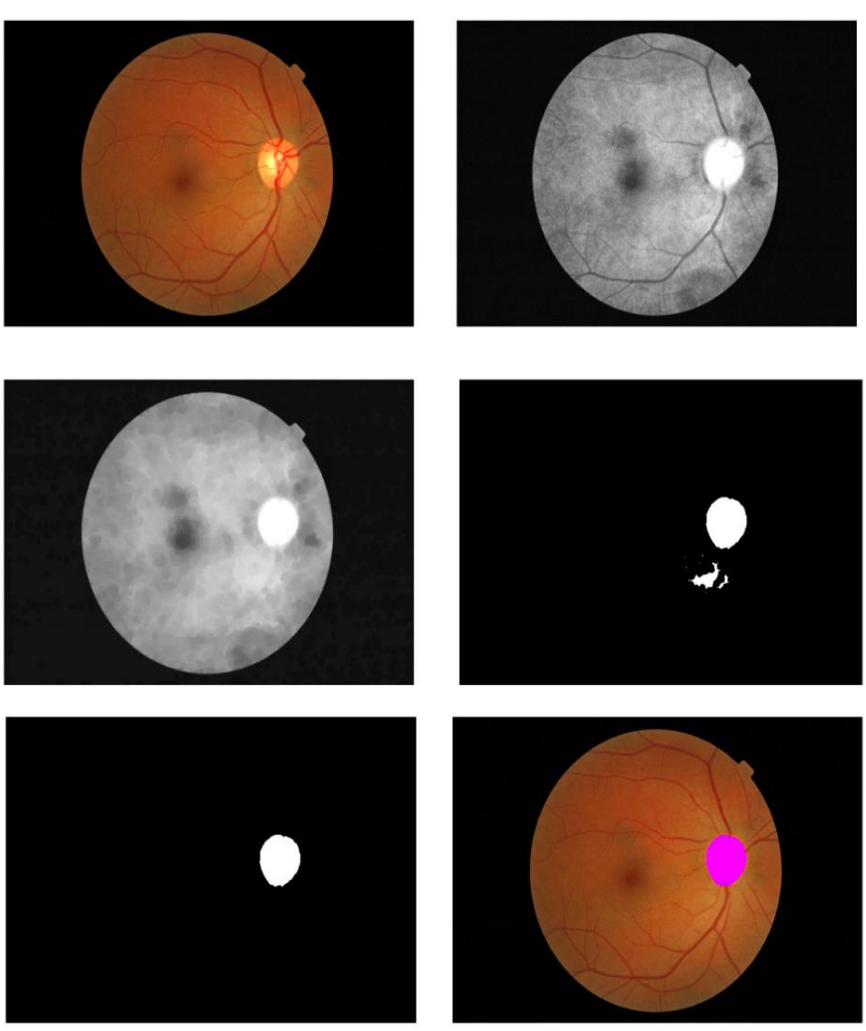

Figure 19 Optic Disc Detection a)Input Image b)Applying Adaptive Histogram Equalization c)After Closing Morphological Operation d)After Image Segmentation e)After removing small regions f)Optic Disc Mapped

5.2.2. Estimation of Severity based on Optic Disc of Fundus Image:

[**16**] It is known that the intensity value of eye image is brighter than the rest of the eye image but with the increase in severity of Diabetic retinopathy the brightness is lowered. So the pixel intensity of diseased eye is not so bright compared to normal parts which become clear by the data model and the calculation of pixel density of optic disc with respect to eye image. It is obtained by dividing total pixels of optic disc with the total pixel of eye image mask image.

In this case number of pixels occupied by the optic disc is calculated and then the number of pixels in eye of the fundus image is calculated. After that a ratio of optic disc by eye pixels count is obtained and store in a text file as 'data.txt' which is going to be used as training data. Now training data is used to train kNN classifier. So any image feature value stored in 'sample.txt' is now compared with training set and the kNN classifier will determine the severity of diabetes level based on nearest neighbours severity.

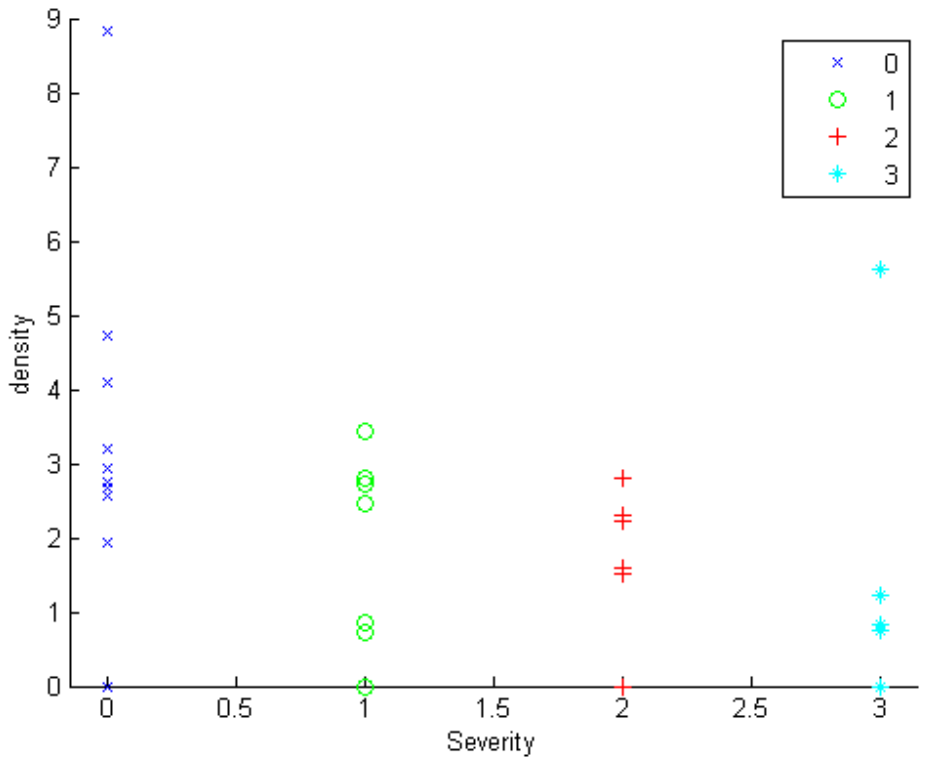

Figure 20 Estimation of Severity level of DR

5.3. DETECTION AND ESTIMATION OF EXUDATES

5.3.1. Detection of Exudates

Exudates are accumulation of lipids and protein in the retina .Exudates are the darkest spots in the retinal images which have sharp boundaries with black background. In order to find exudates in eye and count the number of exudates in the retinal image initially we have to convert the image channel (e.g.: RGB) to gray scale image and we proceed further.

Our main task in finding Exudates in retinal eye image is finding the boundaries of the exudates. In order to find the boundaries of the Exudates we apply Morphological operations on the retinal eye image. Exudates will respond when dilation is applied on the image because exudates have brighter edges and dark yellow color .It occupies most of the part of the green channel we apply dilation on the green channel of the eye image to extract exudates. [**16**]

In order to perform dilation we have function in Matlab Imdilate (param 1, param 2) Param 1 signifies input image to function and param 2 signifies the Structural Element (it is the object used for dilating the image and the objects like rectangle, ring etc.). we have selected rectangle with height and width as 25 and 25 using this we have a developed a matrix which stores information of this object and traverse over the input image and dilate it . It will dilate that part of the image which is same as the rectangular object.

We mainly dilate the image to remove the blood vessels. After applying dilation on the image with SE as rectangle then we get an image with no blood vessels in it. We will apply dilation again with SE as disc on the original image then we will get an image with highlighted exudates with no blood vessels. We will get bright sharp edges of the exudates through this method. Then we will subtract both the outputs in order to get exudates with sharp edges with no blood vessels in it. [**17**]

The output image is binary thresholded to a particular value such that image will contains clear boundaries of the exudates. After getting the boundaries we have two types of exudates present in it soft exudates and hard exudates. Hard exudates will have closed boundaries in the thresholded image while the Short exudates breaks in the contours are connected by smoothing splines.

A morphological filling operation is then used to search for regions bounded by closed contours in the result. We use Matlab function imfill () in order to fill the exudates in the result. We iteratively apply imfill () operation on each and every object in the image until there is no left over.

Morphological filling operation on the binary image thus gives us the candidate exudate patches. However, the candidate regions may contain errors. Therefore, a linear classifier is built which uses the brightness and edge properties of exudates. Exudates are bright yellow or white in color and have high intensity in the green channel. We localize the exudate patches more accurately by taking all the candidate regions whose mean intensities in the green channel are greater than a fraction (obtained by training) of the maximum intensity in the channel. [**18**]

For classifying the patches based on their edge strength, the gradient magnitude image of the green channel is chosen. This gradient magnitude image is thresholded (the absolute threshold obtained by training) and the number of white pixels in the thresholded image for each exudate patch is counted. We denote this as the gradient count of each patch. Patches which do not have sufficient gradient count (_) are discarded.

After this the contours which satisfy both conditions will remain in the output while other will be discarded. But, instead of doing this we still have an object of optical disc in the output image in order to remove that. We extract optical disc object from the original image then we subtract both the outputs then the resultant output will contain exudates only.

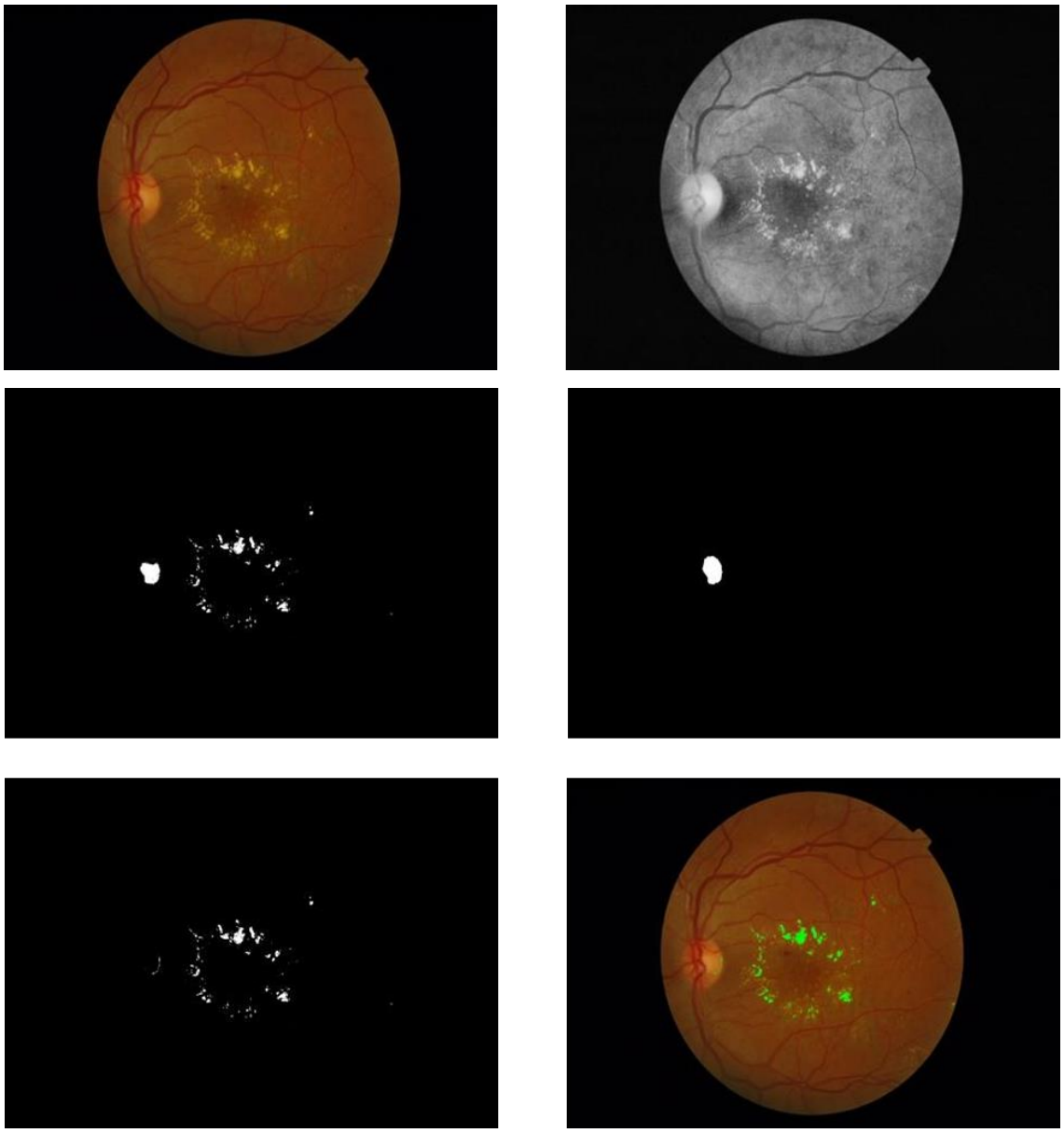

Figure 21 Detection of Exudates a) Input Image b) Image enhancement c) Image Segmentation d) Optic Disc segmentation e) Image Subtraction f) Output image

5.3.2. Estimation of Severity based on Exudates of Eye Image:

[**19**] After finding the exudates of the eye we have to find the number of counts of exudates in the resultant image based on these count we have to classify whether severity is high, mild, moderate, and normal. Initially we have to collect count of exudates of some retinal images and store then in training_data.txt. These data is used for training the kNN algorithm for classifying the input image. So any image feature value stored in 'sample.txt' is now compared with training set and the kNN classifier will determine the severity of diabetes level based on nearest neighbours severity.

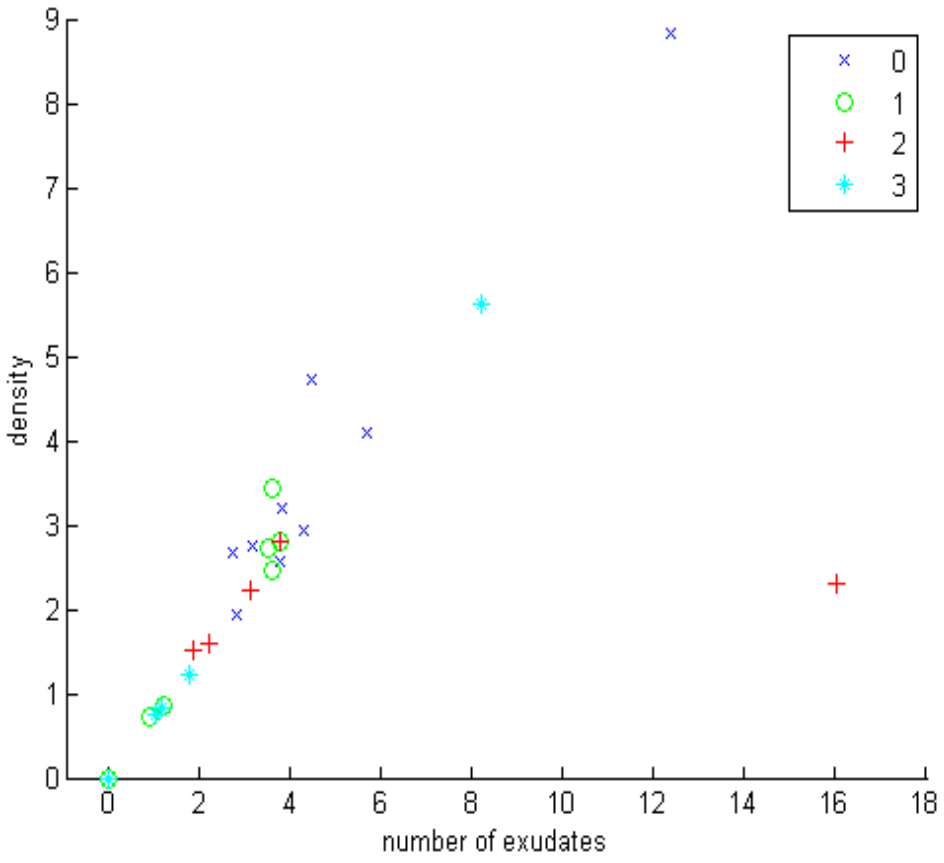

Figure 22 Estimation of Severity level of DR

6. SCREENSHOTS

Figure 23 Homepage of the portal

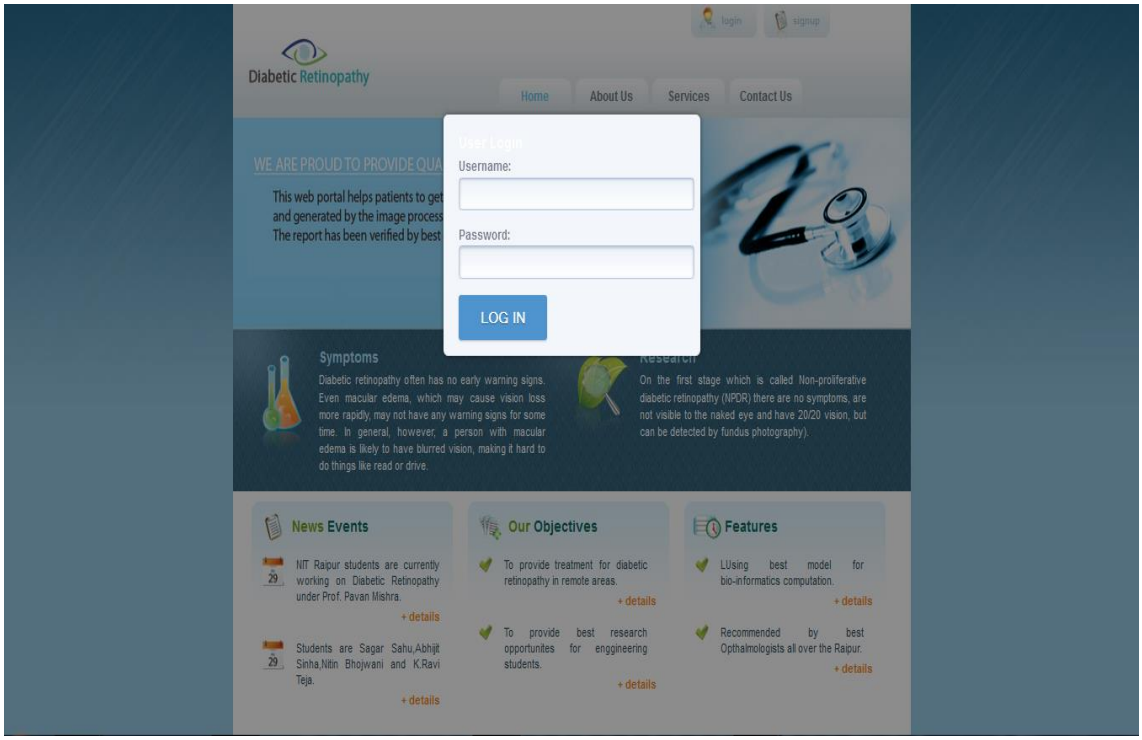

Figure 24 Login page of portal

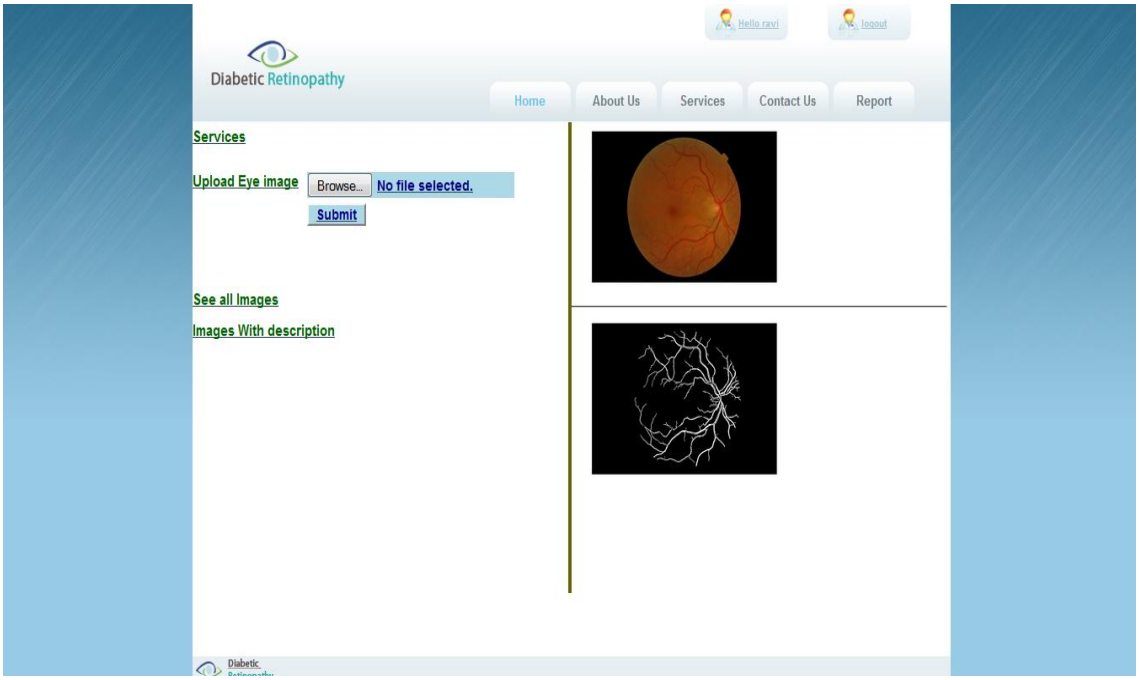

Figure 25 User homepage on portal

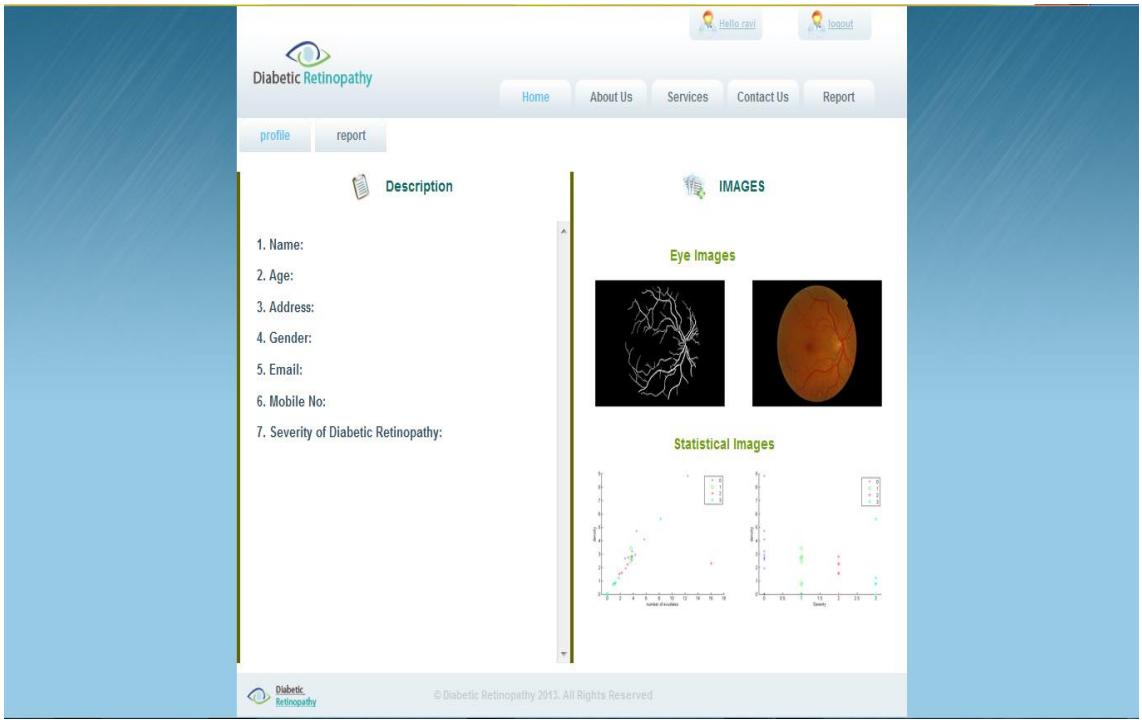

Figure 26 User report page to view and validate report

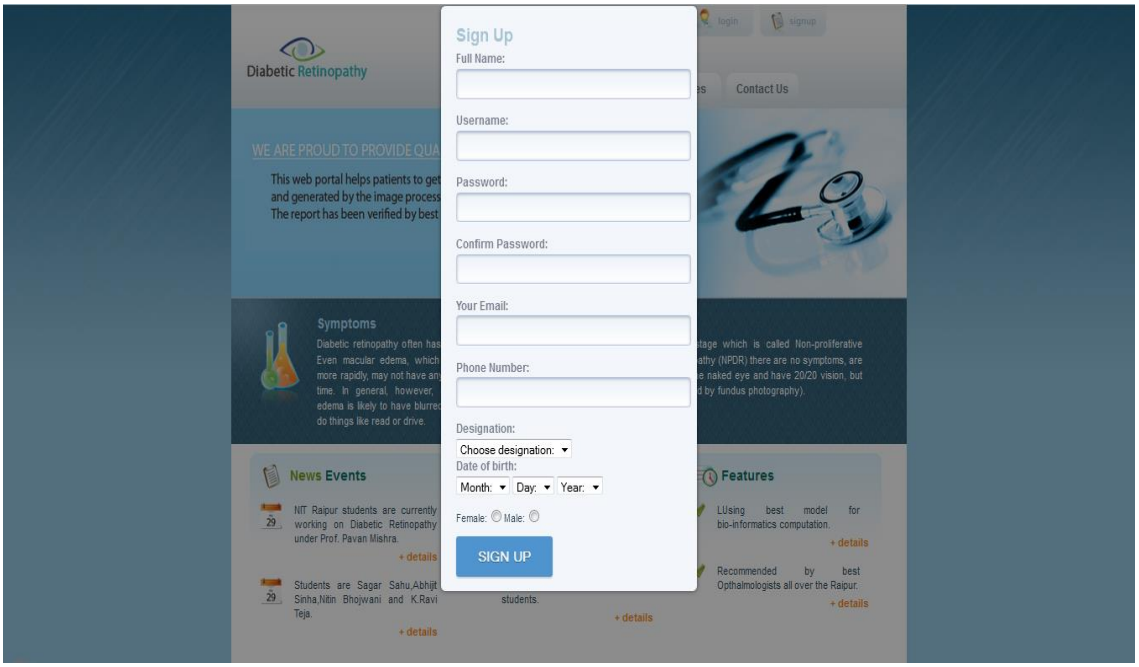

Figure 27 Registration Page of Portal

Figure 28 Homepage after User logged in

7. RESULT ANALYSIS

Various parameters of statistical data are already discussed in the previous section and the result obtained is going to be discussed in this chapter. After performing the blood vessel and optic disc analysis. The following types of data are obtained:

7.1. ANALYSIS OF DATA OBTAINED

Table 2 Values from Blood Vessel Analysis

Pixel Counts	Pixel Density of Vessels	Severity of DR
373378	25.78689542	severe
199213	13.62358148	mild
180585	12.45912158	mild
134585	9.21055513	normal
379916	25.98302523	moderate
227490	15.57941537	mild
483927	33.13858056	severe
169689	11.6101289	normal
220901	15.10684161	mild
22382	33.86952772	severe
41458	21.97428259	severe
13952	25.9779917	moderate
93254	16.03216955	moderate
19033	32.8251384	severe
176488	12.62021302	normal
165971	15.81185182	mild
132726	10.23572254	normal
122399	12.94393349	normal
124730	8.93953967	normal
217409	17.5617625	normal
153911	13.40142991	normal
231684	16.58566547	moderate
337484	24.91129314	moderate

Table 3 Values from Optic Disc Detection

Pixel Count	OD/ Eye Ratio	Severity of DR
27202	2.67884137	normal
37801	2.79027092	mild
22149	1.58559031	moderate
31649	2.75576051	normal
12104	0.86750732	moderate
35973	3.4271032	mild
11587	0.82948372	severe
38290	3.1955761	normal
44648	4.72161327	normal
35288	2.72138222	mild
30995	2.22071285	mild
10228	0.74789481	severe
35973	3.4271032	mild
9233	0.72907454	moderate
56821	4.10149765	normal
123600	8.83832515	normal
18621	1.51176385	moderate
160416	2.29313835	moderate
0	0	severe
35869	2.45297367	mild
0	0	normal
0	0	mild
82100	5.61494217	severe
28156	1.92823429	normal
37493	2.56470769	normal
0	0	moderate
42831	2.93049892	normal
17765	1.21652002	severe

From the above dataset we can observe that the data severity of data in the case of blood vessel vary as per the pixel density of the blood vessel. It confirms the hypothesis that increasing thickness of blood with severity leads to increase in the blood vessel density in the image. While in the case of optic disc the severity is seems to be dependent on the ratio of area covered by optic disc on the eye image. More severity leads to lesser coverage of brighter optic disc area because we know that with severity the brightness of eye become lesser compared to mild or moderate in which case the optic disc is bright and that are covered more than 2%. All this study show the feasibility of the statistical model of the analysis of Diabetic Retinopathy.

8. CONCLUSION AND FUTURE WORK

Prolonged diabetes will ultimately leads to diabetic retinopathy. Where the retina is damaged due to fluid leaking from the blood vessels. In this report we mainly focused on finding of this abnormal behaviour in eye and try to quantify the intensity of effectiveness. Usually, the stage of DR (diabetic retinopathy) is judged based on blood vessels, exudates, haemorrhages, micro aneurysms and their intensity of damage in eye image.

We implemented algorithms to extract features like blood vessels, exudates, optic disc and to find level of severity of these mentioned features in the input eye image. The algorithm implemented is automated so that every image diagnosis is no depends on human value for features. These generalized algorithms are independent of camera used ophthalmologist because the calculation doesn't depend on the size of pixels or dimension of image or format of image.

Automated DR detection can reduce the grading cost and thereby make the whole screening process less expensive. The early detection of DR can save many eyes as people in this modern world are busy and this technique can reduce the time of processing of fundus image. Some of the algorithms and systems reviewed in this paper are close to achieve DR identification in clinical practice but still some data analysis part can be enhanced with more number of image.

Our techniques or algorithms are combined with some learning methods (KNN classification) for possibly even better results. We mainly focused on Adaptability and accuracy in future work i.e. finding new features such as haemorrhages, macula, fats and color of fundus image and finding the level of severity based on these set of features by analysing different. We automate these features detection technique and increase the efficiency of the proposed algorithms.

Automation is where there is a room for improvement because the learning algorithm used are slower and much simpler method by introducing more new methods such as neural networks, Support Vector Machine or Principal components Analysis. Further speed of the system can be enhance by introducing parallelism through CUDA,

OpenCL libraries such that it can take advantage of hardware with the massive level of parallelism.

Our main aim of future work is to have fast and reliable algorithms for feature detection. In future work we also work on the security of user data and provide different modes of user interactive like designing offline interface to work on system or implementing standalone distributed system based application that can accept API calls from anyone and output the result in desired and convenient way to client.

A proper tool for user such that they can upload the patient image and analyse image through above proposed algorithms and generate report which signifies the level of severity. The data used in this system are not so sensitive but still privacy is a concern and so different security techniques can be introduced when the full-fledged application is developed like authentication, user validation etc. [**2**]

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