Bachelor of Science in Computer Science & Engineering

A Cost Effective Smartphone Based Solution for Cataract Detection

by

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Submitted in partial fulfilment of the requirements for
Degree of Bachelor of Science
in Computer Science & Engineering

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The thesis titled '**A Cost Effective Smartphone Based Solution for Cataract Detection'** submitted by ID: 1504075, Session 2019-2020 has been accepted as satisfactory in fulfilment of the requirement for the degree of Bachelor of Science in Computer Science & Engineering to be awarded by the Chittagong University of Engineering & Technology (CUET).

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Abstract

Cataract is one of the most common diseases that people encounter when they get older. The presence of a cloud on the lens of our eyes is referred to as cataract. This results in a loss of vision and vision impairment. The rate at which cataracts grow is slow it can affect one or both eyes. The majority of the time, these symptoms result in difficulty performing a variety of task. Medical facilities in remote areas are limited, and clinics in those areas cannot afford the expensive machines needed for cataract detection. Early diagnosis and treatment of cataract patients will alleviate their pain and prevent vision impairment from progressing to blindness. However, clinical cataract diagnosis and grading require the skills of qualified eye specialists, which can make early intervention difficult for anyone due to the underlying cost. As a result, a simple and cost-effective auxiliary diagnostic method is suggested here. Our main focus is to detect cataract from iris image. So,the iris area have been extracted using a contour detection process from binary masked image. Two types of texture features(GLCM & Histogram texture features) are extracted from the images. Random Forest classifier is used for the automatic detection of cataract. Classification accuracy is improved with the increased number of available samples and achieved an accuracy of 97.92%.
Keywords: Cataract detection,Data augmentation,Image processing,Texture features,Random forest classifier.

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Chapter 1

Introduction

1.1 Introduction

One of the most essential sensory organs in the human body is the eye. Eye disease is a serious health problem that affects people all over the world[1]. One of the most common eye disease is cataract. Cataract is one of the most common causes of visual impairment all over the world. It is also a major cause of blindness around the world. In the developing countries, half or more of the blindness is caused by cataract. Cataract is not only disrupting productivity and mobility of patients, but also causing the social-economic impact that will decrease the quality of life[2]. The contribution of image processing techniques is more prevalent in the modern medical domain. It has more specialized features for a variety of medical diagnoses. In the field of computer vision, the machine learning approach has achieved a lot of success. Machine learning methods can automatically learn critical features and incorporate feature learning into the model-building process, resulting in a more accurate model. The importance of computer-assisted cataract detection is two -fold. For starters,it will aid mass screening. Second, it can be used as a step in the computer-assisted grading process.
Our proposed method is for diagnosing the mentioned eye diseases based on a computationally efficient approach and promises excellent results. The algorithm has the ability to make optometrists' lives easier and, in the end, to save lives.

1.1.1 Overview Of Cataract

Cataract is derived from the Greek words katarrhakkies, in English Cataract, and Cataracta in Latin,which all mean waterfall. To refract light entering the eye and create an image on the retina, the eye lens must be translucent. However, cataracts involve the accumulation of protein clumps or a yellow-brown pigment, which reduces light transmission to the back of the eye. A cataract is a clouding of the lens of the eye that causes vision loss. Cataracts usually appear gradually and can affect one or both eyes. Fading colors, flickering or double vision, halos around light, difficulty with bright lights, and difficulty seeing at night are all possible symptoms. This can make it difficult to drive, read, or recognize faces. Cataracts can cause blurred vision, which can increase the risk of falling and depression.

According to the 2001 World Health Report, there are 20 million people worldwide who are bilaterally blind due to age-related cataracts. By the year 2020, the figure would have risen to 40 million. Cataracts are more common as people getting older, but cataracts are more common in developed countries. Indonesia is one of the developing countries with the largest number of cataract patients[3]. Other nations, on the other hand, are not far behind. By the age of 80, almost 22 million Americans aged 40 and older would have developed cataracts.

1.1.1.1 Reasons of Cataract

There are several reasons of cataract-

- Most of the cataract is age-related. With the aging of the population, the ratio of cataract will increase.
- Due to injury that changes the tissue that makes up our eye's lens.
- Some inherited genetic disorders that cause other health problems can increase risk of cataracts.
- Cataracts can also be caused by other eye conditions, past eye surgery or medical conditions such as diabetes
- Long-term use of steroid medications, too, can cause cataracts to develop.

1.1.1.2 How Cataract Forms

The crystalline lens, which is situated between the iris, vitreous body, and retina, is an optically transparent organ with ectodermal tissue[4]. The crystalline lens can concentrate incident light on the retina due to the refractive index, form, and clarity of the crystalline lens. Aside from the superficial stripes of new cells, the lens' constant growth creates a series of concentrically arranged laminae that steadily increase the number of lens fibers over time[5]. As a consequence, in elderly people, existing crystalline proteins in the lens misfold and accumulate into insoluble clumps. When the lens loses its optical clarity, the result would be a complication known as cataract.

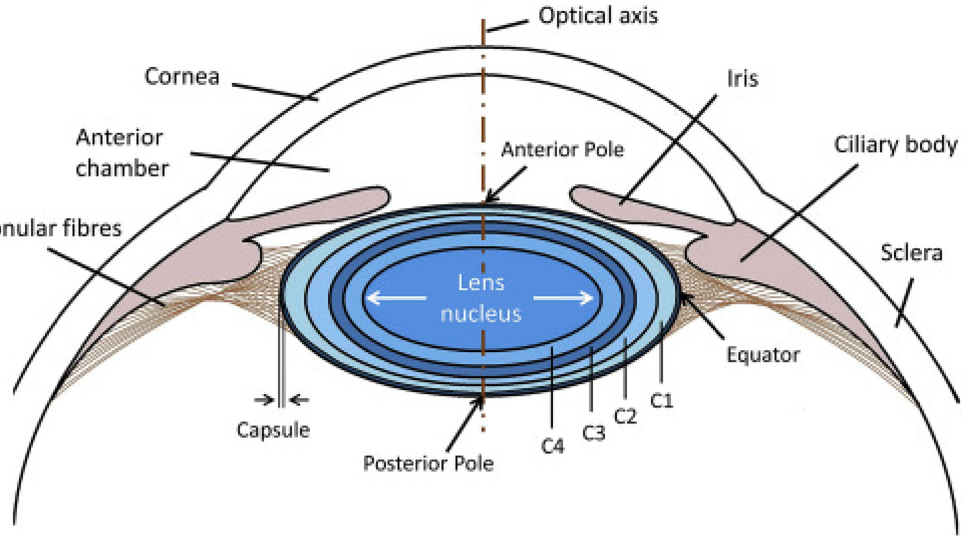


Figure 1.1: Human lens Subsection

1.2 Framework/Design Overview

Our task is automated detection of cataract from eye image. In order to do this, firstly we have to collect eye images of mass people. So, we have collected dataset. Now, the next task is to preprocess and analyze the image data. We have used several digital image processing techniques for preprocessing. Then,the next step was to extract feature from the data. Feature extraction was done for achieving the common attribute or pattern of the data. Next,we have to build up a model for the system. The extracted feature was fed to the model in two phase training and testing. Training is the learning phase. When model was built then we have to check it for validation whether the model predict cataract right or wrong. The framework is depicted in figure 1.2.

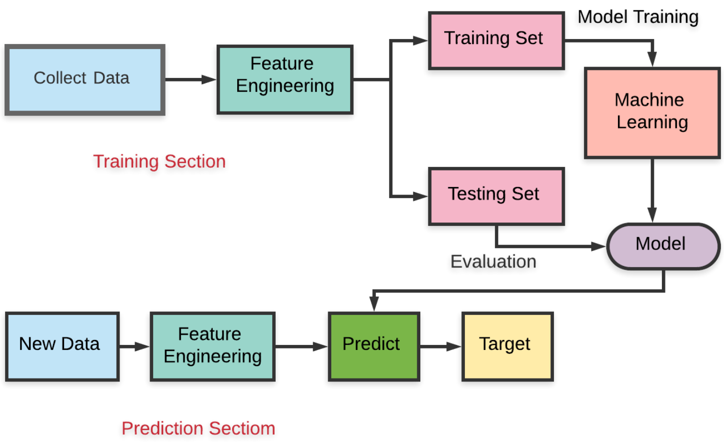


Figure 1.2: Framework of Proposed Method

1.3 Difficulties

Difficulties means facing any kind of obstacles or hardship while doing a project. There can be several issues or problem that may occur whether for technical or environmental issues and so on. We have encountered several difficulties while doing this project. They are discussed below:

• Collection of image data:

Collecting real images of cataract patients in this pandemic situation was very tough. Moreover,there were no sufficient data on several dataset sites.

• Image Capture Angle:

Different capturing angles of different images have caused a problem for detecting the exact location.

Figure 1.3: Image of different capturing angle

• Uneven Illumination:

Different types of images have different brightness.Some images have high brightness some have low.

• Perfect Segmentation problem:

As size of iris are varied from people to people, so perfect segmentation of pupil area by a specific threshold value is quite tough.

1.4 Applications

If a cataract is not treated promptly, it may result in blindness. Early diagnosis and treatment of cataract patients will alleviate their pain and prevent vision impairment from progressing to blindness. The typical diagnosis methods consumes more time.Hence, a convenient and cost-effective auxiliary diagnosis system is proposed here.so general people who will have this system can easily test their eyes. Optometrists are eye care professionals who may observe, diagnose, and treat eye problems medically. They can use this machine to diagnose cataracts. Ophthalmologists and opticians are a type of medical doctor who are specialize in surgical procedures of the eye .Our system will help them a lot.
The system Can be used for primary vision impairment testing of an applicant in any kind of institution for instance Navy,Army,Air force etc.

1.5 Motivation

As per the report of the World Health Organization (WHO) for the year, 2010, globally 285 million people are estimated as visually impaired, in which 39 million people are blind[6]. As per the report, cataract is 51% responsible for world blindness, which represents about 20 million people. Cataract is also the main cause of low vision in both developed and developing countries[4]. Currently, doctors diagnose cataracts or well-trained graders rate them. However, clinical cataract diagnosis and grading require the expertise of qualified eye specialists, which can make early intervention difficult for anyone due to the underlying costs. To detect cataracts, ophthalmologists use different tools such as a slit lamp camera or an ophthalmoscope. However, there are some drawbacks to using these machines, such as the need for specialized training and the high cost methodology of investigation. In a developing country like Indonesia, where ophthalmologists and health facilities are in scarce, especially in rural areas[2]. In our region, cataract awareness is still in its early stages. Early detection and treatment can reduce the suffering of cataract patients and prevent visual impairment from turning into blindness. Hence, a convenient and cost-effective auxiliary computer vision system is proposed here.

1.6 Objective

The key objectives of this thesis are as follows-

- Automated detection of cataract eye
- To save time of patients by early detection of cataract.
- To develop a cost effective solution.

1.7 Contribution of the thesis

Thesis or Research work is performed, to achieve a specific set of goals, in regards of the accuracy of results or data processing time. The contribution of our proposed method is-

- A system that simulates slit-lamps is used in recent state-of-the-art studies on cataract scoring. This system is connected to the camera on the smartphone. While they produce high-quality images that are comparable to those produced by slit-lamps in hospitals, access to such equipment in rural areas of developing countries can be difficult. As a result, the current study aims to compete with portable slit-lamp-based approaches by proposing a precise and accurate screening automated process.
- The current work aims to address the non-frontal poses and Eye detection problem in the used dataset by proposing an eye detection approach that is realistic for non-frontal facial poses.
- To extract reliable features from images with inconsistent orientations, facial

poses, backgrounds, lighting, and distances between camera and subject, a general feature extraction method was needed.

• In the earlier methods, the classification result on a dataset with 160 images[2] indicates that the KNN classifier cannot process effectively and needs a larger dataset. So we used larger dataset then that.

1.8 Thesis Organization

The rest of this thesis report is organized as follows: i.Chapter 2 gives a brief summary of previous research works in the field of Cataract Detection.
ii.Chapter 3 describes the proposed methodology for Cataract Detection.
iii.Chapter 4 provides the description of the working dataset and analysis of the performance measure for the proposed method.
iv. Chapter 5 contains the overall summary of this thesis work and provides some future recommendations as well.

1.9 Conclusion

In this chapter, an overview of our thesis work is provided. The motivation behind this work and contributions are also stated here. In the next chapter, background and present state of the problem will be provided.

Chapter 2

Literature Review

2.1 Introduction

The focus of this thesis is to automatic detection of cataract and to present a comprehensive review of various cataract detection process. Through providing a brief summary of previous study this chapter discusses various feature representation and detection methods applied by different researches, and the performances of these researches on different datasets. The problem of cataract detection can be divided into two major parts depending on the parts of eye. A detailed description of both this discussed in this chapter.

2.2 Related Literature Review

In this section previous research on cataract detection is discussed in accordance with different feature extraction method and classification method. We have divided this section into two sub section where one is discussed base on retinal based detection and other is pupil based.

2.2.1 Literature Review Of Retinal Based Cataract Detection

In [7] Zhang et al. proposed a solution that aim to investigate the performance and efficiency by using Deep Convolutional Neural Network (DCNN) to detect and grad cataract automatically. It also displays some of the feature maps at the pool5 layer along with their high-order empirical semantic sense, explaining the DCNN feature representation. E5-2609 CPU, 8GB RAM, Qudro K620 GPU, and Ubuntu 16 as the operating system were used for this proposed retina fundus images classification with Deep Convolutional Neural Networks. The effect of the G-filter on removing unequal illumination of fundus images and the effect of data quantity on the classification accuracy of DCNN were both verified separately in this paper. The accuracy the got is 86.69%. The limitations of this paper is they trained their model using fundus image which has equipmental cost. They didn't detected eye and their model needs huge amount of data.

Kaur et al.[8] developed an android application system for detecting cataract. They used a microscopic lens in mobile camera for capturing retinal images. For the rooted method implementation, they used a modified Neural Network. Network is a Java application for neural training that runs on a personal computer. The network parameters follow the same topology as the mobile development library of the mobile-based diagnostic framework. The limitations of this method is it's needed an extra microscopic lens which is costly.

In [9] Dong et al. provided a solution for classification of cataract fundus image using deep learning. They have trained a CNN model for feature extraction. Five convolution layers were used. Following the feature extraction step, SVM and Softmax are used to classify the features extracted from the fc5 deep learning system. Training the model takes a long time. The preparation will take a long time. They stated that because of the image's high quality, training the current sample has taken a long time, and if the number of images grows rapidly, they will face significant challenges.

Harini et al. [10] developed a system of automatic cataract classification system using the SVM classifier, the fundus image is graded as non-cataract or cataract. The RBF Network is used to grade the cataract picture as mild or extreme. The analysis is carried out using the MATLAB software. The dataset they used is not so large(60 images).

2.2.2 Literature Review of Pupil Based Cataract Detection

Pathak et al. [11] presented a texture information based automated algorithm for detection of cataracts from a digital eye image of adult human subjects. Experiments were performed on true color images obtained from a compact digital camera.Screening for cataracts based on texture characteristics such as uniformity, density, and standard deviation. These characteristics are computed and mapped with the help of a diagnostic opinion from an eye specialist. As The proposed algorithm detects presence of cataract by reading texture information from circular pupil of adult human subjects. It cannot detect cataract if the children who suffering from colomba, i.e., the children who have non circular pupils.
IK et al. [12] aim to research on an alternate cataract screening solution with flash enabled smartphone. In this method a red reflex flash method is used. Eye image of patient is captured in a dark room.Before capturing images eyes are dilated using a drop and all this step is done by an ophthalmologist camera flash is able to replicate red reflex, there were reports of individuals who has experienced pain and dizziness after being exposed to the camera flash in a dark environment. They used smartphone that must have greater light intensity it ensures no light source are present when image is captured and the angle between eye and camera should be best. So, these are the limitations of this method.
In [13] Zhang et al. proposed a solution for cataract classification that used an approach dependent on residual focus. The B-Scan Eye ultrasound dataset were used. An object detection network, three pre-trained classification networks: DenseNet-161, ResNet-152, and ResNet-101, and a model ensemble module make up the proposed model..They began by detecting objects and then processed the B-Scan ultrasound images. The only drawback is that cataracts are difficult to classify in B-ultrasound images because the eyeball occupies such a small portion of the image. In most cases it gives faulty detection
Nayak et al. [14] developed e solution that is aim to grading Natural, cataract, and post-cataract photographs of the eyes. The Big Ring Area (BRA), Small

Ring Area (SRA), Edge Pixel Count (EPC), and Object Perimeter of the optical eye image are extracted. The characteristics are statistically evaluated and found to be important for automatic classification. For automatic classification, the same features are used in an automatic classifier such as Support Vector Machines (SVM). They used a very small dataset (174)images.They trained their model using NMR images.

In[15] Jagadale et al. presented a system which uses slit lamp imagesfrom ophthalmologist at eye hospital with computer aided image processing to detect cataract at earlier stage. The challenge of detection of cataract at earlier stage is attended in steps like lens detection, lens segmentation, feature extraction and categorization. The overall accuracy is enhanced by use of Hough circle detection transform for lens detection and support vector machine for categorization.

In [16] miguel et al. developed a system in which ultrasound technique can be used to early detect nuclear cataract invivo,classify its severity degree, and estimate its hardness. Features were extracted from the eyes' collected signals and then used to train and test different classifiers in order to accurately identify the healthy and cataractous lenses, as well as automatically classify the nuclear cataract according to the following degrees: incipient, moderate, and severe.

2.3 Conclusion

A detailed description of the literature review is provided in this chapter. The discussion was divided into two parts depending on the procedure of detecting method for convenience. The different target feature representation and detection techniques used by the researchers were described here. The next chapter contains an explanation of the methodology of the proposed system.

Chapter 3

Methodology

3.1 Introduction

In this chapter we will discuss about the proposed methodology of our research work. It includes flow charts, working steps to clearly understand our proposed method.

3.2 Diagram/Overview of Framework

This section will demonstrate a full perspective of this thesis' methodology. A framework for automatic cataract detection is shown here. Initially, data of eye images for both cataract and normal eye are collected. Then the images are processed for formatting and removing the anomalies. Next, data is augmented for increasing the quantity of dataset. After that several feature is extracted from the augmented data. Lastly,Random forest classifier is used for classifying the cataract or normal eye. Hence,the suggested framework comprises of 7 primary steps. The steps are :(1)Input Eye Image; (2)Image Preprocessing; (3)Data Augmentation; (4)Feature Extraction; (5)Labelling the Data; (6)Random Forest Classifier; (7)Classifies cataract/normal.
To offer a clear and complete knowledge of the thesis, we will portray the notion of each step with appropriate equations, tables, statistics.

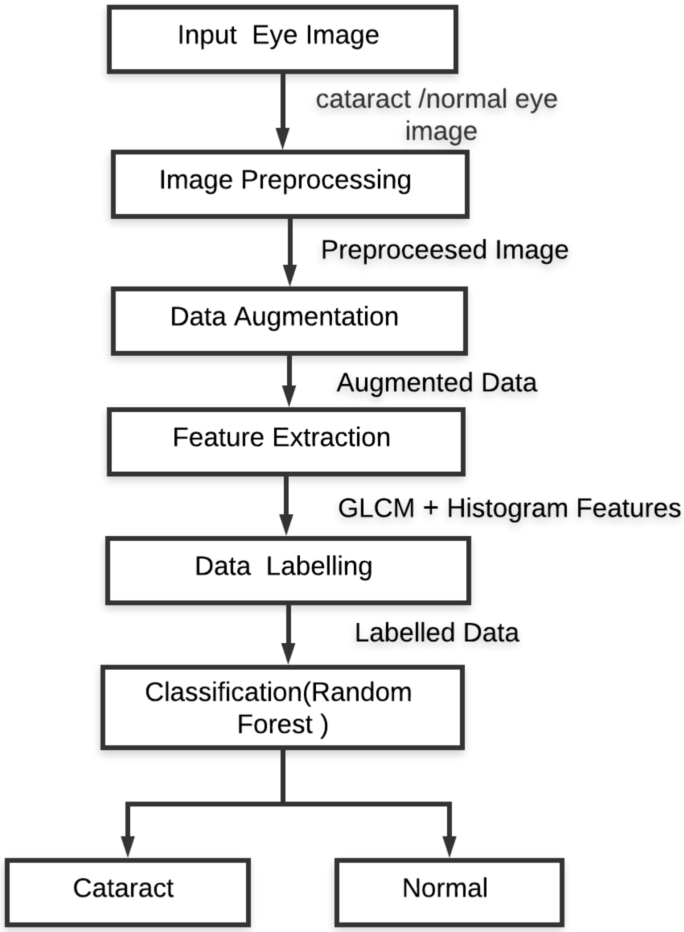


Figure 3.1: Proposed Method for Cataract Detection Based on Random Forest classifier

3.3 Detailed Explanation

In this section will provide detailed explanation of the above framework step by step.

3.3.1 Input Eye Image

Input eye image means image aquisition which is the fast and foremost step of Digital Image Processing. It is known as the action of retrieving an image from a source, typically a hardware-based source, for processing. It is the first step in the workflow sequence because no processing can take place without an image. So,we have collected images from different dataset sites & from google. Then we have processed image one by one.

3.3.2 Image Preprocessing

Data pre-processing is an important phase, and the researcher should devote a significant amount of time to it before constructing the model. The aim of pre-processing is to improve image data by suppressing unwanted distortions or enhancing certain image features that are essential for subsequent processing and analysis. In order to preprocess our image we have followed several steps. The steps are demonstrated below in a flow chart:

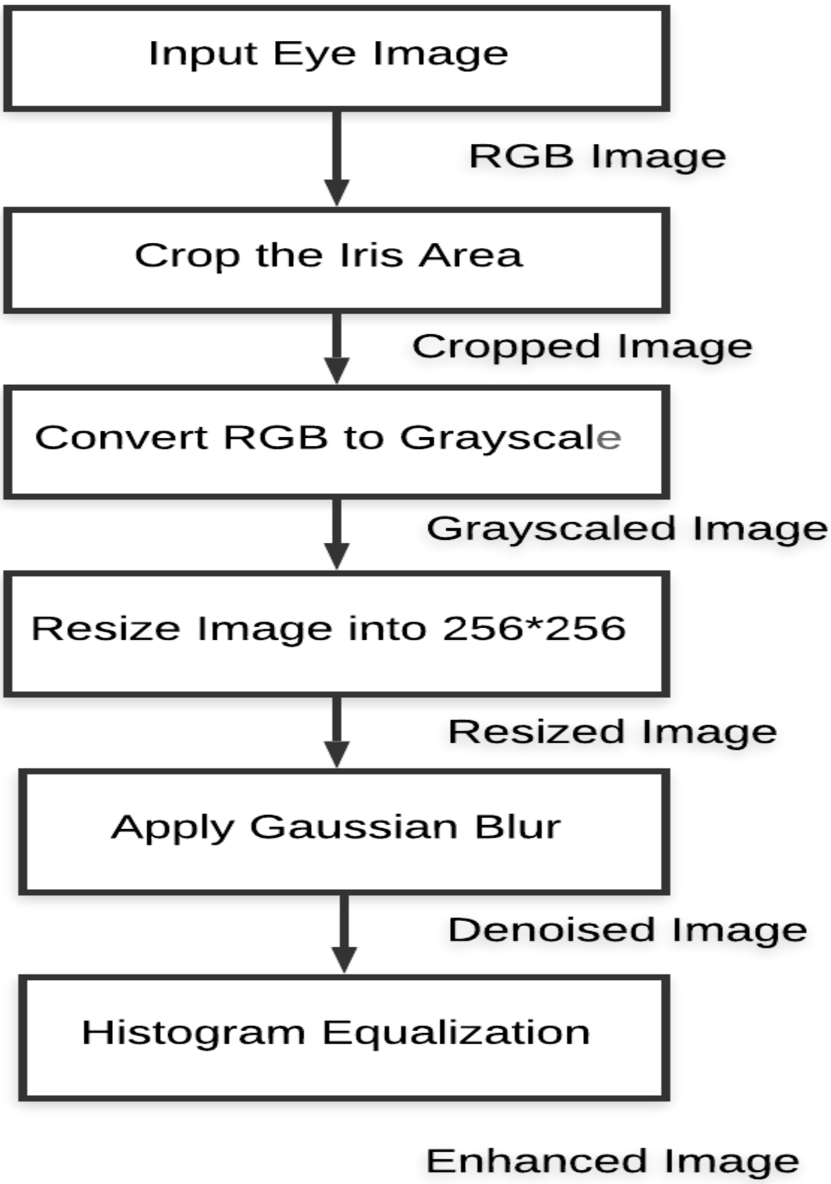


Figure 3.2: Image Preprocessing technique Steps

3.3.2.1 Cropping the Iris Area

It's often interesting to process a single sub region of an image while leaving the rest of the image alone. The method is known as region-of-interest (ROI) processing. ROI varied from image to image. Cataract is formed mainly in the eye lens. As we are detecting cataract from pupil area. But we all know that pupil area is changable. It changes due to respond to light or other stimuli. The colored part of the eye that helps to control the amount of light that enters it is known as iris. The iris closes the pupil to let less light in when there is bright light. When there is a lack of light, the iris widens the pupil to let more light in.That's why it will not a wise decision to crop the pupil area. So,We have cropped the iris area instead of pupil area. So our region of interest is iris. It can be done in two ways-manually or by using algorithm. In training phase we have done it manually.

(a) Real Eye Image

(b) Cropped Iris Area

Figure 3.3: Cropping Iris Area from full eye Image

3.3.2.2 Conversion from RGB to Grayscale

The images of the sequence are RGB images. RGB image has channels of red, green and blue. The combination of red, green, and blue intensities contained in each color plane at the pixel's position determines the color of each pixel. The image of the RGB will then be transformed to a gray image. The input image is an RGB image which is mainly three images layered on top of each other; a red image, a green image, and a blue image with 8 bits of each pixel in it.

Grayscale is a collection of monochrome shades ranging from black to white. A color image may be converted to black and white, or grayscale, in many image editing programs. This method removes all color details from each pixel, leaving only the luminance. The grayscale image is achieved by multiplying the red pixels of the RGB image by 0.2989 times, the green pixels by 0.5870 times and the blue pixels by 0.1140 times as follows:

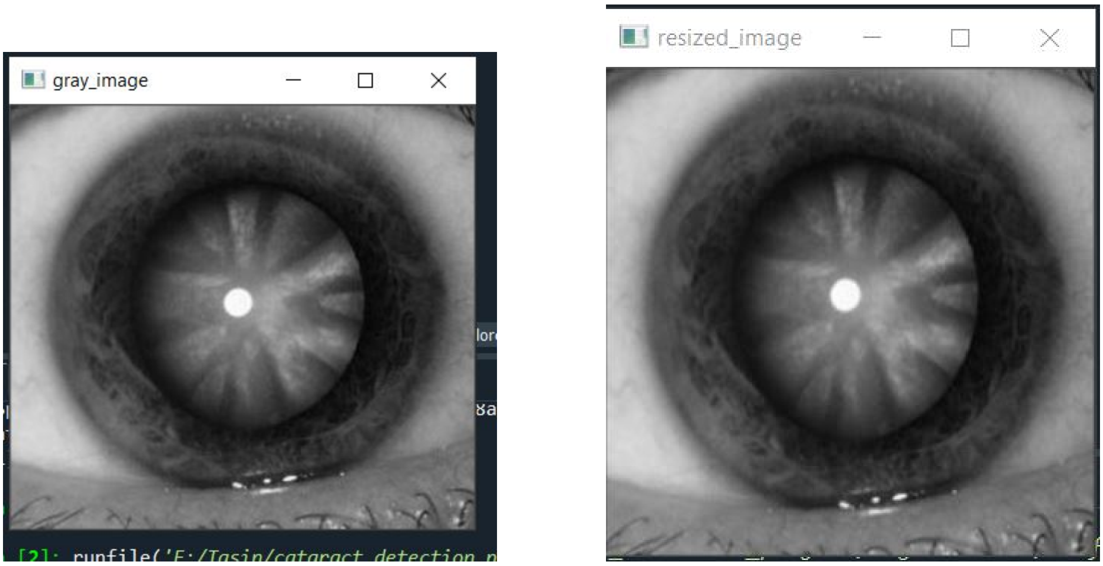
Gray scale image = 0.2989 * R + 0.5870* G + 0.1140 * B

(a) RGB Image (b) Grayscale Image

Figure 3.4: RGB Image to GrayScale Image Conversion

3.3.2.3 Resize Grayscale Image

Image resizing is necessary in order to increase or decrease the total number of pixels. It is important for turning all images into same size for getting the same number of pixels. Moreover,the larger the image size the longer it will take to process the image. That's why, we have resized all the images into 256*256. That means the image has 256 pixels in horizontal and 256 pixels in vertical dimensions.



(a) Grayscale Image (b) Resized Image

Figure 3.5: Resize the Image into 256*256

3.3.2.4 Apply Gaussian Filter

Applying a Gaussian blur to an image referes convolving the image with a Gaussian function mathematically. Since it reduces the image's high-frequency portion, the isotropic Gaussian filter is commonly used as a low-pass filter. It is used to denoise images. Gaussian function is simply the product of two 1D Gaussian functions (one for each direction: horizontal and vertical) and is given below

$$G\left(x,y\right)=1/\left(2\pi\sigma^2\right)e^{\left(\left(x^2+y^2\right)/\left(2\sigma^2\right)\right)}$$

where x is the horizontal axis distance from the origin, y is the vertical axis distance from the origin, and σ is the standard deviation of the distribution. The general expression of a convolution is

$$g\left(x,y\right)=\omega *\ f\left(x,y\right)=\sum_{dx=-a}^{a}\sum_{dy=-b}^{b}\omega\left(x,y\right)f(x+dx,y+dy)$$

Here, g(x,y) is the filtered image, f(x,y) is the original image ω is the filter kernel. We have used 5*5 kernel for Gaussian Blurring. The kernel we have used is:

(a) Resized Image

(b) Blurred Image

Figure 3.6: Applying Gaussian Blur

3.3.2.5 Histogram Equalization

To obtain greater contrast, the histogram equalization basically spreads intensity values along the complete value spectrum. There are a number of distinct kinds of histogram equalization algorithms, such as cumulative equalization of histograms, normalized equalization of cumulative histograms, and localized equalization. For this thesis, we have applied cumulative histogram equalization.

Histogram equalization includes transforming the intensity values to roughly match a defined histogram with the histogram of the output image. With most pixel values in the center of the intensity range, the initial image has low contrast. The function of OpenCV creates an output picture with pixel values distributed uniformly across the range. The cumulative probability value will be multiplied by the maximum value of the range. For example, if the maximum value of the intensity is 150; which is a 8 bit binary number. The maximum value of the 8-bit binary number is 255. So, the cumulative probability will be multiplied by 255 and the contrast will be stretched within this range. If the maximum intensity level is 90; which is a 7-bit binary number. The maximum value of the 7-bit binary number is 127. So, the cumulative probability will be multiplied by 127 and the contrast will be stretched within this range. We acquire the histogram equalized pictures and their respective histogram before and after equalization of the histogram by applying the method to both the picture frames. The steps to implement histogram equalization are

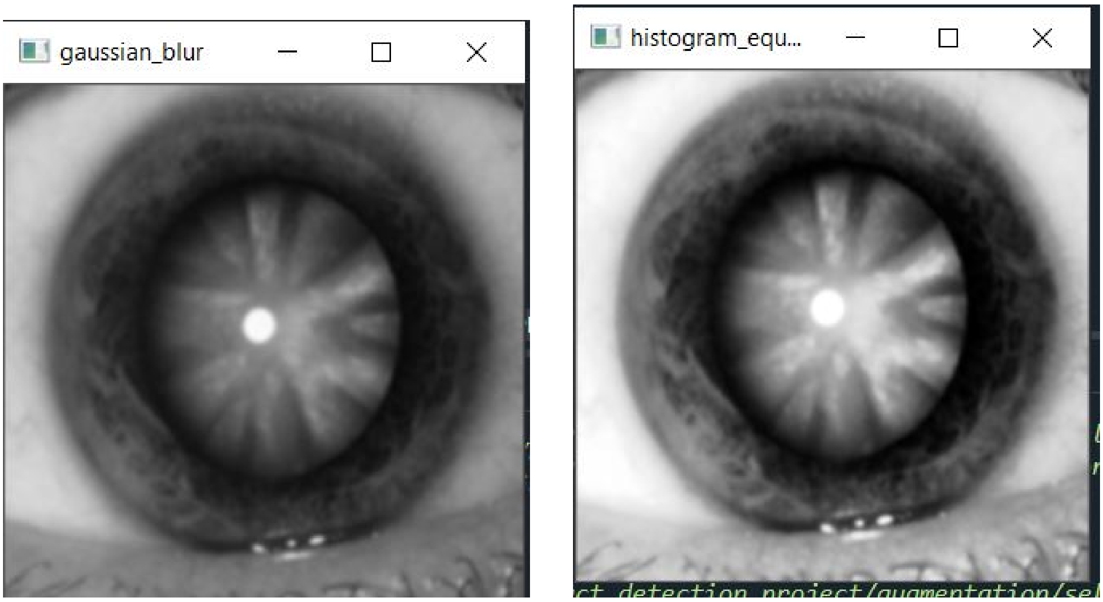
1.We count the number of pixels associated with each pixel intensity.

2. We calculate the probability in the image matrix for each pixel intensity.

3. We calculate the cumulative probability.

4.We multiply cumulative probability by the maximum value of the range.

5. Finally, we round the decimal value to its lower value called floor rounding



(a) Blurred Image (b) Equalized Image

Figure 3.7: Applying Histogram Equalization

3.3.3 Data Augmentation

In general, training data is complex using a few sample data. Data augmentation is a strategy that enables practitioners to significantly increase the diversity of data available for training models, without actually collecting new data[17]. In the real world, we might have a dataset of images taken under specific conditions. However, our target application could occur in a number of settings, including various orientations, locations, scales, and brightness levels. We account for these scenarios by using synthetically updated data to train our model. Machine learning models that are trained on more data become more skilled, and augmentation techniques may generate variations of the images that enhance the fit models' ability to generalize what they've learned to new images.There are Two categorical way of data augmentation techniques-(1)Position Augmentation (2)Color Augmentation.Each Category have several ways-

Position augmentation:

- Scaling
- Cropping
- Flipping
- Padding
- Rotation
- Translation
- Affine transformation

Color augmentation

- Brightness
- Contrast
- Saturation
- hue

We have applied both of this categories in our dataset. Random Rotation; Horizontal Flip and Change Brightness is applied in our dataset.

Horizontal Flip:

In the case of a horizontal flip, a picture flip involves reversing the columns of pixels. A boolean horizontal flip or vertical flip argument to the ImageDataGenerator class constructor specifies the flip augmentation.

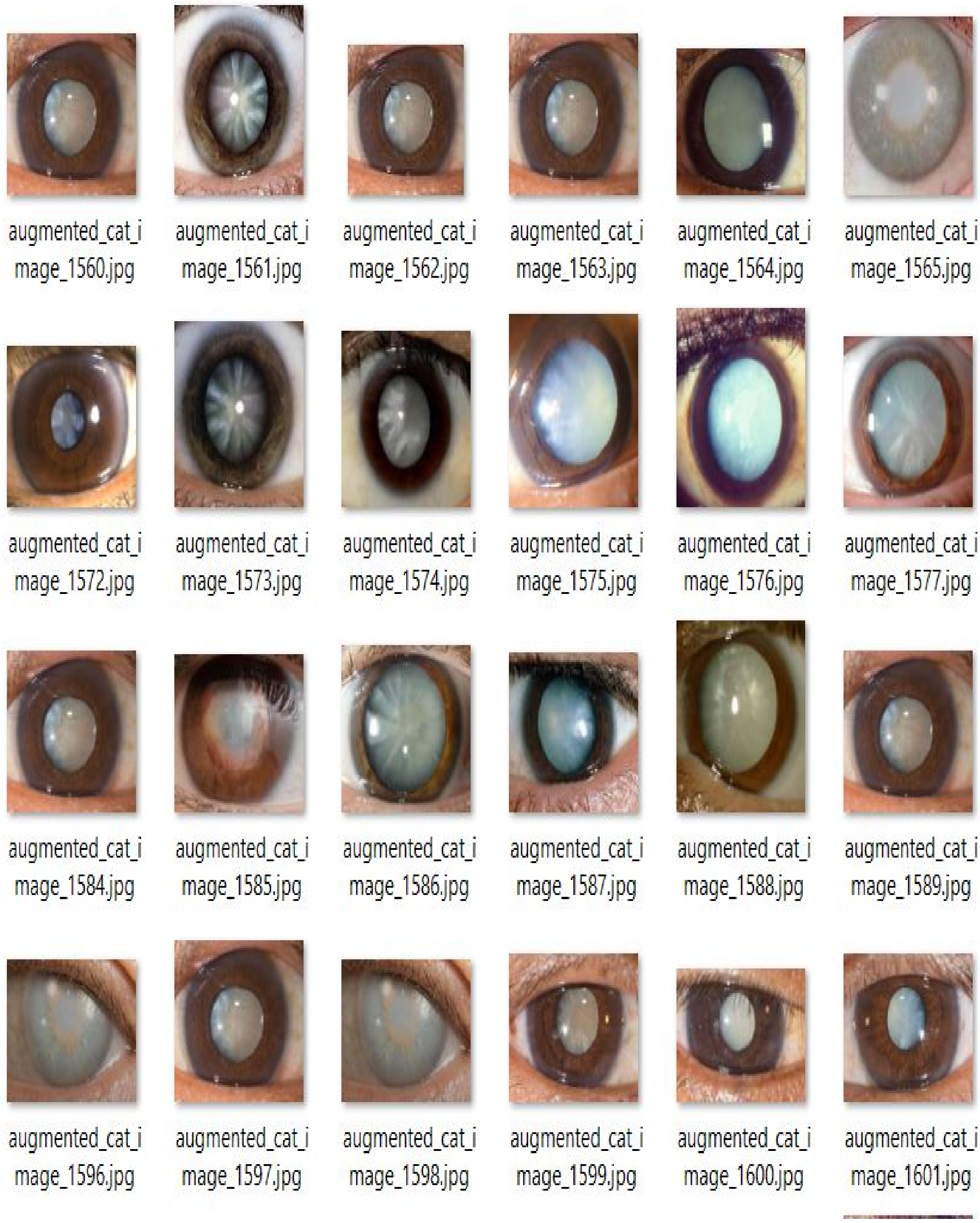


Figure 3.8: Data Augmentation by Horizontal Flip

Random Rotation:

A rotation augmentation rotates the image clockwise by a defined number of degrees between 0 and 360 at random. The rotation would most likely move pixels out of the image frame, leaving blank areas in the frame that must be filled in.

Figure 3.9: Data Augmentation by Random Rotation

Change Brightness:

Randomly darkening images, brightening images, or both may be used to boost the image's brightness. The aim is for a model to be able to generalize across images with different lighting levels. This is accomplished by passing the brightness range argument to the ImageDataGenerator() constructor, which defines the min and max range as a float representing a percentage for determining the amount of brightening. Values less than 1.0 darken the picture, e.g. [0.5, 1.0], while values greater than 1.0 brighten it, e.g. [1.0, 1.5], with 1.0 having no effect.

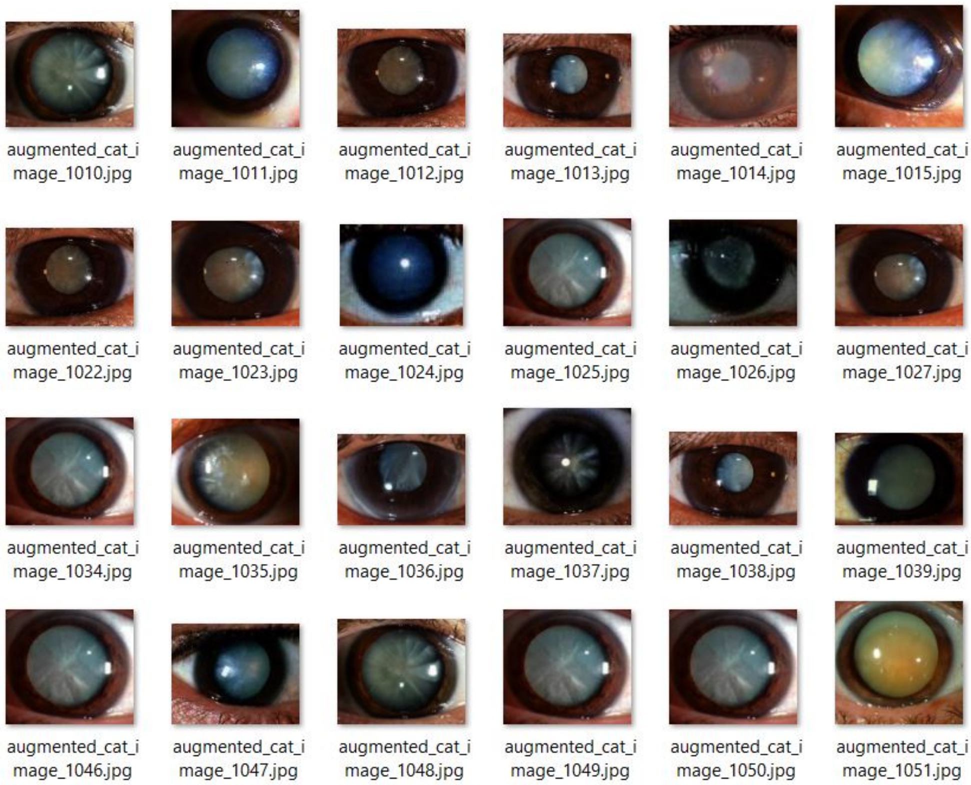


Figure 3.10: Data Augmentation by Changing Brightness

3.3.4 Feature Extraction

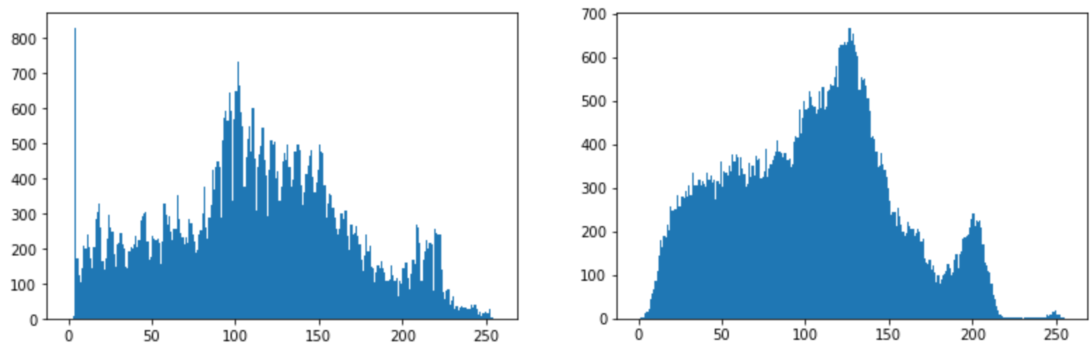
Feature extraction is a dimensionality reduction method that reduces a large collection of raw data into smaller groups for processing. The large number of variables in these large data sets necessitates a lot of computational resources to process. Feature extraction refers to methods for selecting and combining variables into features in order to reduce the amount of data that needs to be processed while still accurately and completely representing the original data set. There are several feature extraction methods. We have worked on statistical texture features. Texture is a set of metrics reflecting the spatial organization of pixel values of an image[18]. We have extracted two type of texture features. The first-order statistical texture method and the second-order statistical texture method are the two methods of statistical texture analysis. We have applied both in order to extract feature from our dataset.

3.3.4.1 Histogram Texture Feature

The first-order statistical texture method produces a function dependent on the histogram image's characteristics. It calculates texture using pixel incidence likelihood.The probability of occurrence of a pixel of particular grey level (intensity) is called the histogram. Assume that the grey levels in an image are in the range, where Ng is the total number of specific grey levels, to demonstrate the histogram approach to texture analysis.1)If N(i) is the total number of pixels with intensity i and M is the total number of pixels in the image, then the pixel occurrence probability P(i) is given by

$$P(i) = \frac{N(i)}{M} \tag{3.1}$$

Histogram Analysis:



(a) Histogram of Normal Eye (b) Histogram of Cataract Eye

Figure 3.11: Histogram of Normal Cataract Eye

We have used two histogram features mean intensity and standard deviation.

Mean Intensity: Since the whitish color of cataract eyes comes from the lens, it is easy to conclude that cataract eyes have higher intensities than normal eyes. The formula for calculating mean intensity in the form is:

$$M = \sum_{i=0}^{L-1} \frac{I_i}{N} \tag{3.2}$$

Here, M represents the mean intensity, I represents the possible intensity, N represents the number of pixels in an image, and L is the value of the possible intensity levels.

Standard Deviation: In image processing, a low standard deviation value means that pixel values appear to be very similar to the average value, wheras a higher value of standard deviation represents that the pixel values are broadly spread out over a large range of values. The standard deviation is calculated using a formula as follows:

$$S = \sqrt{\frac{\sum(x_i - \overline{x})^2}{N}} \tag{3.3}$$

Where S represents the standard Deviation ,Xi represents the individual pixel , $\overline{x}$ represents the mean of the pixel values N is the Total No of pixels

3.3.4.2 GLCM Texture Feature

The co-occurrence matrix is a second-order histogram that looks at the grey-level distribution of pixels in pairs. The probability of finding a pixel with a given grey level (i) at a defined distance (d) and a defined angle (a) from another pixel with a defined grey level (j) is calculated using the grey-level co-occurrence matrix process.

Contrast:

Contrast is an exponentially increasing measure of variation between gray levels in a picture. The size of the deployment (moment of inertia) elements of the co-occurrence matrix is indicated by the contrast value. The value of contrast would be greater if these components are distributed away from the main diagonal of the co-occurrence matrix. The equation for determining the value of contrast is as follows.

$$contrast = \sum_{i,j=0}^{N-1} P_{ij} \left(i - j\right)^2$$

Where p(i,j) states is the value in row i and column j of co-occurrence matrix.

Dissimilarity: Dissimilarity is a measure of the difference in gray levels in a picture as they increase linearly. Dissimilarity increases as the elements spread away from the main diagonal of the co-occurrence matrix, much as it does with comparison. As in, the equation for calculating dissimilarity is shown.

$$Dissimilarity = \sum_{i,j=0}^{N-1} P_{i,j} \left|i - j\right|$$

Where p (i,j) states is the element value in row i and column j of co-occurrence matrix.

Correlation: Correlation is a metric for the degree of linear dependency between gray levels, which indicates the presence of a linear image structure. As in, the equation for calculating correlation is shown:

$$Correlation : \sum_{i,j=0}^{N-1} \frac{(i-\mu)(j-\mu)}{\sigma^2}$$

Where p(i,j) states the value in row i and column j of the co-occurrence matrix, i stated average value of the pixels in row i, μ stated average value of the pixels in column j and i indicate pixels standard deviation in a row i and σj indicate pixels standard deviation in column j.

Homogeneity: Homogeneity is a measure homogeneity of variations in image. The equation to calculate homogeneity is showed,

$$Homogeneity : \sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$$

Where p (i,j) states is the value in row i and column j of co-occurrence matrix.

Entropy: Entropy is a measure of an image's disorder, and it reaches its maximum value when all elements in the P matrix are equal. Many GLCM elements have very small values when the picture is not textually uniform, implying that entropy is very high. As a result, entropy and GLCM energy are inversely proportional.

$$Entropy : \sum_{i,j=0}^{N-1} - \ln\left(\left(P_{ij}\right) P_{ij}\right.$$

Here,We have shown a portion of feature measurements of cataract eye image.

3.3.5 Classification:

3.3.5.1 Random Forest Classifier

Random forests is a supervised learning algorithm. It can be used both for classification and regression. Random forests generate decision trees from randomly chosen data samples, obtain predictions from each tree, and vote on the best solution. It also serves as a good indicator of the value of a function. There are four stages to it:

- Choose random samples from a collection of results.
- Create a decision tree for each sample and use it to generate a prediction result.
- Make a vote for each expected outcome.
- the final prediction, choose the prediction with the most votes.

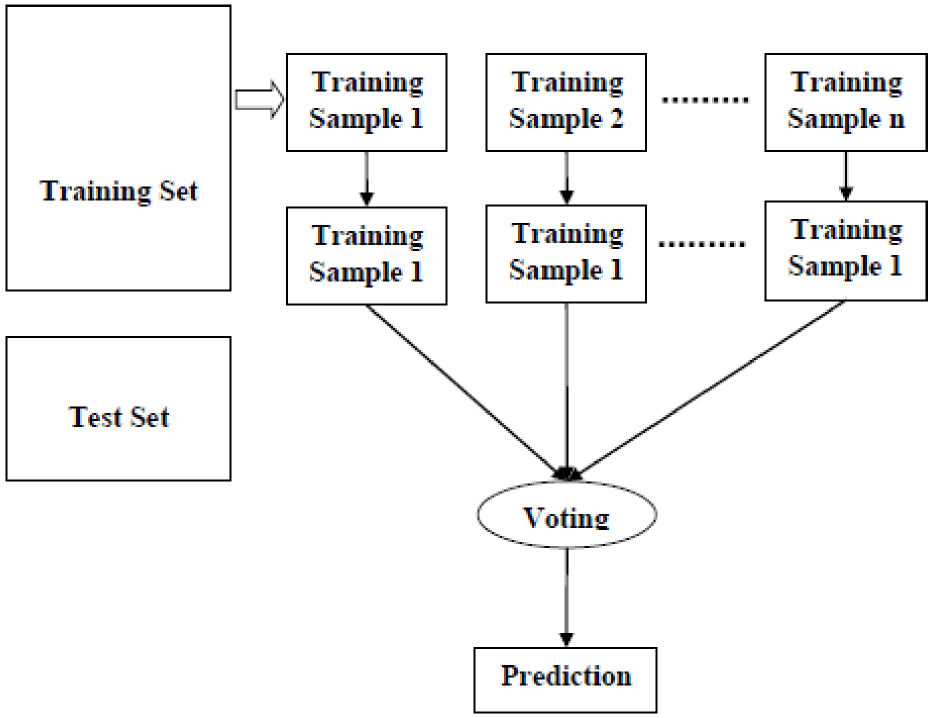


Figure 3.12: Random Forest Algorithm Framework

3.4 Implementation Environment:

We will give a brief description of what hardware and software tools we have used for implementing our system.

3.4.1 Implementation Tools:

The necessary tools to implement this system can be divided into two categories- Hardware & software as illustrated below:

3.4.1.1 Hardware Requirements:

First of all we need a laptop or desktop which has sufficient properties to complete our task. But some hardware is recommended for fast calculations in our system architecture for image processing. Minimum hardware requirements are-

- Operating System 32 bit Windows 7(minimum)
- Dual core 2.66 GHz or faster processor
- USB 2.0 bus
- 2 GB RAM

3.4.1.2 Software Tools and Libraries

Python and opencv is used for implementing our method.

OpenCV (Open Source Computer Vision)

OpenCV (Open Source Computer Vision) is a programming function library that focuses primarily on real-time computer vision. The library is used for image processing in easy English.It is primarily used to perform all images-related operations. OpenCV was constructed to provide a common infrastructure for computer vision apps and to accelerate the use in business products of machine perception. As a BSD-licensed product, OpenCV makes the code simple to use and change for companies. The library has over 2,500 optimized algorithms, including an extensive collection of computer vision and machine learning algorithms, both classic and state-of-the-art. These algorithms can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera motions, track moving objects, extract 3D models of objects, create 3D point clouds from 47 stereo cameras, stitch pictures together to create a high-resolution picture of a whole scene, find comparable pictures from an image database, remove red eyes from flash pictures

Image Formats Supported by OpenCV

The list of image formats supported in OpenCV is given below:

- Windows bitmap (bmp)
- Portable image formats (pbm, pgm, ppm)

- Sun raster (sr, ras)
- JPEG (jpeg, jpg, jpe)
- JPEG 2000 (jp2)
- TIFF files (tiff, tif)
- Portable network graphics (png)

3.5 Conclusion

This chapter gave us the overall methodology about how we are going to detect a Cataract or Normal eye. Though explained in brief this chapter will guide us through proposed method by learning about the output after every process. The next chapter is about the experimental result analysis of the proposed methodology.

Chapter 4

Results and Discussions

4.1 Introduction

This chapter describes the implementation details of our proposed methodology and the experimental results. Sample input-output and a comparative analysis are included in this chapter.

4.2 Dataset Description

Collecting dataset was the main challenge of our work. As in different dataset sites retinal images were available. As,typically cataract is detected from retinal image in medical section and they use very high resolution camera for that i.e slit camera, fundus camera. So, retinal images were available. Our first target was to captured patient's eye image from hospital. But it was not possible in this pandemic situation. So.we have collected images from google. We have collected more than 300 images of cataract and normal eye. Translation, rotation, and blur were all issues with the photos. Since the images were unconstrained, some data pre-processing and data cleaning were used in the first phase to prepare the input images and make them available for model input. Therefore, the images were checked one by one manually, and 19 images from a total of because of blurriness, poor quality, or closed captions, images were removed. Then, we augmented the data for making varieties of data. The overview of data measurement is given in the following table:

Session	Image No
Collected Cataract Image	150
Collected Normal Image	150
Elliminated Images	19
Cataract Images(augmented)	1502
Normal Images(augmented)	1502
Total Images	3004

Table 4.1: Dataset Analysis

4.3 Impact Analysis

Project Impact is how your project affects the matters which it comes in contact with. Assessing a project impact means defining the positive and negative impacts that the project is supposed to have on the climate, company, society, people, and so on.

4.3.1 Social and Environmental Impact

We have developed a system for automated cataract detection. We live in a developing country. Here,People of different professions live. All of the peoples earning capability are not same. Specially in the rural area, most of the villagers don't have proper education or no education at all. So,they don't have proper knowledge about any kind of diseases. Moreover,as a developing country medical treatment in our country is very costly so,the low-earning people can't afford to bear the cost. Only for this reason most of the people overlook their health issues. In our system we don't need any medical equipment. So,It's relatively far cheaper than typical diagnosing system. People can easily get service in low cost using our system.

4.3.2 Ethical Impact

Our work has serious ethical impact too. If this system is implemented successfully and if people use this, there will arise a lot of ethical issues. As we have said that it can be a cost effective alternative for people, So it should be applied in that way. If this work is used in wrong, serious impact will occur in someones life.

4.4 Evaluation of Framework

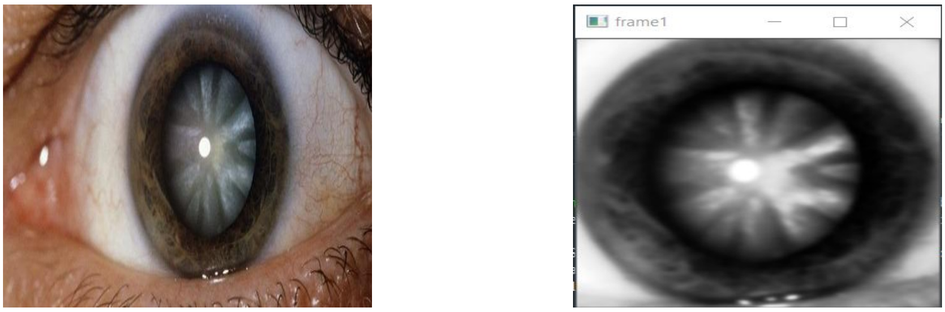
This section will give a brief explanation of how our frameworks works.

4.4.1 Eye Detection

We have detected eye using Haar cascade Classifier. OpenCV provides a pre-trained Haar Cascade model to detect eye from an image. First, a cv::CascadeClassifier is created and the necessary XML file is loaded using the cv::CascadeClassifier::load method. Afterwards, the detection is done using the cv::CascadeClassifier::detectMultiScale method, which returns boundary rectangles for the detected eyes. Now, if the system detects eye from the image, we will proceed for the further steps to detect cataract. Otherwise, we will stop the procedure.

4.4.2 ROI Extraction

Region of Interest is extracted in two steps. In first step,we selected an optimal threshold value, then a binary masked image is found. After that,we have applied morphological closing. To detect areas inside or near the iris, contours are used. In second step, with the co-ordinate of the bounding box the ROI is extracted from the frame. With the co-ordinates of the bounding box, we can extract the region of interest from the original image frame.



(a) Input Image (b) ROI Extraction

Figure 4.1: ROI Extraction of Cataract Eye Image

4.4.3 Feature Extraction:

We have extrated seven features. All of the features are calculated for cataract and normal eye. Feature of cataract and normal eyes are saved in two different folder. Then,all the seven features are combined and saved to folder for each image. Then, the features are fed into the model. All this algorithms are implemented in python Opencv library. Feature extraction of a portion of data is shown below:

	0	1	2	3	4	5	6
582	115.139	7.02331	0.220222	0.989394	6.98943	128.494	73.6792
583	161.111	8.19588	0.20474	0.985208	6.91974	128.573	73.7875
584	55.0983	4.75578	0.286908	0.994859	7.37683	128.278	73.35
585	70.3718	5.50633	0.241188	0.993519	7.38514	128.258	73.65
586	93.377	6.47999	0.212444	0.991397	7.56315	128.161	73.6326
587	83.7296	5.81634	0.265167	0.992291	7.12859	128.381	73.8444
588	120.482	6.85248	0.234608	0.988909	7.25493	128.315	73.7127
589	78.6415	5.2811	0.306593	0.992811	6.84755	128.712	73.8886
590	80.7949	5.28249	0.279715	0.992483	7.32012	128.321	73.3457
591	180.579	7.8972	0.238593	0.984356	6.91925	124.465	76.0895
592	55.0983	4.75578	0.286908	0.994859	7.37683	128.278	73.35
593	19.5291	2.54544	0.42126	0.998188	7.53878	128.077	73.4733
594	151.378	7.89136	0.21633	0.986107	6.87729	128.646	73.8272
595	49.7004	4.24164	0.313645	0.995396	7.38448	128.264	73.5232
596	80.7543	5.743	0.2454	0.992567	7.12771	128.469	73.7141
597	95.9731	5.56584	0.315578	0.991181	6.94785	128.649	73.728
598	84.2074	5.84485	0.243852	0.992233	7.12847	128.509	73.6422
599	167.681	8.60159	0.20588	0.984637	6.56486	129	73.8763
600	167.681	8.60159	0.20588	0.984637	6.56486	129	73.8763
601	63.2073	5.19548	0.24802	0.994174	7.28155	128.275	73.7094
602	44.8449	2.85908	0.473604	0.996561	7.1338	111.712	80.8406
603	145.866	7.86801	0.212985	0.98662	6.87265	128.666	73.8252
604	49.7004	4.24164	0.313645	0.995396	7.38448	128.264	73.5232

Figure 4.2: Extracted Features from a Portion of Data

4.4.4 Train Random Forest Classifier

This training data set consists of 1502 cataract images and 1502 normal images. Totally, 3004 image's feature values are saved in random forest.model file. We have applied 30 n-estimators.

Some Cataract Eye Images for Training:

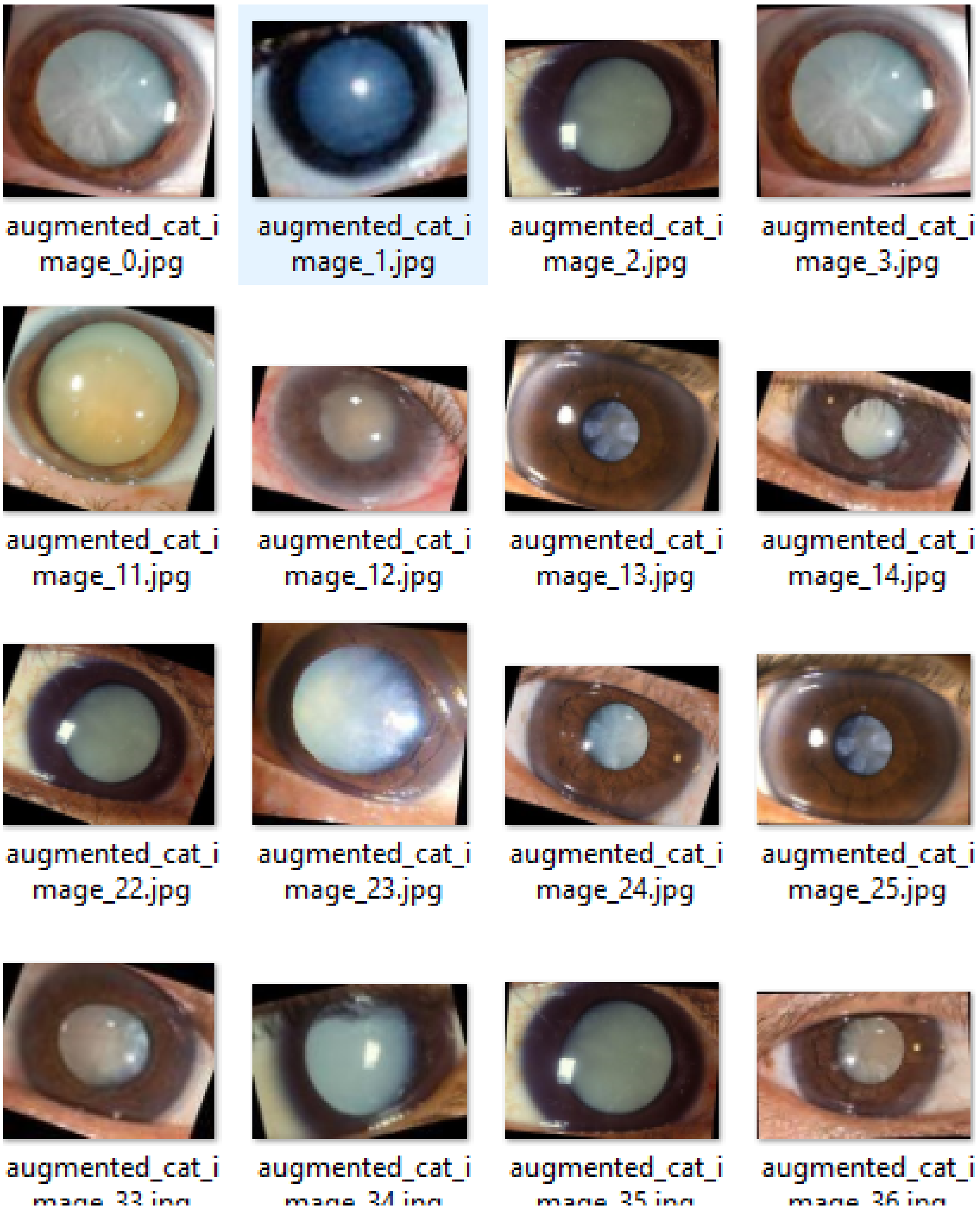


Figure 4.3: Positive Image for Training Random Forest Model

Some Normal Eye Images for Training:

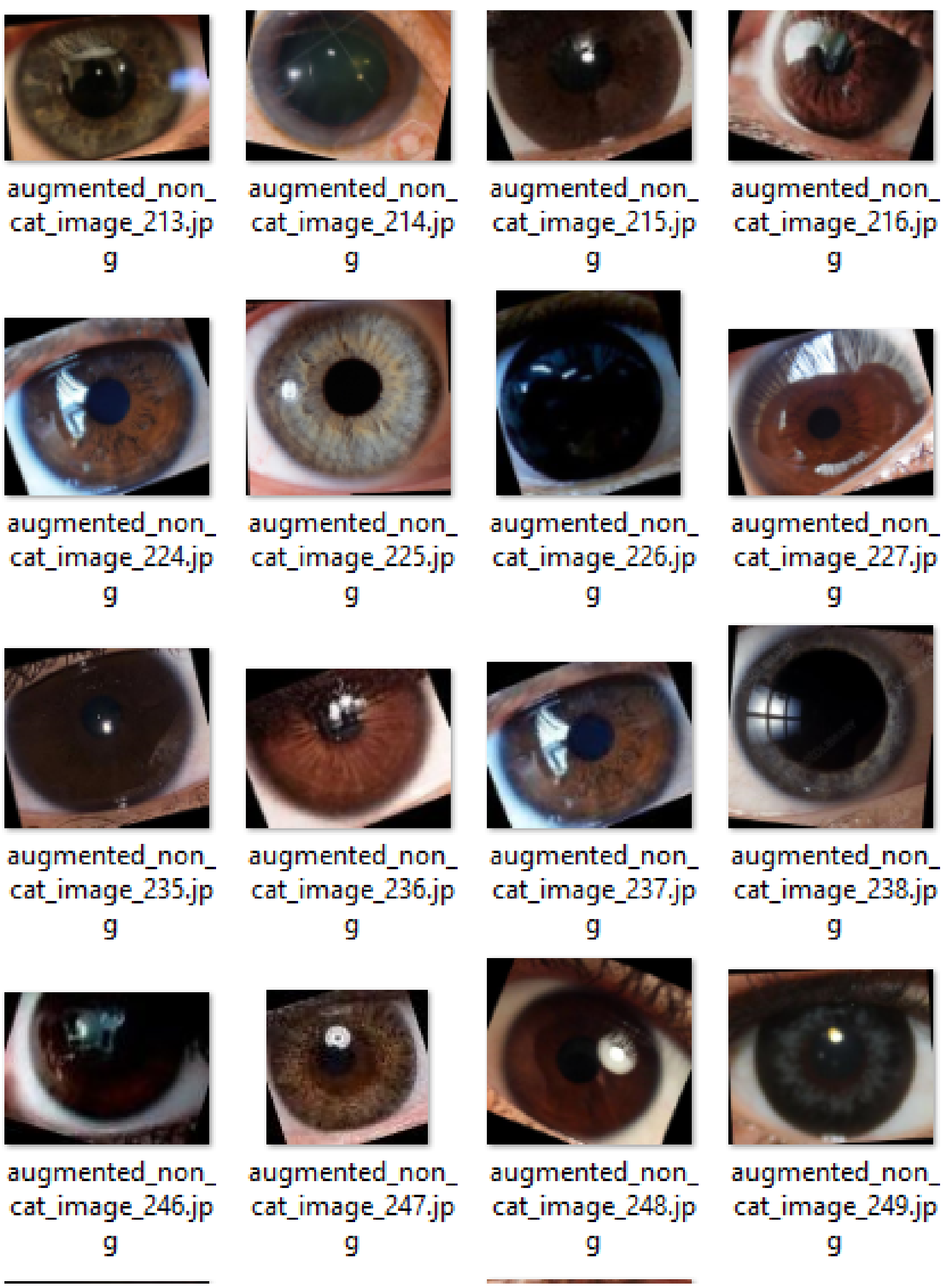


Figure 4.4: Negative Image for Training Random Forest Model

4.4.5 Sample Input Output

In this section we will check our system by analysing output for sample input.

4.4.5.1 For Normal Eye

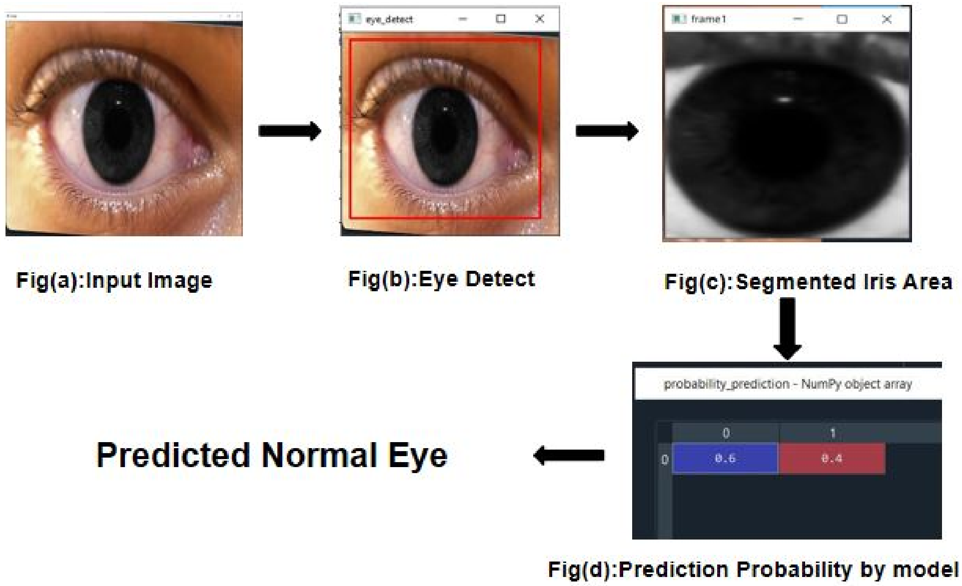


Figure 4.5: Prediction of Normal Eye

4.4.5.2 For Cataract Eye

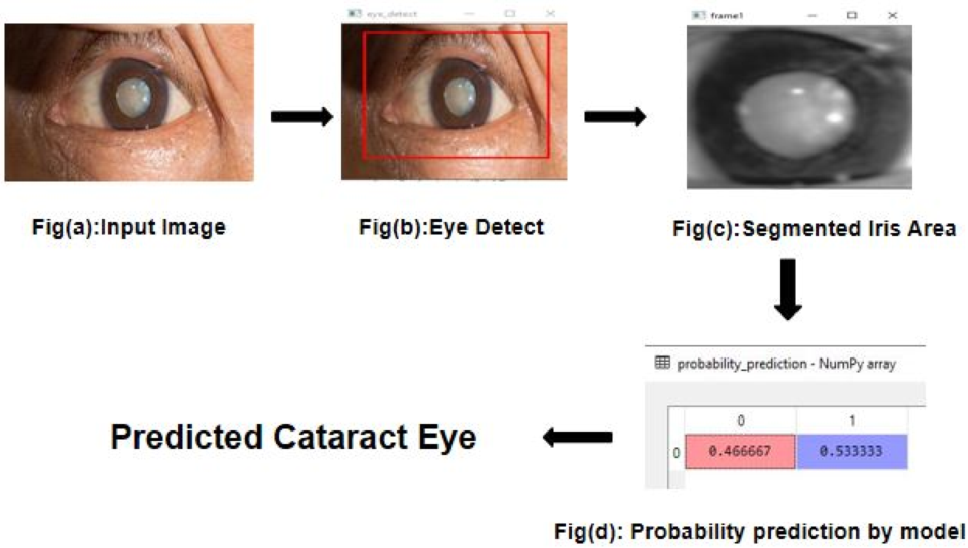


Figure 4.6: Prediction of Cataract Eye

4.5 Evaluation Matrics

Performance of a system is measured by its ability to handle challenging situations in an effective manner. Evaluation metrics are often used to measure the integrity of mathematical or machine learning models. The evaluation of machine learning models or algorithms is essential for any system. There are several different types of measurement criteria that can be used to measure a model. Some significant evaluation matrics are:

- Accuracy
- Precision
- Recall
- F1 Score
- Confusion Matrix

These metrics have an effect on how we evaluate the importance of different features in algorithm/model results, as well as how we choose which algorithm/model version to use. Furthermore, it is essential to employ several assessment criteria in order to assess a model's efficiency from various perspectives, as this greatly helps in demonstrating the model's worthiness. We have measured our performance using this evaluation matrics.

4.5.1 Confusion Matrix

A confusion matrix is the N x N matrix used to test the effectiveness of a classification model, where N is the number of classes in the dataset. The number of predictions made by the model to decide if the classes are correctly categorized is represented by each value in the confusion matrix. There are four kinds of assessing values in a confusion matrix, which are illustrated below:

- **True Positive:** It refers to the number of times the model has estimated that the positive class will be positive.
- **False Positive:** It reflects the number of predictions in which the model incorrectly classifies the negative class as positive.
- **True Negative:** It denotes the number of predictions where the negative class is accurately predicted as negative by the model.

• **False Negative:** It reflects the number of predictions in which the model incorrectly classifies the positive class as negative.

As there are two classes Cataract and Normal, so the confusion matrix will be 2 x 2 matrix containing a total of 4 values. From the Table 4.2 we can visualize that our model classified 724 samples correctly among 750 samples.

		Target	
		Cataract	Normal
Testing Result	Cataract	374	19
	Normal	7	350

Table 4.2: Confusion Matrix of Random Forest Model

4.5.2 Performance Analysis of Trained Model

True Positive, True Negative, False Positive, and False Negative are the four parameters that determine the accuracy of any machine learning algorithm. Confusion Matrix displays all four parameters and other parameters such as recall, precision, F-Score, and ROC evaluated based on the confusion matrix.

$$Recall = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$F1Score = 2 * \frac{Precision * R\ e\ c\ a\ l\ l}{Precision + Recall}$$

No of input image	Precision(%)	Recall(%)	F1 Score(%)	Accuracy(%)
750	97.16	98.72	97.93	97.92

Table 4.3: Performance Analysis of Proposed Model

4.5.3 ROC Curve

A receiver operating characteristic curve, or ROC curve, is a graphical plot that illustrates the diagnostic ability of a binary classifier system as its discrimination threshold is varied. We have used k-fold cross validation for determining the

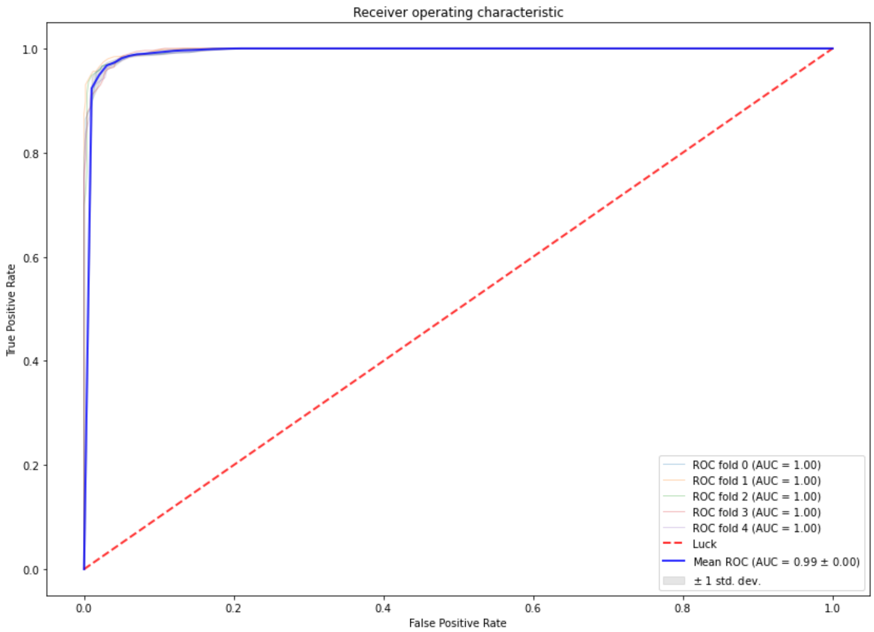


Figure 4.7: ROC Curve of the Proposed Framework

actual accuracy. We have folded our data five times.Then the mean of this five accuracy is counted.The Receiving Operating Characteristic (ROC) curve of this framework is represented in Figure 4.7. From the curve we can visualise that our true positive rate is very high and accuacy is around 97%.

4.5.4 Comparison Analysis

Comparison with [2] Y. N. Fuadah, A. W. Setiawan, T. L. R. Mengko and Budiman, "Mobile cataract detection using optimal combination of statistical texture analysis," 2015 4th International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering (ICICI-BME), Bandung, Indonesia, 2015, pp. 232-236, doi: 10.1109/ICICI-BME.2015.7401368. is represented below:

Method	Accuracy(%)
GLCM+KNN [2]	90.23
GLCM+Histogram+Random Forest(proposed)	97.92

Table 4.4: Comparison With Recent Work

4.5.4.1 ROC Curve

The Receiving Operating Characteristic (ROC) curve of KNN model is represented in Figure 4.8. From the curve we can visualise that accuracy achieved from KNN is around 90%.

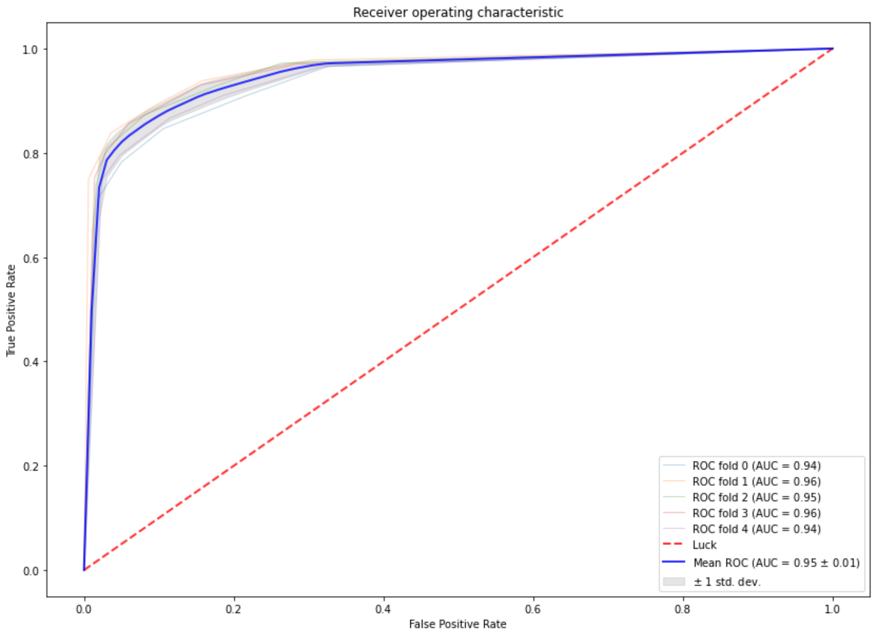


Figure 4.8: ROC Curve of the KNN Model

4.6 Conclusion

This chapter shows the result of cataract detection system. Performance of the proposed framework is also discussed here. As shown by the results, the proposed provides better accuracy. In the next chapter, the conclusion is drawn on this thesis work.

Chapter 5

Conclusion

5.1 Conclusion

Cataract is one of the most common diseases associated with aging, and as a result, many people suffer from it. Since the dawn of civilization, cataract has been recognized as the most common cause of blindness. About 16 to 20 million people suffering from blinding cataract. So,early detection is a must for this disease. In this thesis, an efficient method for cataract detection from pupil images was proposed. However, this task was challenging because there are scarce of data. Hence, Data have been collected from google & augmentation of data is done for increasing variety in images. Two types of texture feature-GLCM and Histogram feature have been extracted. Extracted feature is then fed into the Random Forest Classifier. Then it classify the image as cataract or normal eye image. Moreover, our system gives a extra facility of eye detection. If the testing image is not eye then the system will not go to the further procedure. Efforts are being made to obtain more precise results and identify cataracts in their early stages.

5.2 Future Work

We will try to improve segmentation techniques of extracting the iris area more efficiently in future.As our plan was to develop an android application for cataract detection and we have developed a model with better accuracy so,we will implement it in mobile application.

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