A Project Report

On

DETERMINING METRICS FOR RECONSTRUCTION OF CORNEA USING IMAGE PROCESSING

BY

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Birla Institute of Technology and Science-Pilani,

Hyderabad Campus

Certificate

This is to certify that the project report entitled "**DETERMINING METRICS FOR RECONSTRUCTION OF CORNEA USING IMAGE PROCESSING**" submitted by Mr. ABISHEK KRISHNAN (ID No. 2011B5A3511H) in partial fulfillment of the requirements of the course BITS F423T – First Degree Thesis, embodies the work done by him under my supervision and guidance.

Date: 19.03.2016 **(P.K.THIRUVIKRMAN)**

BITS- Pilani, Hyderabad Campus

ABSTRACT

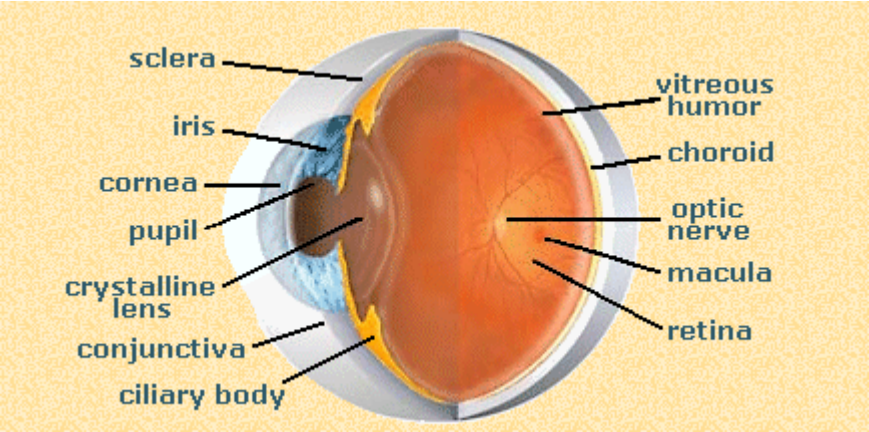
In this project I intend to measure and predict metrics (Thickness of Cornea) of damaged eye (**Spherical Abberation**), donor eye and surgeried eye using techniques involving Image Processing which is intended to use in the reconstruction of Cornea where the images of the Cornea was obtained using Optical Coherence Tomography (A variation of **Michelson Interferometer** Experiment).

CONTENTS

1. Human Eye and Visual Process

Eye is the most valuable sense organ.

The below image shows the important parts of an eye.



Steps involved in the process of visual experience

1. The light rays enter the eye through the cornea which converges/bents the light.

2. The light then progress through the pupil the center part of the colored iris.

2. a. Pupil changes its size to accommodate for the change in Intensity from smaller (for Intense light) to large (for dimmer light).

2. b. Iris changes its curvature to refocus the object on the retina whose images initially were formed behind the retina.

3. The image which was converged first by the cornea is converged further by the crystalline lens where just behind it the image gets inverted.

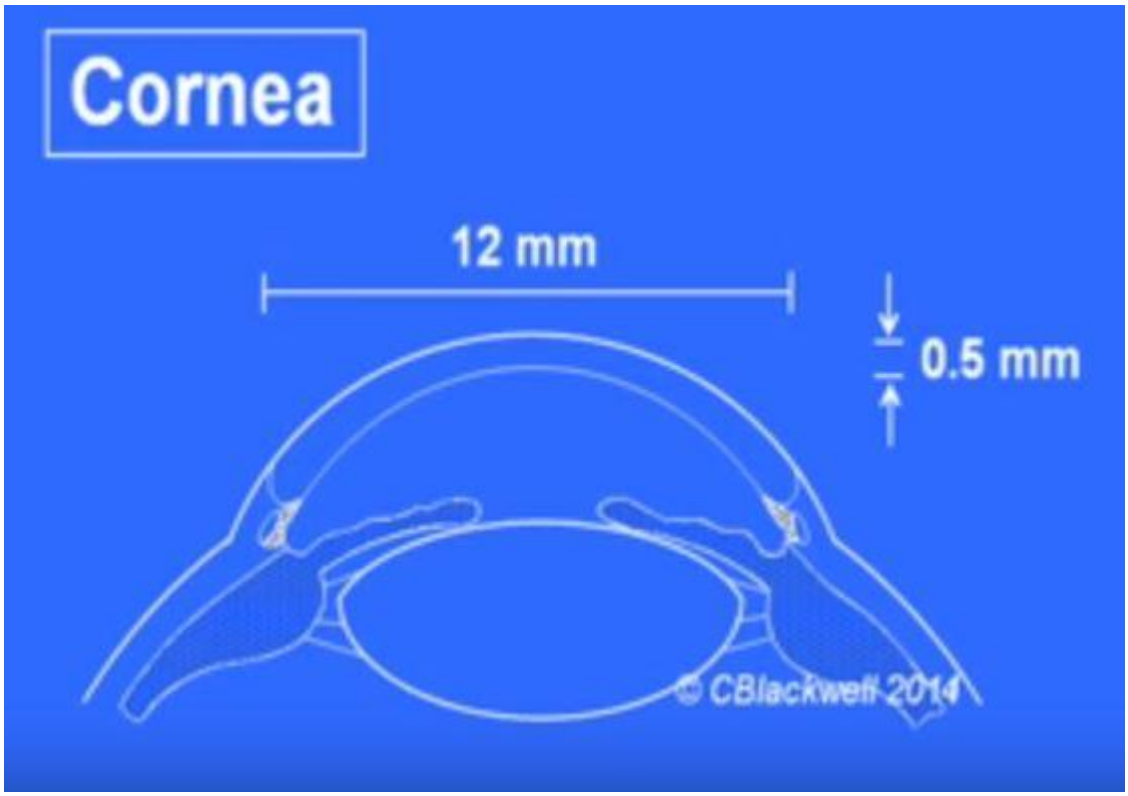
4. The light rays travels through the vitreous humor and to retina (macula is the central region of the eye where the best visual location resides).

5. The retina converts these light impulses to electrical signals which are sent via the optic nerve to the occipital cortex located at the posterior of the brain.

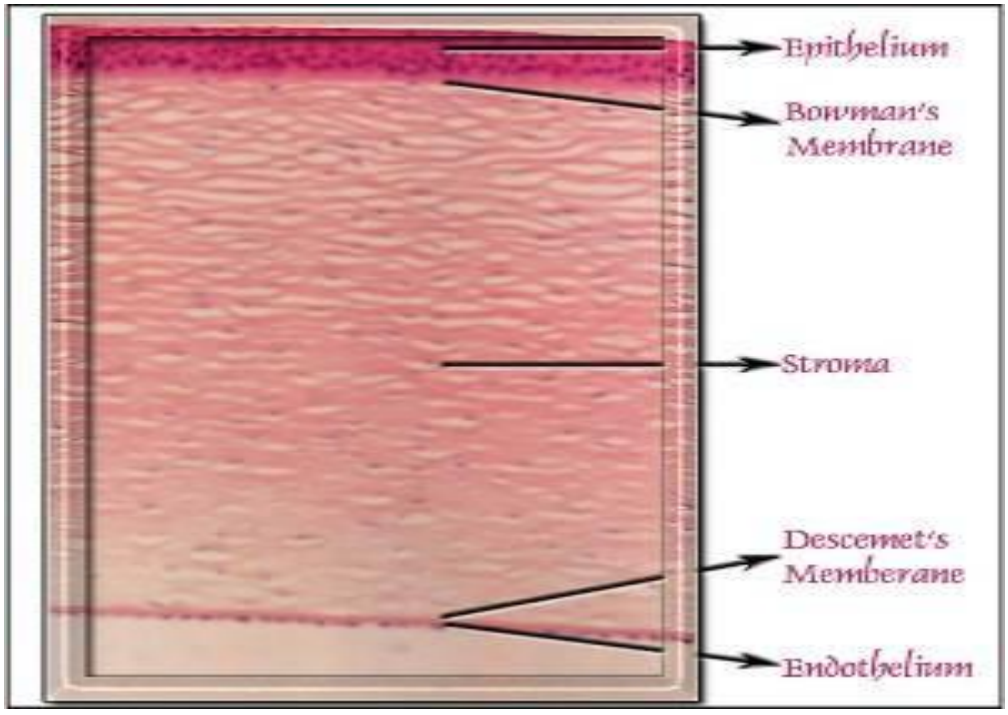
CORNEA

It is a transparent dome like structure and also a powerful structure which focuses the incoming light rays.

The typical dimensions of the cornea can be seen from the below figure:-



It consists mainly of 5 parts:-



1. Epithelium

It is the outer most layer of the cornea and is made up of the tissue's which make up the skin thereby it also has a lifecycle like skin cells which is typically from 7-10 days to form and then to eventually die.

Its functions include:-

a) To protect eye from foreign materials like dust.

b) To absorb oxygen and cell nutrients from tears and then redistribute them.

2. Bowman's Membrane

It is a transparent tissue which has strong layer of protein fibers known as collagen.

3. Stroma

It forms about 90% thickness of the cornea and mainly consists of water and collagen.

The collagen's spatial shape, arrangement leads to the light conducting transparency property of the cornea.

4. Descemet's Membrane

It is strong tissue composed of collagen fibers which are different from the ones present in the Stroma.

Its function is protect the eye from injuries and even injured to recover in a short span of time.

5. Endothelium

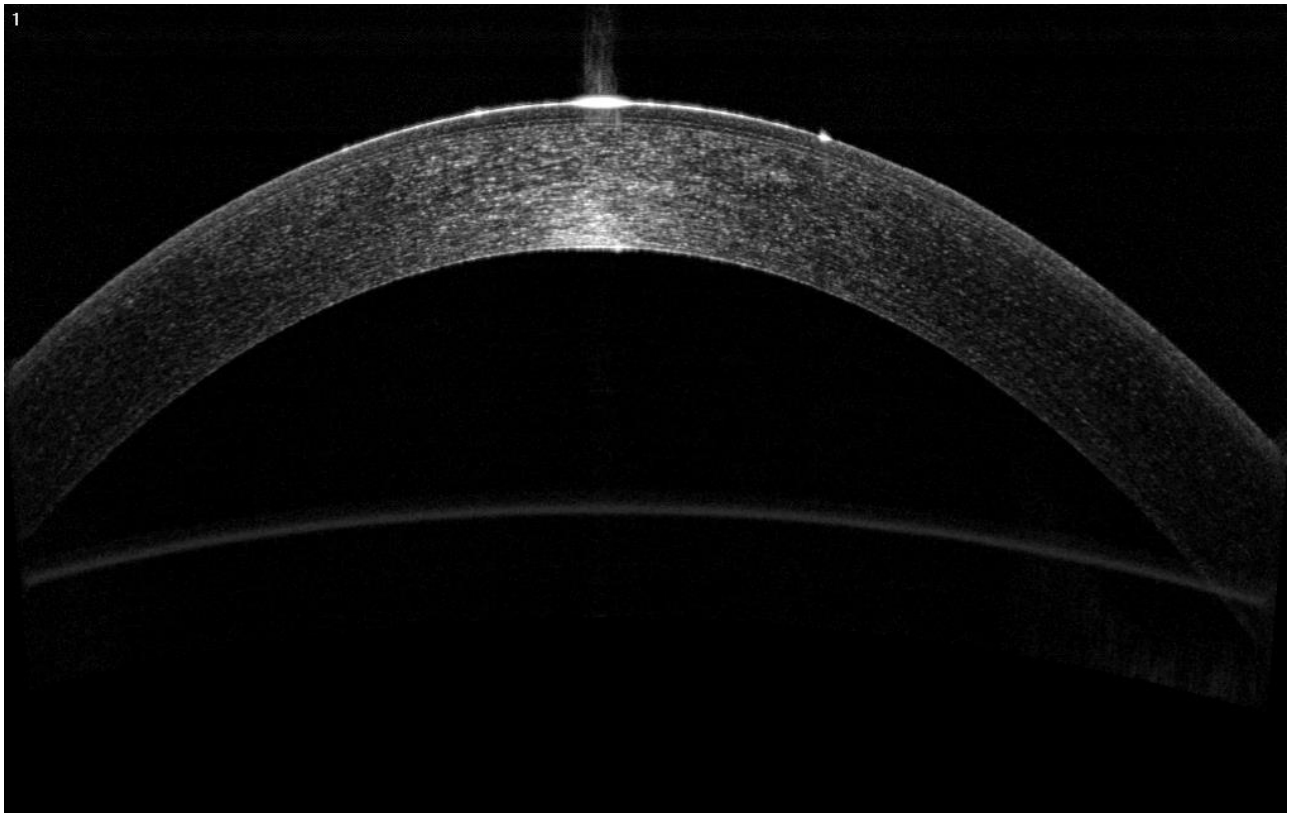
It helps in removing excess fluid out of the Stroma so it basically helps in maintaining the balance of the fluid moving in and out of the cornea.

The shape of the cornea is prolate spheroid. To understand the shape of the cornea takes a sphere and one where it is a parabola.

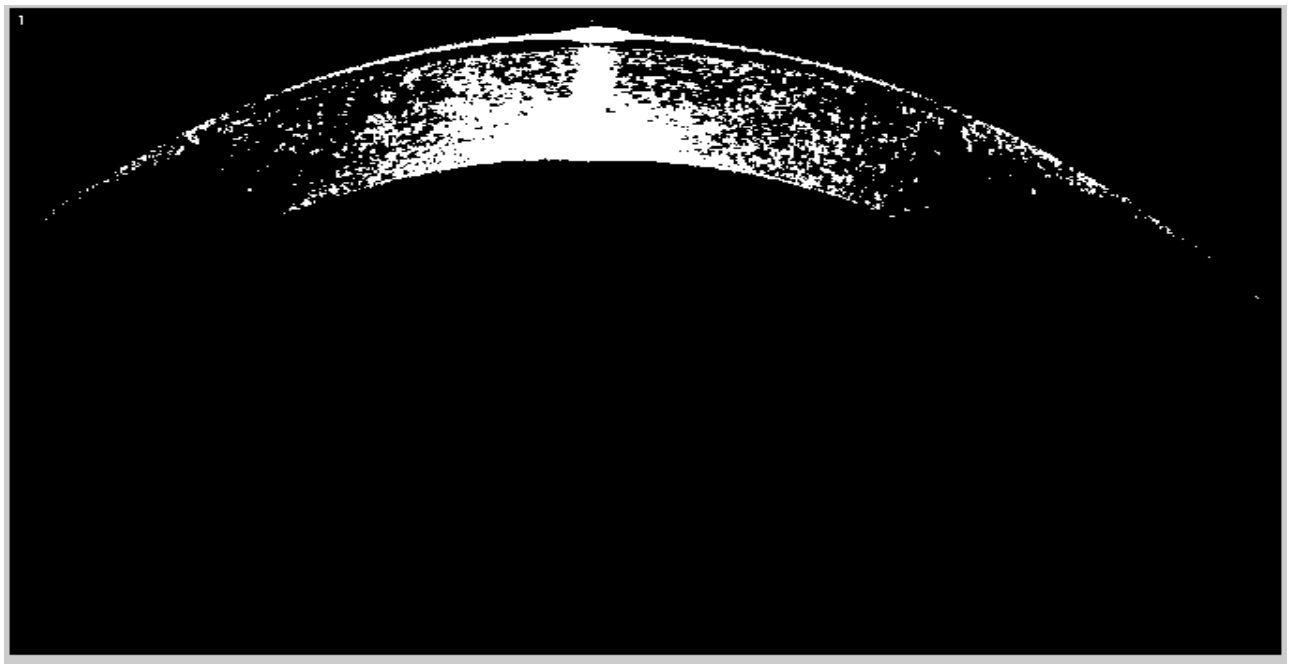
2.IMAGE PROCESSING

This section details the steps involved in MATLAB for measuring the thickness of Cornea (Step-1 Edge Detection and Step-2 Measuring the thickness)

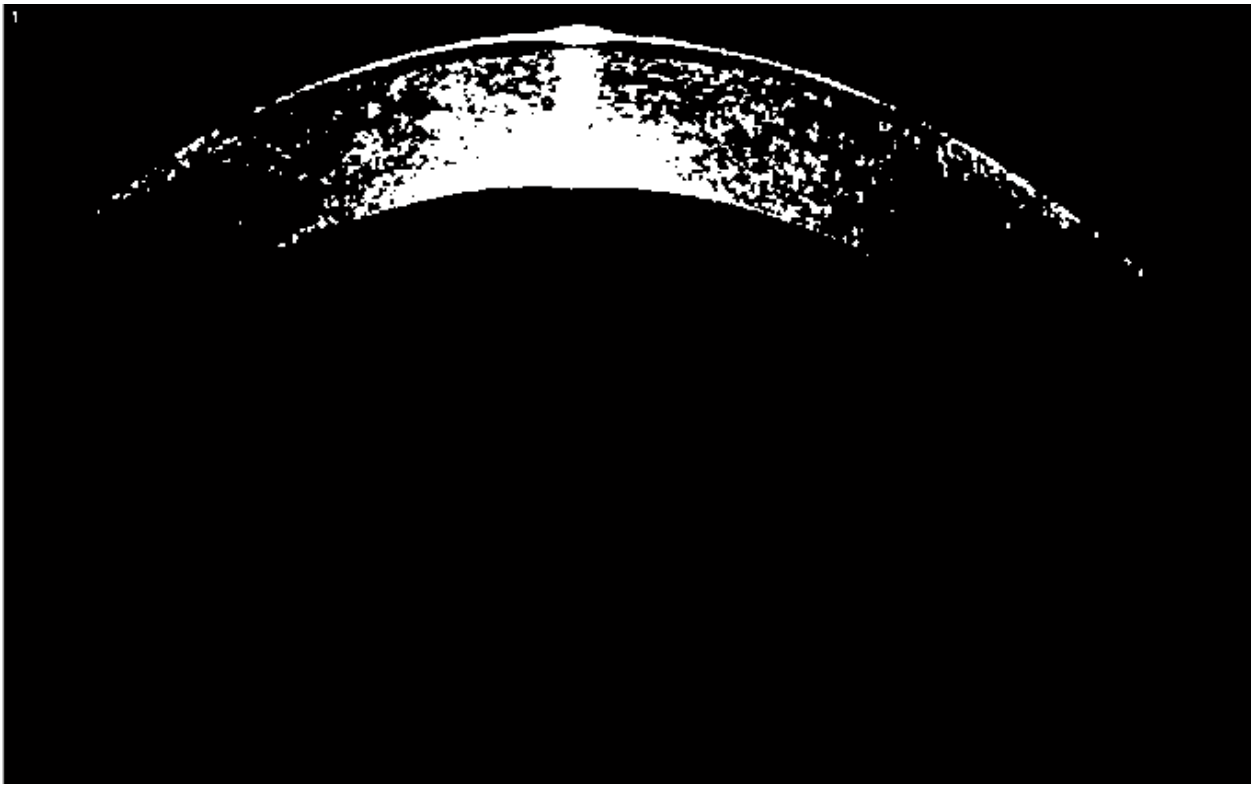
2.1.a) A Sample Image of Cornea



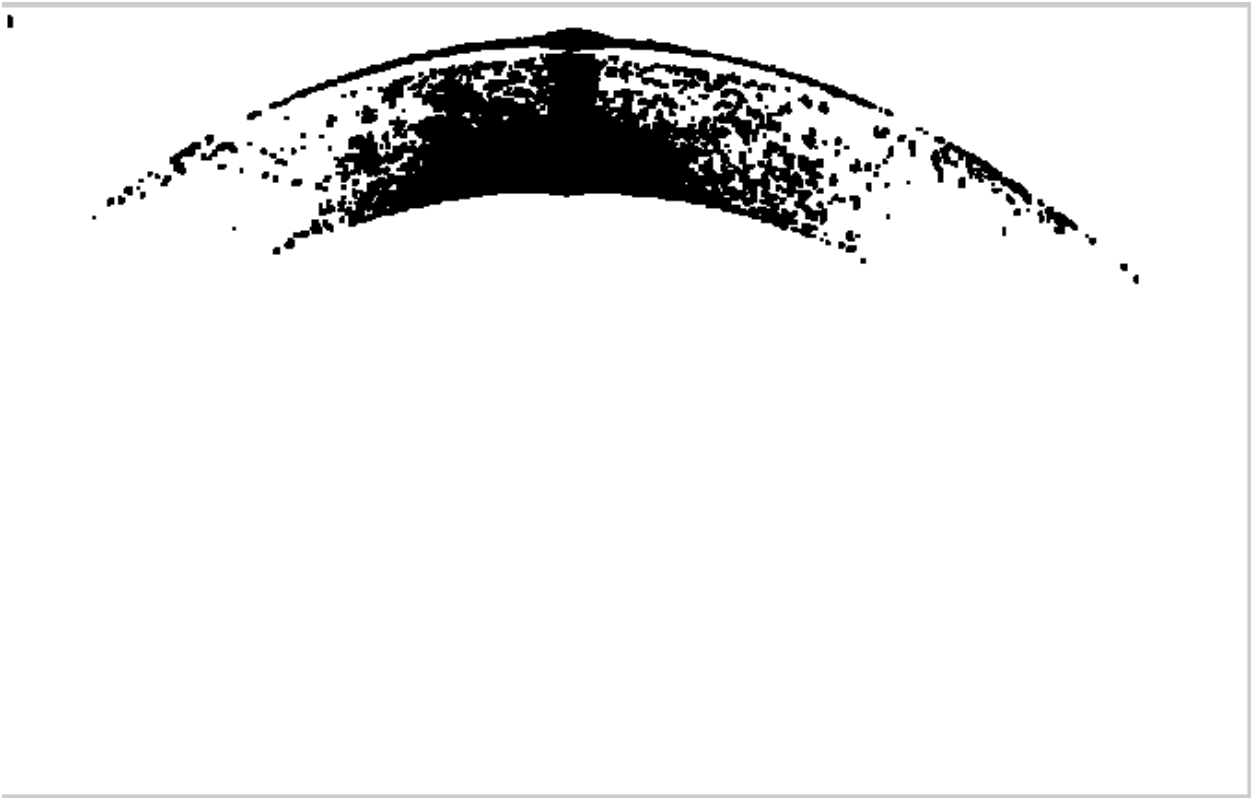
2.1.b) Convert the given into binary image using gray threshold level



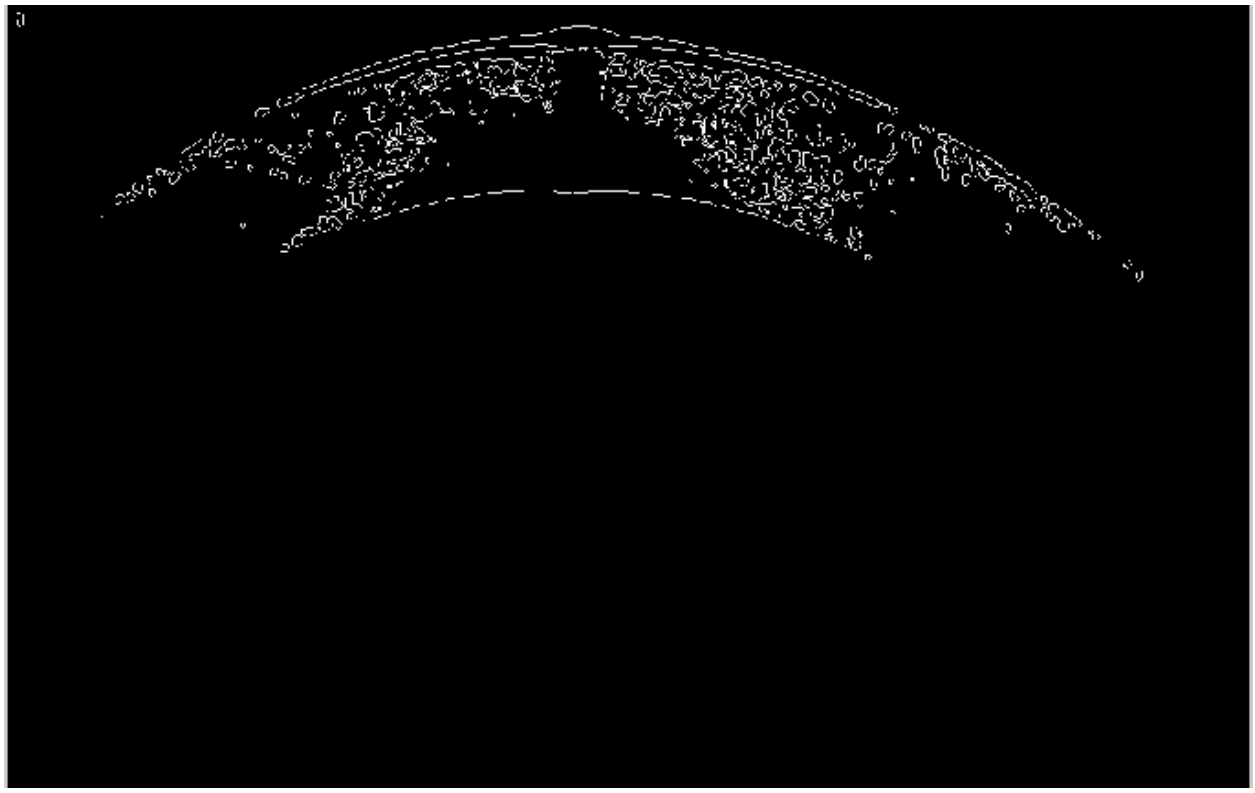
2.1.c) Remove solved and pepper noise



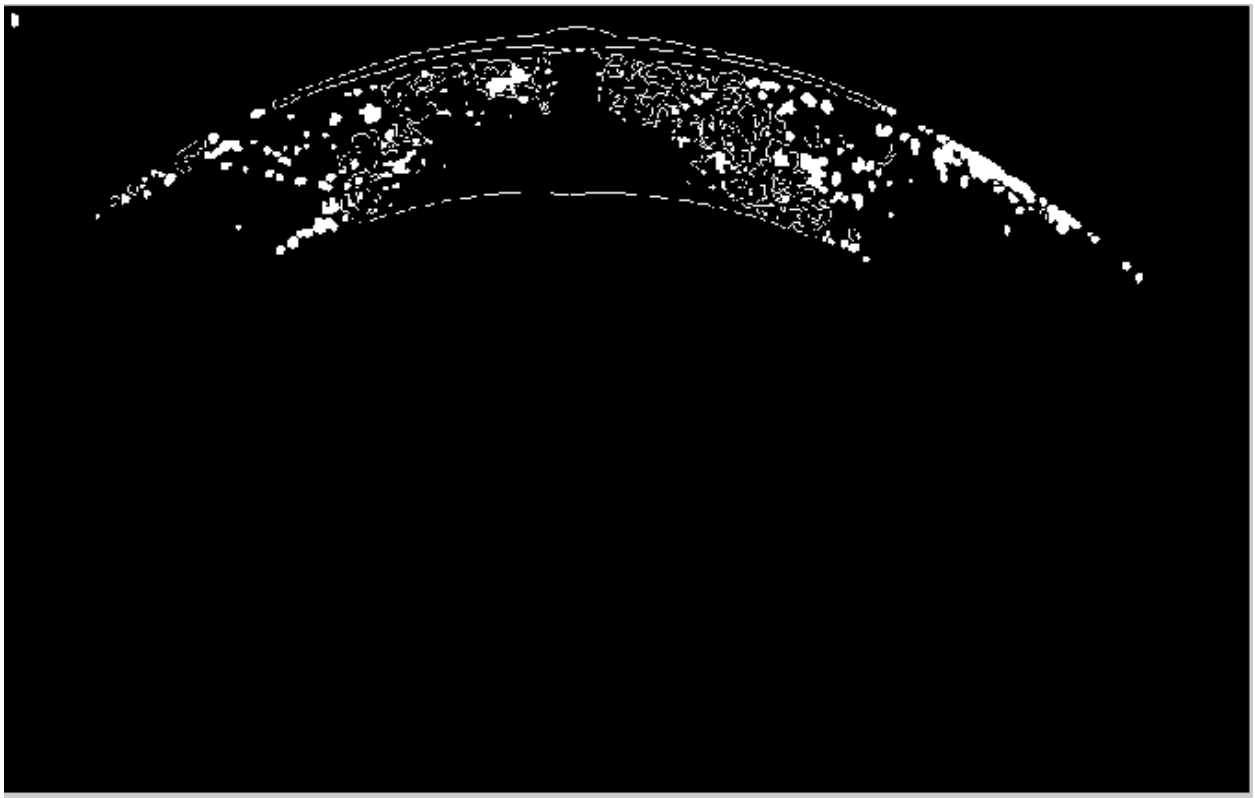
2.1.d) Binary complement the image



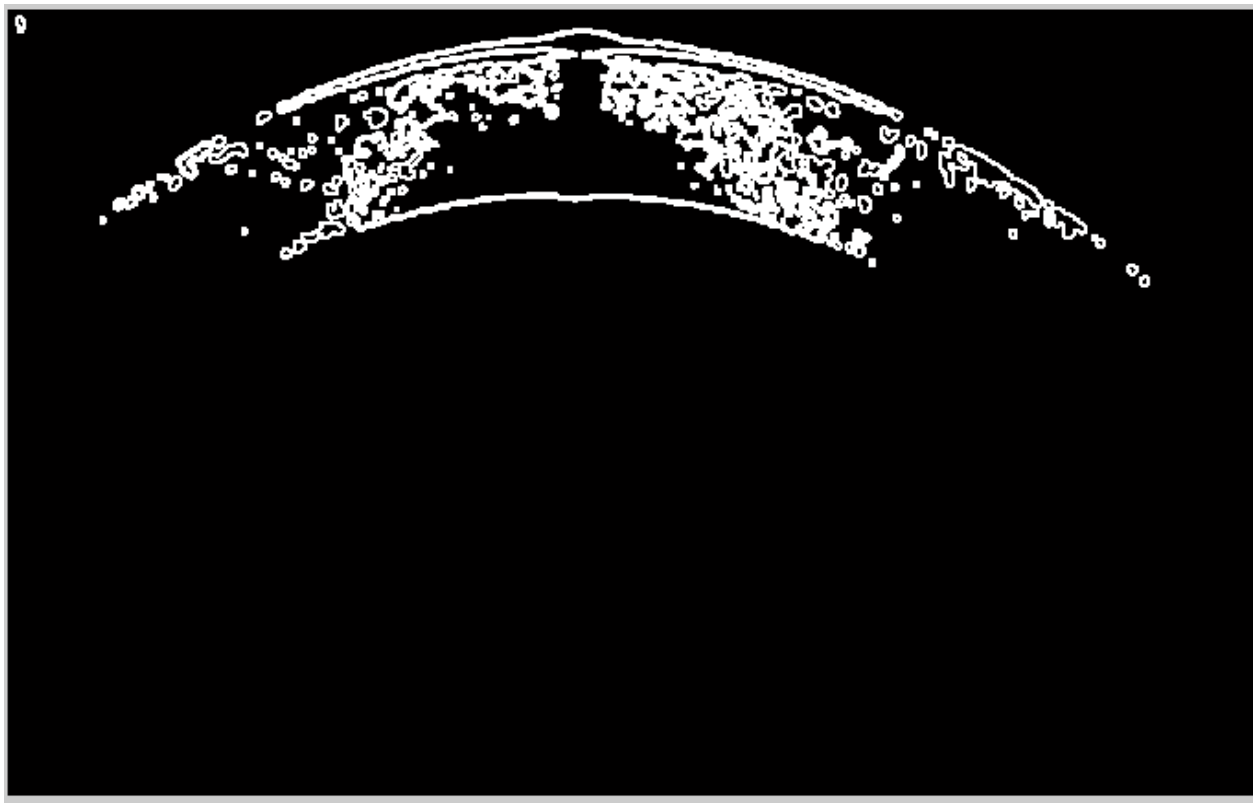
2.1.e) Apply Sobel operator for edge detection



2.1.f) Fill the holes in the resultant image



2.1.g) Apply the sobel filter once again and dilate the image for second step which is to measure thickness of the Cornea



The MATLAB code for the Edge Detection is as follows (Modifications of the code where used for certain images to provide better results in that specific case)

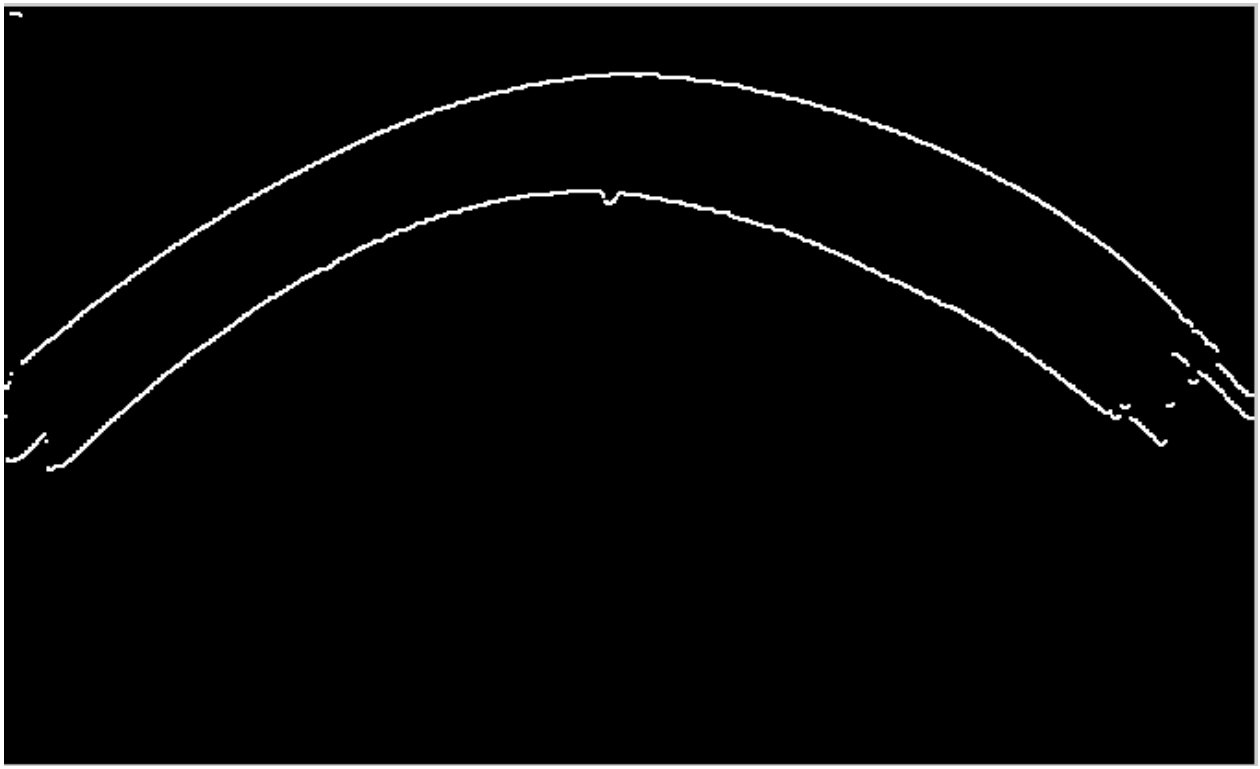
```
%To find the edges of the images.
%Author:ABishek Krishnan
clc;
close all;
clear all;
%Read all the images from a folder
warning('off', 'Images:initSize:adjustingMag'); %To turn off the warning the
image is to big to fit in this window
d = dir('*.jpg');
files = {d.name};
number_of_images = length(d);
%To segments for morphological operations
se1 = strel('line',3,0);
se2 = strel ('line',3,90);
se1e = strel('line',2,0);
se2e = strel ('line',2,90);
for k=1:number_of_images
    I{k} = imread(files{k});
    level = graythresh(I{k});
    level1 = graythresh(I{1});

    I_binary = im2bw(I{k},level);
    I_binary1 = im2bw(I{1},level1);
```

```
    I_noise_remove_salt_and_pepper = medfilt2(I_binary,[3 3]);
    I_noise_remove_salt_and_pepper1 = medfilt2(I_binary1,[3 3]);

    I_noise_removed = wiener2(I_noise_remove_salt_and_pepper,[3 3]);
    I_noise_removed1 = wiener2(I_noise_remove_salt_and_pepper1,[3 3]);

    I_binary_complement = imcomplement(I_noise_removed);
    I_binary_complement1 = imcomplement(I_noise_removed1);

    I_sobel = edge(I_binary_complement,'sobel');
    I_sobel1 = edge(I_binary_complement1,'sobel');

    I_filled_holes = imfill(I_sobel,'holes');
    I_filled_holes1 = imfill(I_sobel1,'holes');

    I_extra_sobel = edge(I_filled_holes,'sobel');
    I_extra_sobel1 = edge(I_filled_holes1,'sobel');

    I_dilated = imdilate(I_extra_sobel,[se1e se2e]);
    I_dilated1 = imdilate(I_extra_sobel1,[se1e se2e]);

    Result{k} = I_dilated;
end
```

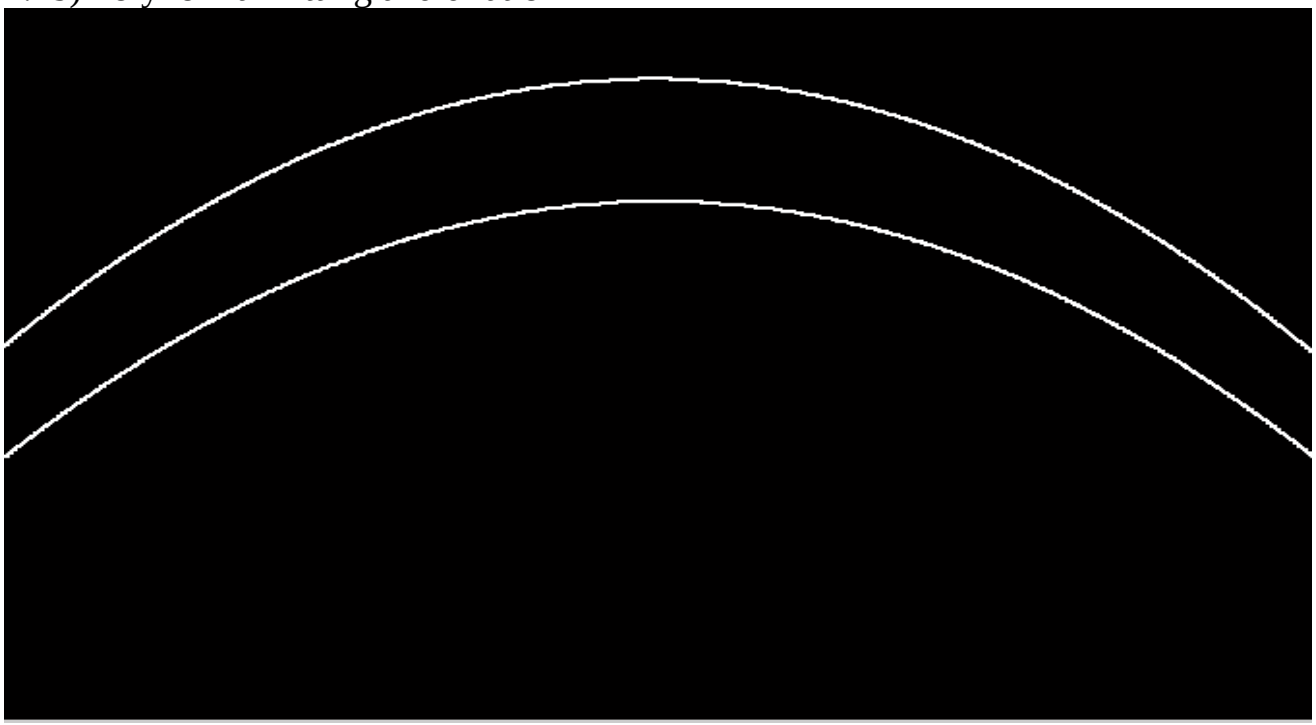
Step-2 involved extracting the thickness of the cornea after detecting the edges the algorithm is as follows:-

1) First, move row wise from the top until we encounter an white pixel and store the coordinate value and move to the next column
2) Repeat Step-1 from bottom.
3) Polynomial fit the top and bottom lines obtained and mesure the thickness from the middle of the column or as suited for certain images.
4) Plot of how the distance between the top and bottom portion of the cornea varies, this information is needed for predictive analysis (After Mid-semester work).
4) Variations of the above procedure were used in situations where the results obtained was not satisfactory

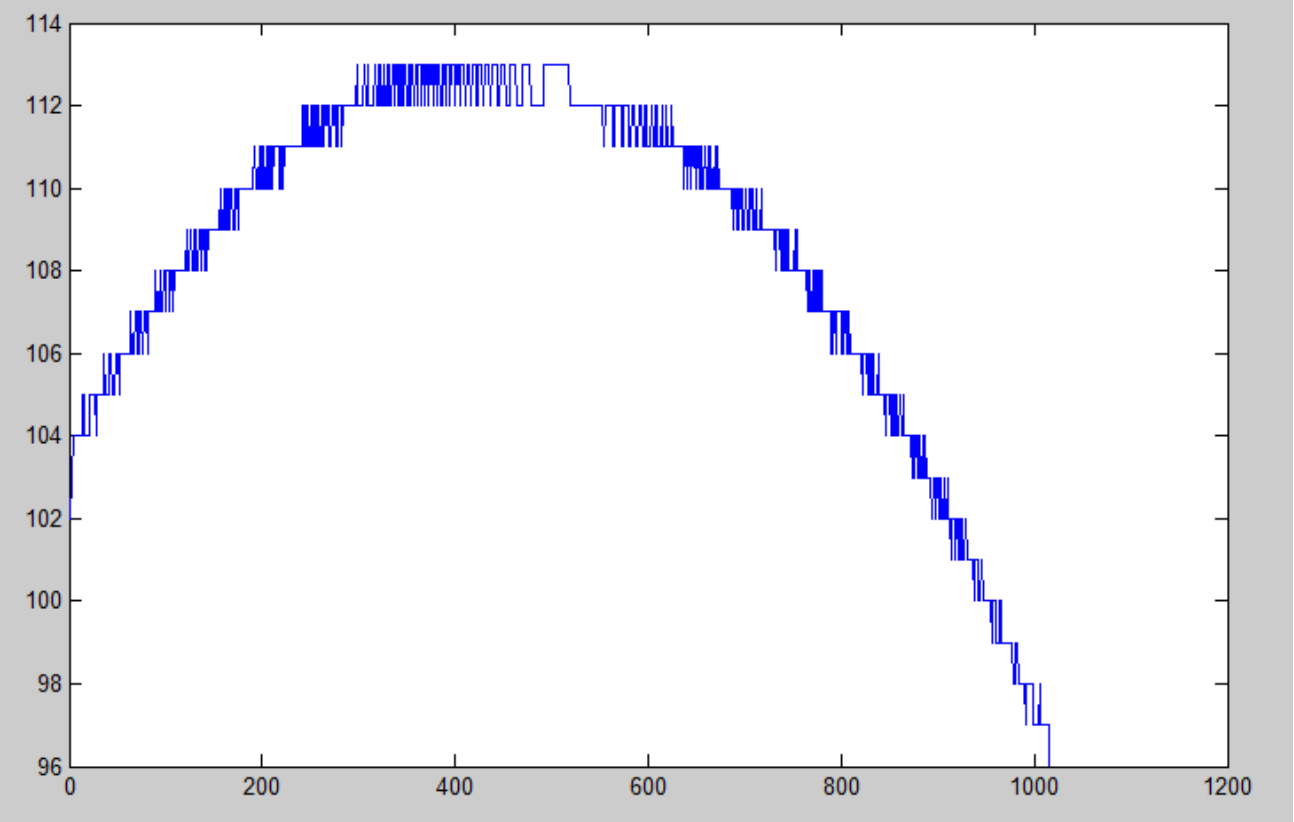
2.2.a) Extract and dilate



2.2b) Polynomial Fitting and dilation



2.2.c) Plot of distance variation (Distance from L->R vs Pixel Value of the width)



The MATLAB code:-

```
%To measure the thickness of Cornea.
%Author:ABishek Krishnan
clc;
close all;
clear all;
warning('off', 'Images:initSize:adjustingMag'); %To turn off the warning the
image is to big to fit in this window

I  = imread('ODa_after_extraction.jpg');
level = graythresh(I);
I_bin = im2bw(I,level);
[rows columns] = size(I_bin);
ad = zeros(rows,columns);
al = logical(ad);
alr = logical(ad);

count = 1;
rcount = 1;
se1 = strel('line',2,0);
se2 = strel ('line',2,90);

for c = 1:columns;
    for r = 1:rows;
        if(I_bin(r,c)==1)
            al(r,c) = 1;
            xset(count) = c;
            yset(count) = r;
            count= count +1;
            break;
        end

    end
end

for cr = 1:columns;
    for rr = rows:-1:1;
        if(al(rr,cr)~=1 && I_bin(rr,cr) == 1)
            alr(rr,cr) = 1;
            rcount = rcount+1;
            break;
        end;
    end;
end;
I_before_dilation_top = mat2gray(al);
I_extracted = imdilate(I_before_dilation_top,[se1 se2]);
I_before_dilation_bottom = mat2gray(alr);
I_bottom_extracted = imdilate(I_before_dilation_bottom,[se1 se2]);
imshow(I_extracted)
imshow(I_bottom_extracted)
I_final = I_extracted + I_bottom_extracted;
imshow(I_final)

%Polyfit
[r1, c1] = find(I_extracted);
figure;
plot(c1,r1,'.');
hold on;
```

```
f1 = fit(c1, r1, 'poly2');
plot((min(c1):max(c1)),f1(min(c1):max(c1)), 'red', 'LineWidth', 1);

[r2, c2] = find(I_bottom_extracted);
figure;
plot(c2,r2,'.');
hold on;
f2 = fit(c2, r2, 'poly2');
plot((min(c2):max(c2)),f2(min(c2):max(c2)), 'red', 'LineWidth', 1);


%Change of origin
x = (min(c1):max(c1))';
y = round(f1(x));
I1 = zeros(size(I_extracted));
I1(y +((x-1)*size(I1,1))) = 1;
figure
imshow(I1)

x1 = (min(c2):max(c2))';
y1 = round(f2(x));
I2 = zeros(size(I_bottom_extracted));
I2(y1 +((x1-1)*size(I2,1))) = 1;
figure
imshow(I2);

I3 = I1+I2;
imshow(I3)

%Trying to dilate the final image and apply a morph to it
I_f = imdilate(I3,[se1 se2]);
imshow(I_f)

%On this apply the up down algo and populate the array
[rf cf] = size(I_f);
adf = zeros(rf,cf);
alf = logical(adf);
alrf = logical(adf);
countf = 1;
rcountf = 1;

for c = 1:cf;
    for r = 1:rf;
        if(I_f(r,c)==1)
            alf(r,c) = 1;
            top(countf,:) = [c,r];
            countf= countf +1;
            break;
        end

    end
end

for cr = 1:cf;
    for rr = rf:-1:1;
        if(alf(rr,cr)~=1 && I_f(rr,cr) == 1)
            alrf(rr,cr) = 1;
            bottom(rcountf,:) = [cr,rr];
            rcountf = rcountf+1;
            break;
```

```
        end;
    end;
end;

count = countf-1;

%Subtracting the distance
for i = 1:count
    sub(i) = abs(top(i,2)-bottom(i,2));
end

%Plot the graph of difference in length

x = 1:count;
y = sub(x);
p = polyfit(x,y,2);
plot(x,y);
```

CONCLUSION

Until the mid semester I was able to extract the edges of the Cornea and measure the thickness of the cornea using image processing techniques with constant inputs and suggestions from Prof.P.K.Thiruvikraman and Dr.Jagadesh Reddy.
Moving forward I intend to develop a neural network based predictive model which will help in prediction of thickness of Cornea post surgery .

REFERENCES

1) Digital Image Processing Using MATLAB, 2e , Gonzalez and Woods

2) MATLAB Resources – Help Feature of MATLAB

3) http://stackoverflow.com – Questions and Answers Site –

(I received lots of answers on questions about MATLAB and paritculrs of various steps to help me develop the algorithm from Registered Users of this site)

4) http://www.tedmontgomery.com/the_eye/ - Anatomy and Visual Process.