

# An Autonomous way to detect and quantify Cataracts using Computer Vision

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**Abstract:** Our project is based on the detection of cataracts through python. A cataract is a clouding of the normally clear lens of the eye and the clouded vision caused by cataracts can increase difficulties in daily activities like reading and driving a car. Cataracts are the biggest cause of blindness in older people and data from the National Eye Institute (NEI) shows that over 65% of people of ages 80 and older are diagnosed with cataracts. However, there are limitations in the current method of cataract detection which include: Lack of clinical skill as cataracts are diagnosed by ophthalmologists by using slit-lamp bio microscopy and established clinical scales. This presents a barrier, specifically in rural areas where expert ophthalmologists are low in supply. Another limitation exists in the method used to calculate IOL power. Currently, the algorithm used for power calculation is unstandardized and at times, is at the surgeon's subjective judgment.

To address this problem, we have created a program through the use of python libraries which include OpenCV, NumPy, and FPDF. Our program takes the patient's formalities and eye image as input and generates a pdf report, informing whether the patient is diagnosed with a cataract or not. If yes, the program also adds the percentage of the eye area covered by the cataract and the severity of the cataract to the pdf. The program creates colour masks, white for the cataract detection and other colors like brown and black, to account for different eye colours. We also added ranges to the color masks to check the intensity of the cataract. Using all the masks it detects the cataract and also extracts important information like whiteness, size of the cataract, and also its percentage in the eye. All this information helps us quantify the severity of the disease. The object report output of our solution can help doctors to easily detect the cataract and solve the issue.

**Keywords:** Cataract, Eye Disease, Blindness, Cataract detection, Image Processing, Eye Detection, Whiteness in the eye, Cloudiness in eyes.

## Introduction:

### What is a cataract?

A cataract is a dense, cloudy area that forms the lens of the eye. A cataract begins when eye proteins form clumps that prevent the lens from sending clear images to the retina. The retina works by converting light through the lens into signals. It sends signals to the optic nerve, which carries them to the brain. It grows slowly and eventually disrupts your vision.



### What causes cataracts?

Several causes which include- overproduction of oxidants, which are oxygen molecules that have been chemically altered due to -

- normal daily life
- smoking
- ultraviolet radiation
- the long-term use of steroids and other medications
- certain diseases, such as diabetes
- trauma
- radiation therapy

### Types of Cataracts-

- Nuclear cataracts form inside the lens and cause the nucleus, or center, to turn yellow or brown.

- Cortical cataracts are wedge-shaped and form around the edges of the nucleus.
- Posterior capsular cataracts form faster than the other two types and affect the back of the lens.
- Congenital cataracts, which are present at birth or form during a baby's first year
- Secondary cataracts are caused by diseases or medications. Diseases associated with the development of cataracts include glaucoma and diabetes. The use of steroid prednisone and other drugs can sometimes lead to cataracts.
- Traumatic cataract begins after an eye injury
- Radiation can develop after a person has been treated for radiation cancer.

### Symptoms-

Common symptoms of cataracts include:

blurry vision

- trouble seeing at night
- seeing colors as faded
- increased sensitivity to glare
- halos surrounding lights
- double vision in the affected eye
- a need for frequent changes in prescription glasses

Some risk factors are -

older age

heavy alcohol use

smoking

obesity

high blood pressure

previous eye injuries

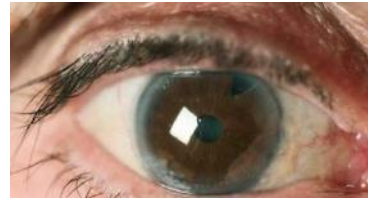
a family history of cataracts

too much sun exposure

exposure to radiation from X-rays and cancer treatments

### Stages of cataracts-

**Early cataract:** The very beginnings of cataract disease. The lens is still clear, but the ability to change focus between near and far vision has begun to be compromised. The patient may see the beginnings of blurring or cloudiness, glare from lights may begin to bother him/her and they may feel increasing eye strain.



**Immature cataract:** Proteins have started to cloud the lens, making it slightly opaque, especially in the center. At this point, ophthalmologists would recommend new glasses, anti-glare lenses, and increased attention to the light, such as that needed to read properly. The progression of an immature cataract can take up to several years.



**Mature cataract:** The opacity has increased to such a point that it can appear milky and white, or amber in color. It has spread to the edges of the lens and has a considerable effect on vision. At this point, ophthalmologists would ask patients how their quality of life and daily activities are affected. If the cataract seriously affects their life, removal surgery may be recommended.



**Hypermature cataract:** The cataract has become very dense, impairing vision to a significant extent, and has hardened. At this point, it would impair vision to an advanced stage. It can be more difficult to remove. If not treated, hypermature cataracts can cause inflammation in the eye and/or increased pressure within the eye, which can cause glaucoma.



#### Prevention from cataracts-

- protect your eyes from UVB rays by wearing sunglasses outside
- have regular eye exams
- stop smoking
- eat fruits and vegetables that contain antioxidants
- maintain a healthy weight
- keep diabetes and other medical conditions in check

#### Diagnosis-

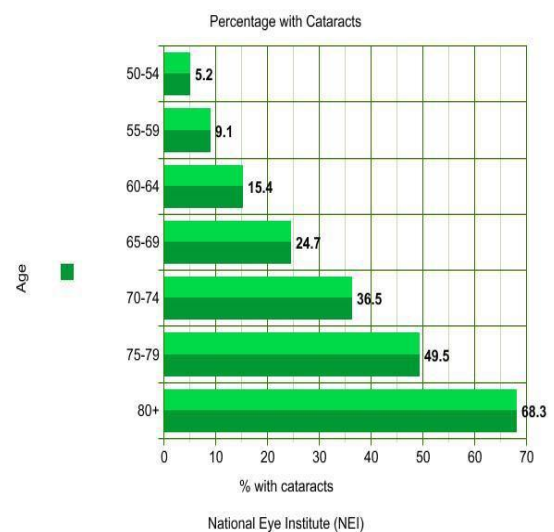
- **Visual acuity test:** A visual acuity test uses an eye chart to measure how well a person can read a series of letters. Eyes are tested one at a time. Using a chart or a viewing device with progressively smaller letters, the eye doctor determines if a person has 20/20 vision or if his/her vision shows signs of impairment.
- **Slit-lamp examination:** A slit-lamp allows an eye doctor to see the structures at the front of a person's eye under magnification. The microscope is called a slit lamp because it uses an intense line of light, a slit, to illuminate the person's cornea, iris, lens, and the space between the iris and cornea. The slit allows the doctor to view these structures in small sections, which makes it easier to detect any tiny abnormalities.
- **Retinal exam:** To prepare for a retinal exam, the eye doctor puts drops in your eyes to open your pupils wide (dilate). This makes it easier to examine the back of your eyes (retina). Using a slit lamp or a special device called an ophthalmoscope, the eye doctor can examine the person's lens for signs of a cataract.
- **Applanation tonometry:** This test measures the fluid pressure in the person's eye. There are multiple different devices available to do this.

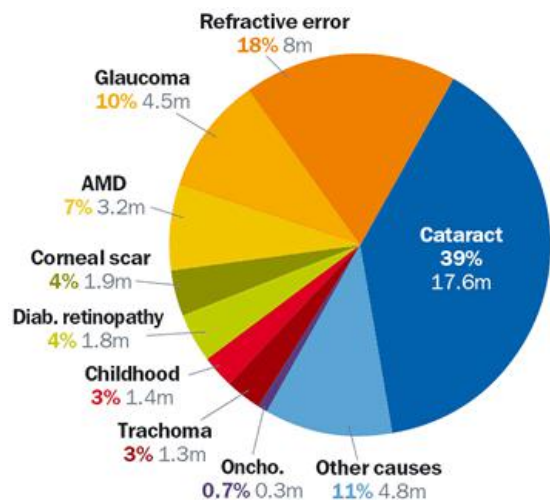
#### What happens during cataract surgery-

Cataract surgery involves removing the clouded lens and replacing it with a clear artificial lens. The artificial lens, called an intraocular lens, is positioned in the same place as your natural lens. It remains a permanent part of your eye. Cataract surgery is generally safe, but it carries a risk of infection and bleeding. Cataract surgery increases the risk of retinal detachment.

#### Treatment-

Presently, surgery is the only way to treat cataracts. There is no non-surgical cure for cataracts that has been approved by the Food and Drug Administration or other government body medical procedure regulators. There are no natural cures, and no studies have proven how to prevent or stop the progression of a cataract. If we consider the case of eye drops, it has been found that a compound called sterol improves lens transparency. The chemical binds to misfolded proteins in the eyes of mice, partially reversing cataracts. It is theorized that the compound N-acetylcarnosine, which metabolizes into the protein L-carnosine when it penetrates the cornea, may be used as an eye drop solution to reverse or prevent cataract progression. Studies must be conducted to confirm this hypothesis.





**Cataracts are the biggest reason for blindness in old people**

#### Literature review:

#### Non-Surgical Cataract Treatment-

New spectacles, anti-glare sunglasses, or magnifying lenses may help alleviate cataract symptoms. Lenses can also be tinted or coated to help alleviate discomfort. Even better lighting or reading light placement can assist. To assist prevent additional cataract development, your eye doctor may prescribe that you wear a hat in addition to quality sunglasses when you go outside.

#### Surgical Cataract Treatment-

Surgical Cataract Treatment is considered when a cataract progresses and decreases vision to a point that it starts to affect your lifestyle and daily activities. But if a person has other eye conditions in addition to a cataract, he or she should speak to a healthcare provider regarding the risks, benefits, alternatives, and expected results of the cataract surgery

#### The three most common ways of removing cataracts are-

##### Phacoemulsification

The most common type of cataract removal technique nowadays is phacoemulsification (phaco).

Through a very small incision, an ultrasonic instrument vibrating at a very high speed is inserted into the eye.

This gadget uses ultrasonic waves to gently soften and break up the lens, allowing it to be suctioned out.

After that, the surgeon places a prosthetic lens in the eye. Depending on the style of incision utilized, the wound may only require one stitch (or none at all). "Small incision cataract surgery" is another name for this cataract therapy.

#### Extracapsular Cataract Surgery

This operation is similar to phacoemulsification, but it requires a considerably larger incision to remove the nucleus, or the center part of the lens, in one piece.

Because the incision is so big, it will take multiple stitches or sutures to seal it. Because of the potential for problems, longer healing, and induced astigmatism (an imperfection in the curvature of your eye's cornea or lens), this procedure is less commonly performed.

#### Intracapsular Cataract Surgery

During this rare procedure, the entire lens and its capsule are removed through a large incision. Surgeons may reserve this method for extremely advanced cataract formation or trauma.

#### Technical Solutions for Diagnostics:

##### Artificial Intelligence for Cataract Detection and Management:

AI development in the domain of cataracts is still relatively underexplored. In this regard, several previous studies explored algorithms for automated cataract assessment using either slit lamp or color fundus photographs. However, several other study groups proposed or derived new AI-based calculations for pre-cataract surgery intraocular lens power. Along with advancements in the digitization of clinical data, data curation for future cataract-related AI developmental work is bound to undergo significant improvements in the foreseeable future. Even though most of these previous studies reported early promising performances, limitations such as lack of robust, high-quality

training data, and lack of external validations remain. In the next phase of work, apart from the algorithm's performance, it will also be pertinent to evaluate deployment angles, feasibility, efficiency, and cost-effectiveness of these new cataract-related AI systems.

### Limitations In The Current Method Of Cataract Detection And Intraocular Lens Power Calculation

Cataracts are currently diagnosed and evaluated by ophthalmologists utilizing slit-lamp biomicroscopy and established clinical scales. This procedure requires clinical skill and so presents a substantial barrier, particularly in impoverished nations or rural areas where experienced ophthalmologists are in low supply. As a result, with the rising health burden associated with cataracts, new strategies to solve existing limitations and revolutionize cataract detection systems are urgently needed.

The current treatment for cataracts includes surgical removal of the cataract and implantation of an intraocular lens (IOL). Importantly, the prognosis and the visual result of cataract surgeries are heavily reliant on IOL power calculations, which are based on preoperative ocular biometry measures. In the clinic, the choice of IOL power calculation algorithm is currently unstandardized, and at times, at the surgeon's subjective judgment. When assessing the applicability of each formula, ocular metrics such as axial length and keratometry readings are crucial.

### HD Analyser:

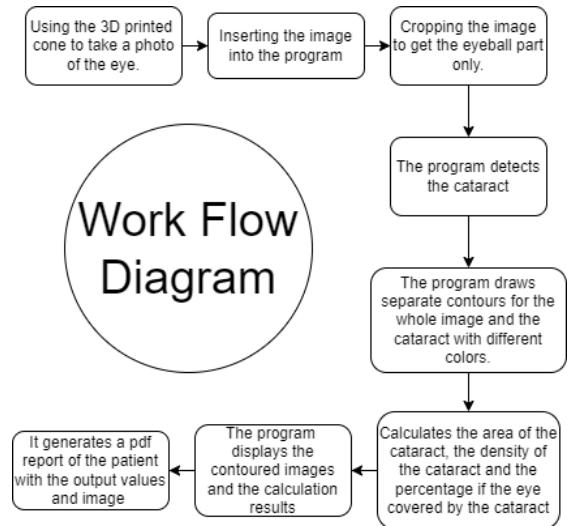
HD Analyzer is the first device of its kind that provides ophthalmologists with an assessment of light scatter inside the eye. This is essential in order to detect the existence of a cataract early on, commonly referred to as **Dysfunctional Lens Syndrome**.

### Our Solution:

Our solution is to detect the cataract and its condition using image processing on the eye. While working on the project we planned to detect the eyeball in the image using a color mask and using that we further detected the whiteness in the eyeball. While testing on a real subject, we found that background lighting and camera flashes create reflections on the eyeball, which hinders our cataract detection. To overcome this problem we designed a special 3D Printed attachment that fits on the eye and blocks the extra light coming from the background.

The attachment helps us get a clear image of the eyeball.

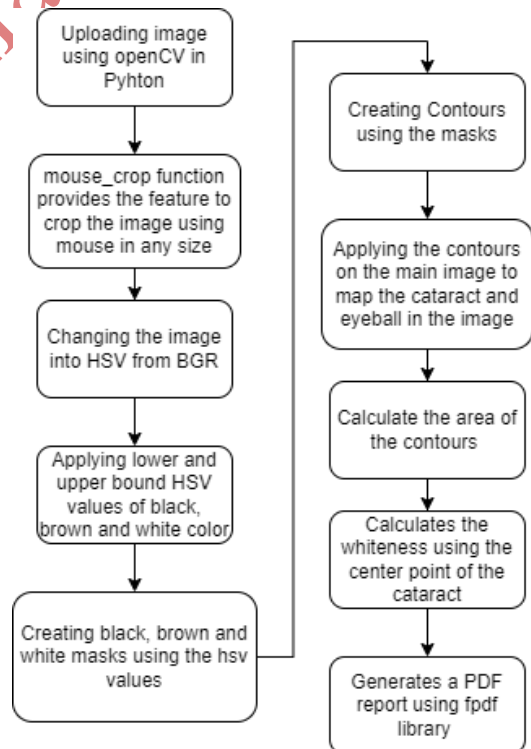
### Flowchart:



### Algorithm:

We have used python to make our program. We have used 3 main libraries to implement image processing and generate the reports. Those libraries are OpenCV, Numpy, and fpdf.

### Flowchart::



We used three python libraries to work on our solution: OpenCV, Numpy, and FPDF

### 1. Taking input from the user

```
pname = input('enter your name')
p_age = input("enter your age")
n = input('enter the name of the image')
image = cv2.imread(n)
oriImage = image.copy()
flag = False
```

In this part, the program asks for the name and age of the user. It asks the name of the image we want to perform image processing on. The program also generates a copy of the image for further use.

### 2. Cropping the image using a mouse

```
def mouse_crop(event, x, y, flags, param):
    global flag
    # grab references to the global variables
    global x_start, y_start, x_end, y_end, cropping

    # if the left mouse button was DOWN, start
    RECORDING
    # (x, y) coordinates and indicate that cropping is being
    if event == cv2.EVENT_LBUTTONDOWN:
        x_start, y_start, x_end, y_end = x, y, x, y
        cropping = True

    # Mouse is Moving
    elif event == cv2.EVENT_MOUSEMOVE:
        if cropping == True:
            x_end, y_end = x, y

    # if the left mouse button was released
    elif event == cv2.EVENT_LBUTTONUP:
        # record the ending (x, y) coordinates
        x_end, y_end = x, y
        cropping = False # cropping is finished

    refPoint = [(x_start, y_start), (x_end, y_end)]

    if len(refPoint) == 2: # when two points were found
        roi = oriImage[refPoint[0][1]:refPoint[1][1],
            refPoint[0][0]:refPoint[1][0]]
        cv2.imshow("Cropped", roi)
        cv2.imwrite("cropped.jpg", roi)
        flag = True
        cv2.namedWindow("image")
        cv2.setMouseCallback("image", mouse_crop)

    while True:
```

```
i = image.copy()

if not cropping:
    cv2.imshow("image", image)

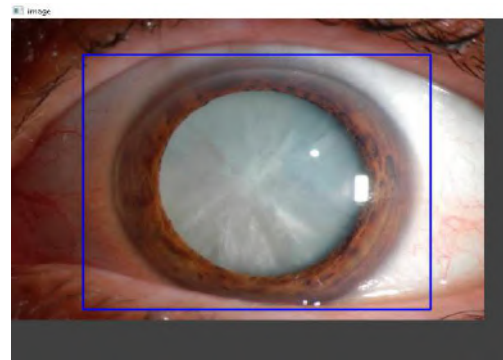
elif cropping:
    cv2.rectangle(i, (x_start, y_start), (x_end,
        y_end), (255, 0, 0), 2)
    cv2.imshow("image", i)
    cv2.waitKey(1)

if flag:
    break

# close all open windows
cv2.destroyAllWindows()

name = "cropped.jpg"
```

In this part, we first created global variables. Using the methods `EVENT_LBUTTONDOWN`, `EVENT_MOUSEMOVE`, and `EVENT_LBUTTONUP`, we recorded the mouse clicks and attached logic like if left click is pressed the mouse will start recording the movements and crop accordingly like so:



When left click is released, the program records the ending coordinates and crops the part area covered in the blue contour. The program then generates an image “cropped.jpg” that we use for the detection of the cataract.

## 3. Image processing

```

while(1):

#_, frame = cap.read()

frame = cv2.imread(name)
img = frame.copy()
hsv = cv2.cvtColor(frame, cv2.COLOR_BGR2HSV)

# define range of white color in HSV
# change it according to your need !
lower_white = np.array([25,5,0], dtype=np.uint8)
upper_white = np.array([112,255,255],
dtype=np.uint8)

lower_brown = np.array([0,50,40], dtype=np.uint8)
upper_brown = np.array([179,255,125],
dtype=np.uint8)

lower_black = np.array([6,17,0], dtype=np.uint8)
upper_black = np.array([179,138,64], dtype=np.uint8)

# Threshold the HSV image to get only white colors

mask_brown = cv2.inRange(hsv, lower_brown,
upper_brown)
mask_black = cv2.inRange(hsv, lower_black,
upper_black)

# Bitwise-AND mask and original image
res2 = cv2.bitwise_and(frame,frame, mask=
mask_brown)
res3 = cv2.bitwise_and(frame,frame, mask=
mask_black)
#res1 = cv2.bitwise_and(frame,frame, mask=
mask_white)

```

In this part, we first convert the image to an HSV image to obtain separate values for the hue and saturation of the image. Then we create a white color mask and add a range for the whiteness of the cataract. We also add ranges for colors like brown and black to account for different eye colors. The variables res1, res2, and res3 apply the different color masks onto the image.

```

forpic, contourinenumerate(contours):
area1 = cv2.contourArea(contour)
if(area1>300):

x,y,w,h = cv2.boundingRect(contour)
break

(contours,hierarchy)=cv2.findContours(mask_bl
ack,cv2.RETR_TREE,cv2.CHAIN_APPROX_
SIMPLE)

forpic, contourinenumerate(contours):
area2 = cv2.contourArea(contour)
if(area2>300):

x1,y1,w1,h1 = cv2.boundingRect(contour)
break

ifarea2>area1:
frame1 = img[y1:y1+h1,x1:x1+w1]

else:
frame1 = img[y:y+h,x:x+w]
#Tracking Colour (Yellow)
hsv1 = cv2.cvtColor(frame1,
cv2.COLOR_BGR2HSV)
mask_white = cv2.inRange(hsv1, lower_white,
upper_white)
res1 = cv2.bitwise_and(frame1,frame1, mask=
mask_white)

(contours,hierarchy)=cv2.findContours(mask_br
own,cv2.RETR_TREE,cv2.CHAIN_APPROX_
SIMPLE)

forpic, contourinenumerate(contours):
area1 = cv2.contourArea(contour)
if(area1>300):

x,y,w,h = cv2.boundingRect(contour)
cv2.drawContours(frame,[contour], -1, (0, 255,
0), 2)
img =
cv2.rectangle(frame,(x,y),(x+w,y+h),(255,0,0),3
)
break
# img2 = frame[y:(y+h),x:(x+w)]

```

```
# hsv1 = cv2.cvtColor(img2,
cv2.COLOR_BGR2HSV)
# mask = cv2.inRange(hsv1, lower_white,
upper_white)
# res = cv2.bitwise_and(img2,img2, mask= mask)

(contours,hierarchy)=cv2.findContours(mask_black,cv
2.RETR_TREE,cv2.CHAIN_APPROX_SIMPLE)

forpic, contourinenumerate(contours):
area2 = cv2.contourArea(contour)
if(area2>300):

x1,y1,w1,h1 = cv2.boundingRect(contour)
cv2.drawContours(frame,[contour], -1, (255, 255, 0),
2)
img =
cv2.rectangle(frame,(x1,y1),(x1+w1,y1+h1),(255,0,10
0),3)
break

# frame1 = img

(contours,hierarchy)=cv2.findContours(mask_white,cv
2.RETR_TREE,cv2.CHAIN_APPROX_SIMPLE)

forpic, contourinenumerate(contours):
area = cv2.contourArea(contour)
if(area>300):

x2,y2,w2,h2 = cv2.boundingRect(contour)
cv2.drawContours(frame1,[contour], -1, (0, 0, 255), 2)
img =
cv2.rectangle(frame1,(x2,y2),(x2+w2,y2+h2),(0,255,2
55),3)

break
```

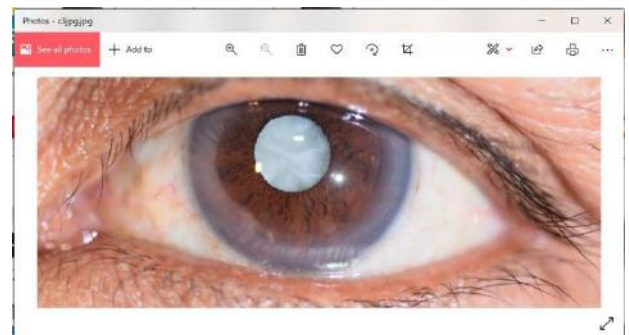
The three different loops run for the detection of the cataract(maskwhite), to check whether it is a brown eye(maskbrown) or whether it is a black eye(maskblack) respectively.

#### 4. Generating the PDF

```
pdf = FPDF("L","mm","A4")
pdf.add_page()
pdf.set_font("Arial",size=20)
pdf.cell(200,20,txt="Patient
Report",ln=2,align="C")
pdf.set_font("Arial",size=12)
pdf.cell(100,8,txt="Patient Name
="+pname,ln=2,align="L")
pdf.cell(100,8,txt="Age =
"+str(p_age),ln=2,align="L")
pdf.cell(100,8,txt="Eye Area =
"+str(area1),ln=2,align="L")
pdf.cell(100,8,txt="Cataract Area =
"+str(area),ln=2,align="L")
pdf.cell(100,8,txt="Percentage of eye area
covered by the cataract =
"+str(percentage),ln=2,align="L")
pdf.image('output.jpg',170,50)
pdf.output("mypdf.pdf")
```

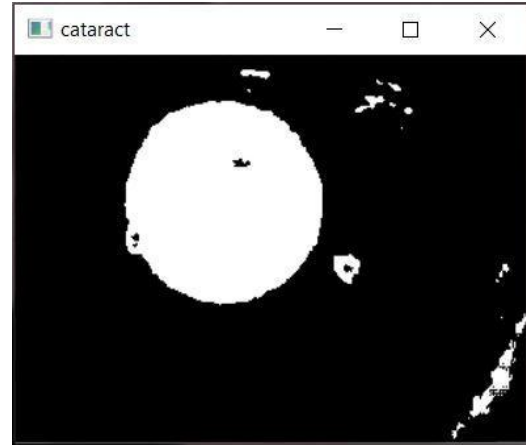
We first create an instance of the pdf and then we add a page to the file. We set the font using the `set_font` method and add the data using `pdf.cell`, which creates sections of different widths and heights, passed into the function as a parameter. We added the image of the cataract using the `pdf.image` method and generated a pdf named "mypdf.pdf"

#### Results:

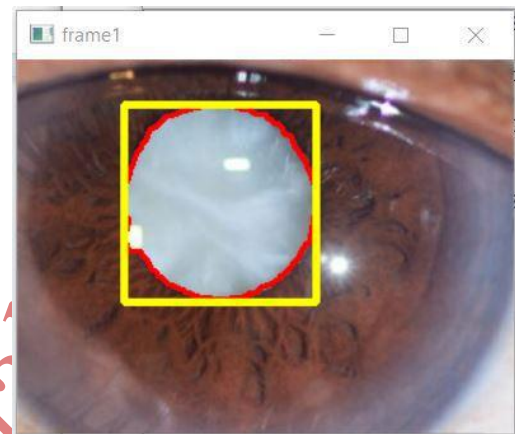
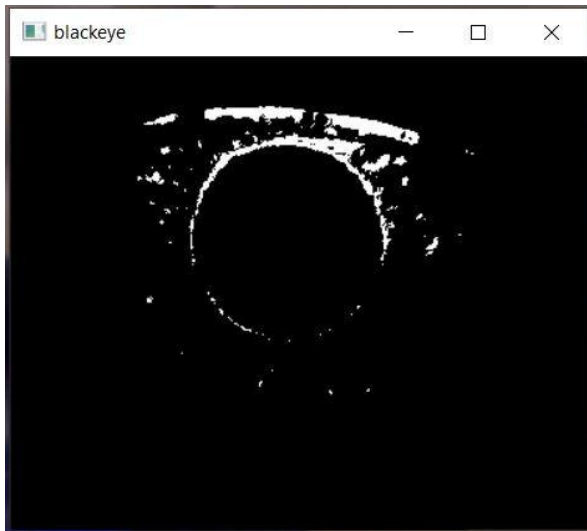


This is the image we used as input



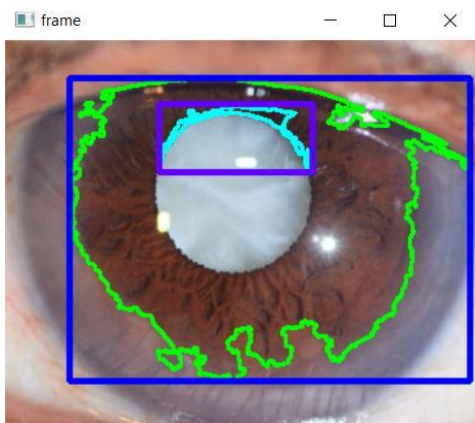


The cataract was detected the same way.



Using the coordinates from the grayscale images, the program applied the contours onto the cropped input image.

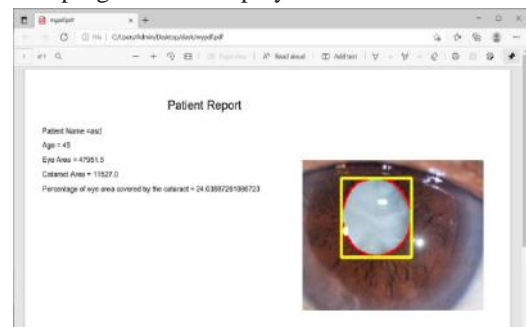
The program cropped the input image, converted the image to grayscale, and detected the eye color (If it was any other color, the image would have been all black like the second image)



Using the coordinates from the grayscale image, the program applied contours onto the cropped input image.

```
===== RESTART: C:\Users\Admin\Desktop'
enter your nameasd
enter your age45
enter the name of the imagec3jpg.jpg
brown area- 47951.5
black area- 675.0
cataract area- 11527.0
percentage= 24.03887261086723 %
127 90
hue= 100 saturation= 33
whitiness = 195
cataract found with the whitiness of - 195
>>> |
```

The program then displayed the results.



The program then generated a pdf report containing the cataract image and results.

### Testing:

For testing, we gathered some volunteers and took images of their eyes using the device shown in the images. As we were not able to find test subjects with a cataract, we included images from the internet to test the accuracy.



### Future Scope:

There are many improvements that can be made in the future since this is just a prototype. Firstly, we will be incorporating machine learning in the program for the early detection of cataracts. To improve our testing methods, there is a big scope in the improvement of the attachment that we use to take a photo of the eye, like making it shorter and more comfortable on the eye, for the convenience of the volunteer. As we used the majority of our testing images from the internet, we could also use this program in clinics under the supervision of an expert ophthalmologist to collect multiple samples of people with cataracts. Testing our program on more images can help us make changes accordingly and improve the accuracy of our program in the future.

### Conclusion:

Through obtaining the whiteness of the cataract and the percentage area of the eye covered by the cataract, we can determine how severe the cataract is and whether it needs surgery at the time of testing. The

program has been tested extensively on team members and has an accuracy of 73%. We believe through further improvements in the code and detection method, the program might become an alternative method of cataract detection and diagnosis in the future.

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