Eye Disease Classification using Deep Learning

This project aims to develop a deep learning model using Convolutional Neural Networks (CNN) to classify retinal images into four categories: Normal, Diabetic Retinopathy, Cataract, and Glaucoma. The dataset comprises approximately 1000 retinal images for each class, collected from various sources, including IDRiD, Ocular recognition, and HRF. The goal is to leverage CNN's powerful feature extraction capabilities to accurately diagnose these eye conditions based on retinal images. This model could assist in early detection and treatment planning for patients, potentially improving outcomes for those with retinal diseases.

Importing Packages

In [5]:
```
import warnings
warnings.filterwarnings('ignore')


import pandas as pd
import numpy as np
import statsmodels.api as sm
from sklearn.linear_model import LinearRegression # Linear Regression Model
from sklearn.preprocessing import StandardScaler #Z-score variables
from sklearn.metrics import mean_squared_error, r2_score, accuracy_score,mean_

from sklearn.model_selection import train_test_split # simple TT split cv
from sklearn.model_selection import KFold # k-fold cv
from sklearn.model_selection import LeaveOneOut #LOO cv
from sklearn.model_selection import cross_val_score # cross validation metrics
from sklearn.model_selection import cross_val_predict # cross validation metri

# preprocessing
from sklearn.preprocessing import StandardScaler #Z-score variables
from sklearn.model_selection import train_test_split
# metrics
from sklearn.metrics import accuracy_score, confusion_matrix, mean_squared_err

# models
from sklearn.svm import SVC

from sklearn.pipeline import make_pipeline
from sklearn.compose import make_column_transformer
from sklearn.model_selection import GridSearchCV

import os

from sklearn.pipeline import Pipeline
```

```
from sklearn.impute import SimpleImputer
from sklearn.compose import ColumnTransformer
```

Reading in Data

In [22]:
```
import os
from PIL import Image
import numpy as np

# path to the unzipped dataset
dataset_path = (r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifi

# Define the classes
classes = ['normal', 'diabetic_retinopathy', 'cataract', 'glaucoma']

# Initialize an empty list to store the images and labels
images = []
labels = []

# Loop through each class folder and load the images
for label, class_name in enumerate(classes):
    class_folder = os.path.join(dataset_path, class_name)
    for file_name in os.listdir(class_folder):
        if file_name.endswith(('.jpg', '.jpeg', '.png')):
            image_path = os.path.join(class_folder, file_name)
            image = Image.open(image_path)
            image = image.resize((224, 224))  # Resize to a consistent size if
            image_array = np.array(image)
            images.append(image_array)
            labels.append(label)

# Convert lists to numpy arrays
images = np.array(images)
labels = np.array(labels)

print(f"Loaded {len(images)} images with labels")
```

```
Loaded 4310 images with labels
```

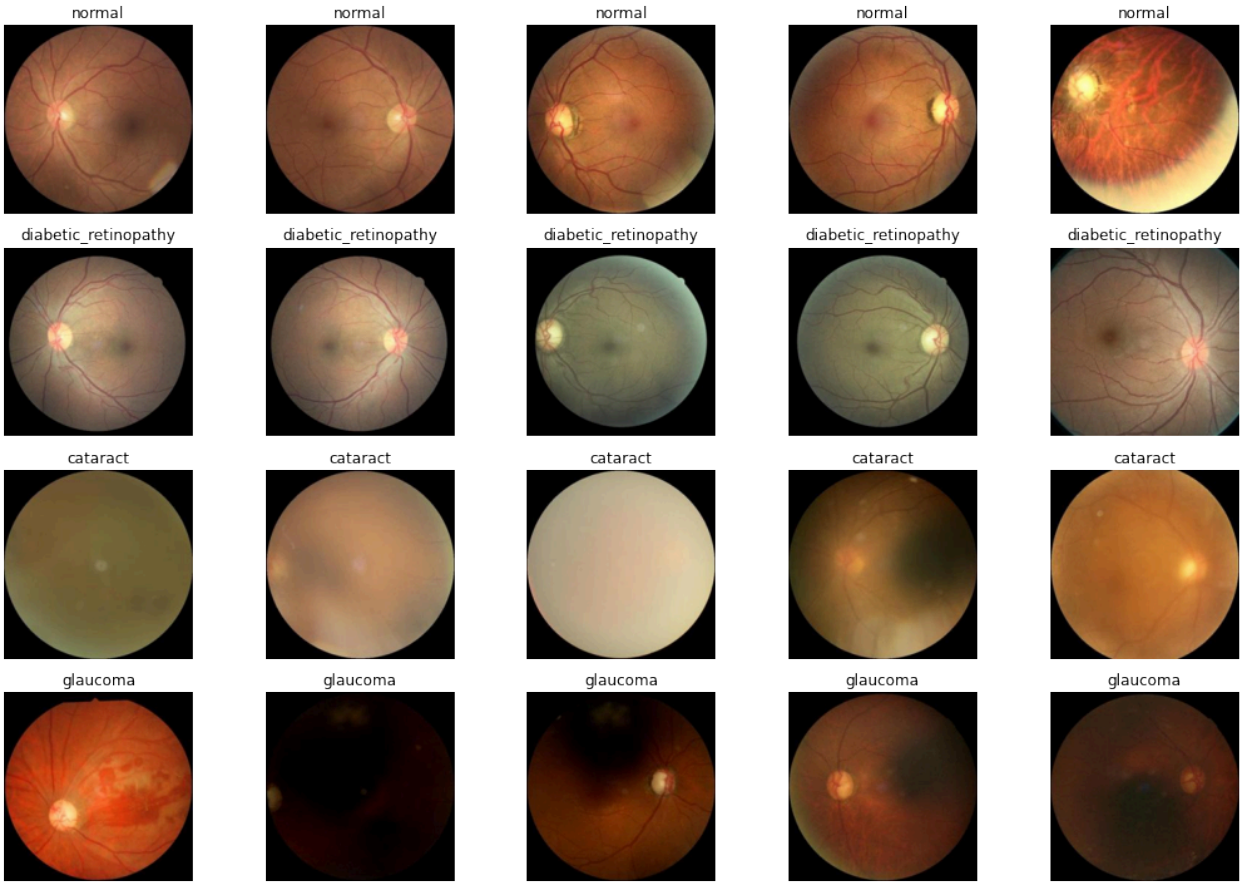
Preliminary Analysis

In [23]:
```
import matplotlib.pyplot as plt

# Number of images to display
num_images = 10

# Select the first 'num_images' from the dataset
subset_images = images[:num_images]
subset_labels = labels[:num_images]

# Plot the images
```

```
plt.figure(figsize=(10, 10))
for i in range(num_images):
    plt.subplot(2, 5, i + 1)  # 2 rows and 5 columns
    plt.imshow(subset_images[i])
    plt.title(classes[subset_labels[i]])
    plt.axis('off')  # Hide the axes

plt.show()
```

In [8]:
```
# Number of images to display per class
num_images_per_class = 5

# empty lists to store selected images and labels
selected_images = []
selected_labels = []

# Loop through each class and select a subset of images
for class_label in range(len(classes)):
    class_indices = [i for i, label in enumerate(labels) if label == class_lab
    class_images = images[class_indices][:num_images_per_class]
    selected_images.extend(class_images)
    selected_labels.extend([class_label] * num_images_per_class)

# Plot images
plt.figure(figsize=(15, 10))
for i in range(len(selected_images)):
    plt.subplot(len(classes), num_images_per_class, i + 1)  # Rows by classes,
    plt.imshow(selected_images[i])
```

```
    plt.title(classes[selected_labels[i]])
    plt.axis('off')

plt.tight_layout()
plt.show()
```



In [9]:
```
# how many images were loaded per class
for class_label in range(len(classes)):
    class_count = sum([1 for label in labels if label == class_label])
    print(f"{classes[class_label]}: {class_count} images")
```

```
normal: 1074 images
diabetic_retinopathy: 1098 images
cataract: 1038 images
glaucoma: 1007 images
```

In [10]:
```
# empty list to store image paths
image_paths = []

# Loop through each class and get the paths of all images
for class_name in classes:
    class_folder = os.path.join(dataset_path, class_name)
    for file_name in os.listdir(class_folder):
        if file_name.endswith(('.jpg', '.jpeg', '.png')):
            image_path = os.path.join(class_folder, file_name)
            image_paths.append(image_path)
```

```
print(image_paths[:10])
```

```
['C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\data
set\\normal\\1034_left.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye
Disease Classification\\dataset\\normal\\1034_right.jpg', 'C:\\Users\\Sara\\Des
ktop\\Personal Projects\\Eye Disease Classification\\dataset\\normal\\1060_lef
t.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classificatio
n\\dataset\\normal\\1060_right.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projec
ts\\Eye Disease Classification\\dataset\\normal\\1253_left.jpg', 'C:\\Users\\Sa
ra\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\normal\\12
53_right.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classi
fication\\dataset\\normal\\2329_left.jpg', 'C:\\Users\\Sara\\Desktop\\Personal
Projects\\Eye Disease Classification\\dataset\\normal\\2329_right.jpg', 'C:\\Us
ers\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\nor
mal\\2331_left.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease
Classification\\dataset\\normal\\2331_right.jpg']
```

In [11]:
```
# image sizes
image_sizes = []
for image_path in image_paths:
    with Image.open(image_path) as img:
        image_sizes.append(img.size)

print(pd.Series(image_sizes).value_counts())
```

```
(256, 256)    4217
Name: count, dtype: int64
```

In [12]:
```
# image quality check
import cv2

def variance_of_laplacian(image):
    return cv2.Laplacian(image, cv2.CV_64F).var()

blurriness_scores = []
for image_path in image_paths:
    image = cv2.imread(image_path)
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
    blurriness_scores.append(variance_of_laplacian(gray))

print(pd.Series(blurriness_scores).describe())  # Summary of blurriness scores
```

```
count    4217.000000
mean      156.644054
std       140.739869
min         2.768325
25%        59.111004
50%       113.896173
75%       206.818091
max       966.930134
dtype: float64
```

In [13]:
```
# class distribution
from collections import Counter
```

```
class_distribution = Counter(labels)
print(class_distribution)
```

```
Counter({1: 1098, 0: 1074, 2: 1038, 3: 1007})
```

In [14]:

```
# to find duplicate images

import cv2
import hashlib

def dhash(image, hash_size=8):
    resized = cv2.resize(image, (hash_size + 1, hash_size))
    gray = cv2.cvtColor(resized, cv2.COLOR_BGR2GRAY)
    diff = gray[:, 1:] > gray[:, :-1]
    return sum([2 ** i for (i, v) in enumerate(diff.flatten()) if v])

hashes = {}
duplicates = []

for image_path in image_paths:
    image = cv2.imread(image_path)
    h = dhash(image)
    if h in hashes:
        # Store duplicates in the list
        duplicates.append((image_path, hashes[h]))
    else:
        hashes[h] = image_path

# Print or handle the duplicate images
for img1, img2 in duplicates:
    print(f"Duplicate found: {img1} and {img2}")

# Extract the list of duplicate image paths
duplicate_image_paths = [img1 for img1, _ in duplicates]

print("List of duplicate image paths:")
print(duplicate_image_paths)
```

Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\normal\2869_left.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\normal\2655_left.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\diabetic_retinopathy\11573_right.jpeg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\diabetic_retinopathy\10675_right.jpeg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\diabetic_retinopathy\1272_left.jpeg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\diabetic_retinopathy\10947_left.jpeg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2104_left.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\normal\2335_right.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2194_right.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\normal\2335_right.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2233_left.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\normal\2332_left.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_046.png and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_035.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_092.png and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_069.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_094.png and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_057.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_133_1300923.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2177_right.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_143_9392801.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2182_right.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_212_7340392.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2235_left.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_248_3607543.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\750_left.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_295_8218216.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_035.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_304_4376168.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_044.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_327_3715152.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\cataract_079.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract_50_1920746.jpg and C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classification\dataset\cataract\2108_left.jpg
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica

```
tion\dataset\glaucoma\Glaucoma_016.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_096.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_029.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\glaucoma\Glaucoma_001.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_034.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_009.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_037.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_009.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_049.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_057.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_054.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_014.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_057.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_057.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_058.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_056.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_066.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_086.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\Glaucoma_098.png and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_029.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\_326_7155812.jpg and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\glaucoma\Glaucoma_021.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\_332_3900734.jpg and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\glaucoma\Glaucoma_027.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\_352_8525027.jpg and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\cataract\cataract_057.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\_357_2893291.jpg and C:\Users\Sara\Desktop\Personal Proje
cts\Eye Disease Classification\dataset\glaucoma\Glaucoma_052.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\_367_403099.jpg and C:\Users\Sara\Desktop\Personal Projec
ts\Eye Disease Classification\dataset\cataract\cataract_096.png
Duplicate found: C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica
tion\dataset\glaucoma\_369_874276.jpg and C:\Users\Sara\Desktop\Personal Projec
ts\Eye Disease Classification\dataset\glaucoma\_355_9019995.jpg
List of duplicate image paths:
['C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\data
set\\normal\\2869_left.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye
Disease Classification\\dataset\\diabetic_retinopathy\\11573_right.jpeg',
'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\datas
et\\diabetic_retinopathy\\1272_left.jpeg', 'C:\\Users\\Sara\\Desktop\\Personal
Projects\\Eye Disease Classification\\dataset\\cataract\\2104_left.jpg', 'C:\\U
```

sers\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract\\2194_right.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract\\2233_left.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract\\cataract_046.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract\\cataract_092.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract\\cataract_094.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_133_1300923.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_143_9392801.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_212_7340392.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_248_3607543.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_295_8218216.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_304_4376168.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_327_3715152.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\cataract_50_1920746.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_016.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_029.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_034.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_037.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_049.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_054.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_057.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_058.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_066.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma\\Glaucoma_098.png', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma_326_7155812.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma_332_3900734.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma_352_8525027.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma_357_2893291.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma_367_403099.jpg', 'C:\\Users\\Sara\\Desktop\\Personal Projects\\Eye Disease Classification\\dataset\\glaucoma_369_874276.jpg']

In [15]:
```python
# color space analysis

for image_path in image_paths:
    with Image.open(image_path) as img:
        rgb_img = img.convert('RGB')  # Convert to RGB if necessary
        rgb_img.save(image_path)  # Save the image
```

Data Wrangling

Make image sizes consistent

In [24]:
```
# target size
target_size = (256, 256)

# Resize images
for class_name in classes:
    class_folder = os.path.join(dataset_path, class_name)
    for file_name in os.listdir(class_folder):
        if file_name.endswith(('.jpg', '.jpeg', '.png')):
            image_path = os.path.join(class_folder, file_name)
            with Image.open(image_path) as img:
                img = img.resize(target_size)  # Resize the image
                img.save(image_path)  # Save the resized image
```

remove images with low quality

In [17]:
```
def calculate_sharpness(image_path):
    # Read the image using OpenCV
    image = cv2.imread(image_path)
    # Convert the image to grayscale
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
    # Compute the Laplacian of the image
    laplacian = cv2.Laplacian(gray, cv2.CV_64F)
    # Calculate the variance of the Laplacian
    sharpness = laplacian.var()
    return sharpness
```

In [18]:
```
threshold = 66.32
low_quality_images = [image_path for image_path in image_paths if calculate_sh
print(f"Number of low-quality images: {len(low_quality_images)}")
```

```
Number of low-quality images: 1198
```

replace duplicate images with augmented versions

In [25]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator, load_img,

# Define the augmentation parameters
datagen = ImageDataGenerator(
    rotation_range=40,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True,
    fill_mode='nearest'
)
```

```
def augment_and_overwrite_image(image_path, num_augmented_images=1):
    """
    Augment a single image and overwrite the original image with the augmented

    Parameters:
    - image_path: Path to the input image.
    - num_augmented_images: Number of augmented images to generate (default is
    """
    # Load the image
    image = load_img(image_path)
    image_array = img_to_array(image)
    image_array = image_array.reshape((1,) + image_array.shape)

    # Generate and overwrite the image with the augmented version
    for i, batch in enumerate(datagen.flow(image_array, batch_size=1)):
        if i >= num_augmented_images:
            break
        augmented_image = batch[0].astype('uint8')
        save_img(image_path, augmented_image)  # Save directly over the origin

# Apply augmentation to all duplicate images
for image_path in duplicate_image_paths:
    augment_and_overwrite_image(image_path)

print("Augmentation complete. Duplicate images have been augmented and overwri
```

```
Augmentation complete. Duplicate images have been augmented and overwritten.
```

data augmentation - to create more images

In [21]:

```
# 93 images for glaucoma

import albumentations as A
from PIL import Image
import numpy as np
import os

# augmentation pipeline
transform = A.Compose([
    A.HorizontalFlip(p=0.5),
    A.RandomRotate90(p=0.5),
    A.RandomCrop(width=256, height=256, p=1.0),
    A.RandomBrightnessContrast(p=0.2),
])

# Load an image
image_path = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificat
image = np.array(Image.open(image_path))

# Folder to save augmented images
save_dir = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificatic

# Ensure save directory exists
os.makedirs(save_dir, exist_ok=True)
```

```
# Generate and save augmented images
num_images_to_generate = 93
for i in range(num_images_to_generate):
    augmented_image = transform(image=image)['image']
    augmented_image_pil = Image.fromarray(augmented_image)

    # Save in the glaucoma folder with a new filename
    augmented_image_pil.save(os.path.join(save_dir, f'augmented_glaucoma_{i}.j
```

In [26]:
```
# 62 images for cataract

# Load an image
image_path = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificat
image = np.array(Image.open(image_path))

# Folder to save augmented images
save_dir = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificatic

# Ensure save directory exists
os.makedirs(save_dir, exist_ok=True)

# Generate and save augmented images
num_images_to_generate = 62
for i in range(num_images_to_generate):
    augmented_image = transform(image=image)['image']
    augmented_image_pil = Image.fromarray(augmented_image)

    # Save in the cataract folder with a new filename
    augmented_image_pil.save(os.path.join(save_dir, f'augmented_cataract_{i}.j
```

In [27]:
```
# 2 images for diabetic_retinopathy

# Load an image
image_path = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificat
image = np.array(Image.open(image_path))

# Folder to save augmented images
save_dir = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificatic

# Ensure save directory exists
os.makedirs(save_dir, exist_ok=True)

# Generate and save augmented images
num_images_to_generate = 2
for i in range(num_images_to_generate):
    augmented_image = transform(image=image)['image']
    augmented_image_pil = Image.fromarray(augmented_image)

    # Save in the diabetic_retinopathy folder with a new filename
    augmented_image_pil.save(os.path.join(save_dir, f'augmented_diabetic_retir
```

In [29]:
```
# 26 images for normal
```

```
# Load an image
image_path = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificat
image = np.array(Image.open(image_path))

# Folder to save augmented images
save_dir = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classificatic

# Ensure save directory exists
os.makedirs(save_dir, exist_ok=True)

# Generate and save augmented images
num_images_to_generate = 26
for i in range(num_images_to_generate):
    augmented_image = transform(image=image)['image']
    augmented_image_pil = Image.fromarray(augmented_image)

    # Save in the normal folder with a new filename
    augmented_image_pil.save(os.path.join(save_dir, f'augmented_normal_{i}.jpg
```

In [32]:
```
# how many images were loaded per class
for class_label in range(len(classes)):
    class_count = sum([1 for label in labels if label == class_label])
    print(f"{classes[class_label]}: {class_count} images")
```

```
normal: 1074 images
diabetic_retinopathy: 1098 images
cataract: 1038 images
glaucoma: 1100 images
```

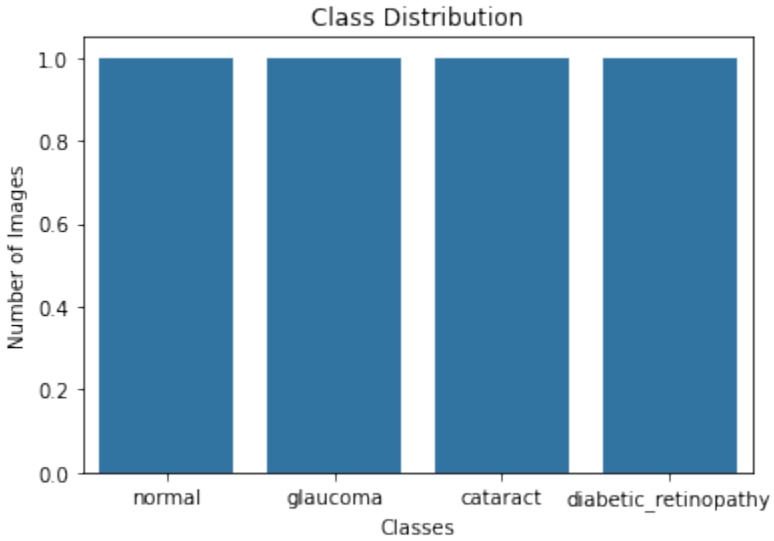
In [33]:
```
import os

# Path to your dataset directory
dataset_dir = r'C:\Users\Sara\Desktop\Personal Projects\Eye Disease Classifica

# List the subdirectories (classes)
classes = ['normal', 'diabetic_retinopathy', 'cataract', 'glaucoma']

# Loop over each class directory and count the number of images
for class_name in classes:
    class_dir = os.path.join(dataset_dir, class_name)
    image_count = len([img for img in os.listdir(class_dir) if img.endswith(('
    print(f"{class_name}: {image_count} images")
```

```
normal: 1100 images
diabetic_retinopathy: 1100 images
cataract: 1100 images
glaucoma: 1100 images
```

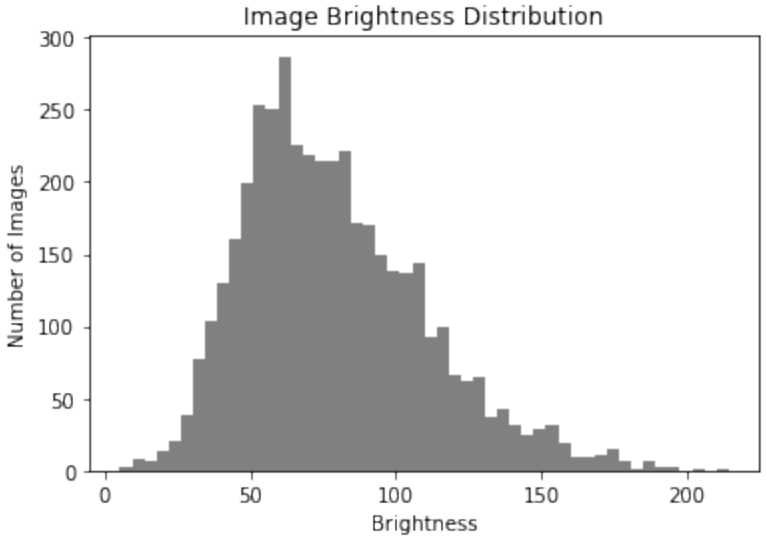
Exploratory Data Analysis

In [34]:
```
import seaborn as sns
```

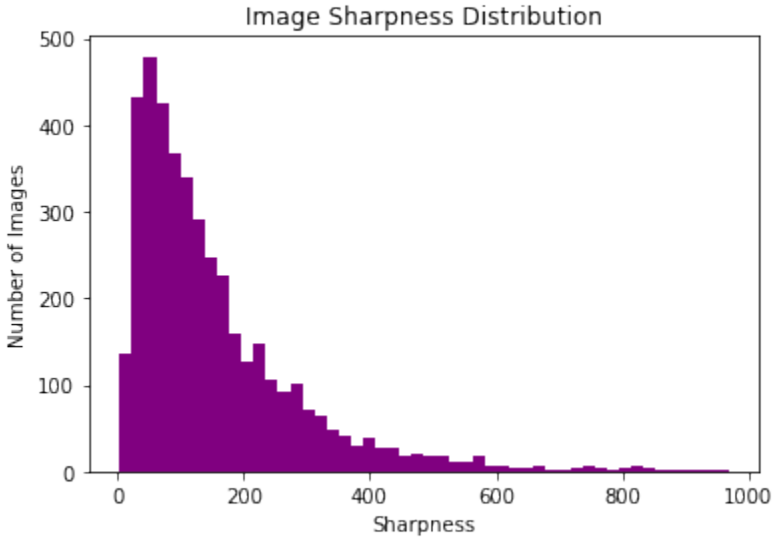
```
image_labels = ['normal', 'glaucoma', 'cataract', 'diabetic_retinopathy']

# to count occurrences of each label
class_counts = Counter(image_labels)

# Plotting class distribution
sns.barplot(x=list(class_counts.keys()), y=list(class_counts.values()))
plt.title("Class Distribution")
plt.xlabel("Classes")
plt.ylabel("Number of Images")
plt.show()
```



In [34]:
```
brightness = []
for image_path in image_paths:
    img = cv2.imread(image_path)
    gray_img = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
    brightness.append(np.mean(gray_img))

# Visualize brightness
plt.hist(brightness, bins=50, color='gray')
plt.title("Image Brightness Distribution")
plt.xlabel("Brightness")
plt.ylabel("Number of Images")
plt.show()
```



In [36]:
```
def calculate_sharpness(image):
    return cv2.Laplacian(image, cv2.CV_64F).var()

sharpness_values = []
for image_path in image_paths:
    img = cv2.imread(image_path)
    sharpness = calculate_sharpness(img)
    sharpness_values.append(sharpness)

# Visualize sharpness
plt.hist(sharpness_values, bins=50, color='purple')
plt.title("Image Sharpness Distribution")
plt.xlabel("Sharpness")
plt.ylabel("Number of Images")
plt.show()
```

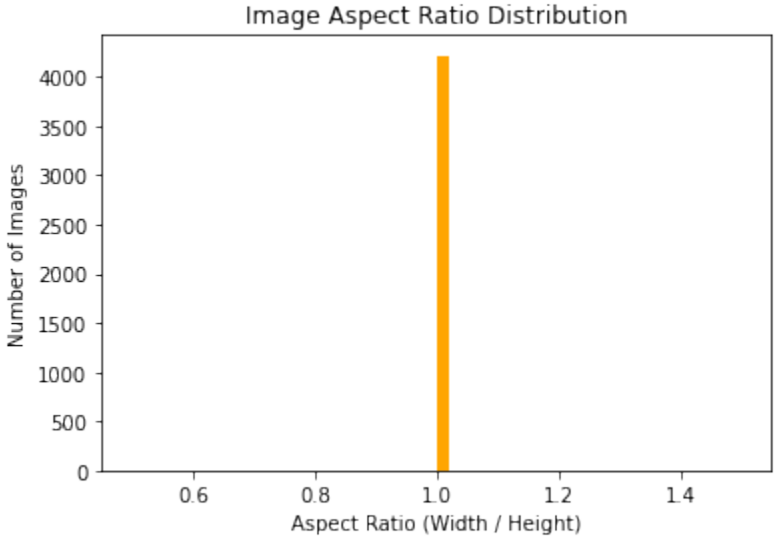


In [37]:
```
corrupted_images = []
for image_path in image_paths:
    try:
```

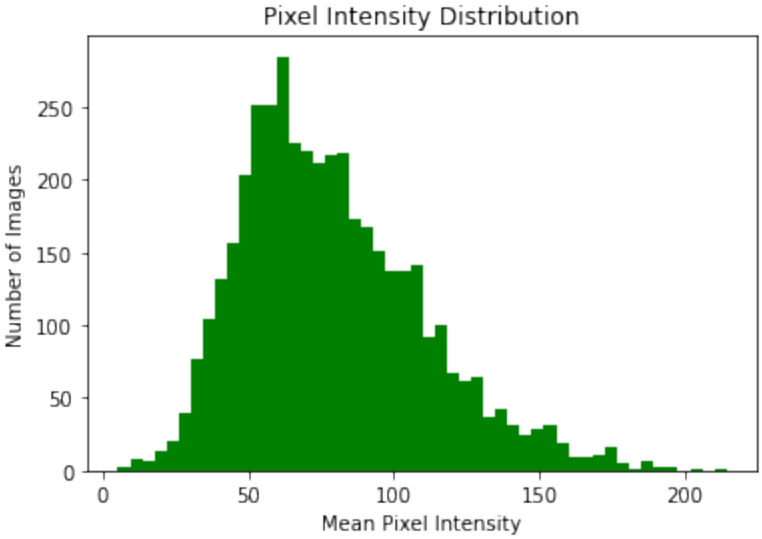
```
        img = Image.open(image_path)
        img.verify()  # Check if the image is corrupted
    except (IOError, SyntaxError) as e:
        corrupted_images.append(image_path)

print(f"Found {len(corrupted_images)} corrupted images.")
```

```
Found 0 corrupted images.
```

In [38]:
```
aspect_ratios = []
for image_path in image_paths:
    img = Image.open(image_path)
    width, height = img.size
    aspect_ratios.append(width / height)

# Visualize aspect ratios
plt.hist(aspect_ratios, bins=50, color='orange')
plt.title("Image Aspect Ratio Distribution")
plt.xlabel("Aspect Ratio (Width / Height)")
plt.ylabel("Number of Images")
plt.show()
```



In [35]:
```
pixel_intensity = []
for image_path in image_paths:
    img = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)  # Use cv2.IMREAD_COLOR
    pixel_intensity.append(np.mean(img))

plt.hist(pixel_intensity, bins=50, color='green')
plt.title("Pixel Intensity Distribution")
plt.xlabel("Mean Pixel Intensity")
plt.ylabel("Number of Images")
plt.show()
```



Machine Learning - Deep Learning

Splitting Data and Standardizing Images

In [36]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator

image_size = (256, 256)  # Resize images to 256x256 pixels

# instance of ImageDataGenerator for training and testing
train_datagen = ImageDataGenerator(
    rescale=1./255,  # Rescale pixel values to [0, 1]
    validation_split=0.2  # Use 20% of the data for validation/testing
)

# training and testing data generators
train_generator = train_datagen.flow_from_directory(
    dataset_path,
    target_size=image_size,  # Resize images to 256x256
    batch_size=32,  # Number of images to process in a batch
    class_mode='sparse',
    subset='training'  # training data
)

validation_generator = train_datagen.flow_from_directory(
    dataset_path,
    target_size=image_size,
    batch_size=32,
    class_mode='sparse',
    subset='validation'  # validation/testing data
)

# Check the number of images in the generators
print(f"Training images: {train_generator.samples}")
print(f"Validation images: {validation_generator.samples}")
```

```
Found 3520 images belonging to 4 classes.
Found 880 images belonging to 4 classes.
Training images: 3520
Validation images: 880
```

CNN Model

In [37]:

```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Drop

# CNN model
model = Sequential()

# Convolutional Layer 1
model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(256, 256, 3)))
model.add(MaxPooling2D(pool_size=(2, 2)))

# Convolutional Layer 2
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))

# Convolutional Layer 3
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))

# Flatten the output to feed into fully connected layers
model.add(Flatten())

# Fully Connected Layer 1
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))  # Dropout to prevent overfitting

# Output Layer (4 classes, use softmax for multi-class classification)
model.add(Dense(4, activation='softmax'))

# Compile the model
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['acc

# model summary
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 254, 254, 32)      896

 max_pooling2d (MaxPooling2D  (None, 127, 127, 32)     0
 )

 conv2d_1 (Conv2D)           (None, 125, 125, 64)      18496

 max_pooling2d_1 (MaxPooling  (None, 62, 62, 64)       0
 2D)

 conv2d_2 (Conv2D)           (None, 60, 60, 128)       73856

 max_pooling2d_2 (MaxPooling  (None, 30, 30, 128)      0
 2D)

 flatten (Flatten)           (None, 115200)            0

 dense (Dense)               (None, 128)               14745728

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 4)                 516

=================================================================
Total params: 14,839,492
Trainable params: 14,839,492
Non-trainable params: 0
_________________________________________________________________
```

In [38]:
```
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
```

In [39]:
```
# Inspect the first batch of data from the train generator
x_batch, y_batch = next(train_generator)
print(f"x_batch shape: {x_batch.shape}")
print(f"y_batch shape: {y_batch.shape}")
```

```
x_batch shape: (32, 256, 256, 3)
y_batch shape: (32,)
```

In [40]:
```
# Inspect the first batch of data from the validation generator
x_val_batch, y_val_batch = next(validation_generator)
print(f"x_val_batch shape: {x_val_batch.shape}")
print(f"y_val_batch shape: {y_val_batch.shape}")
```

```
x_val_batch shape: (32, 256, 256, 3)
y_val_batch shape: (32,)
```

In [42]:
```
from tensorflow.keras.callbacks import EarlyStopping
```

```
early_stopping = EarlyStopping(monitor='val_accuracy',
                               patience=10,
                               restore_best_weights=True)


history = model.fit(
    train_generator,
    epochs=50,
    validation_data=validation_generator,
    callbacks=[early_stopping]
)

model.summary()
```

```
Epoch 1/50
110/110 [==============================] - 204s 2s/step - loss: 0.5500 - accura
cy: 0.7719 - val_loss: 0.7643 - val_accuracy: 0.6284
Epoch 2/50
110/110 [==============================] - 167s 2s/step - loss: 0.5178 - accura
cy: 0.7756 - val_loss: 0.8275 - val_accuracy: 0.6068
Epoch 3/50
110/110 [==============================] - 166s 2s/step - loss: 0.4540 - accura
cy: 0.8179 - val_loss: 0.7851 - val_accuracy: 0.6295
Epoch 4/50
110/110 [==============================] - 172s 2s/step - loss: 0.4213 - accura
cy: 0.8284 - val_loss: 0.9021 - val_accuracy: 0.5841
Epoch 5/50
110/110 [==============================] - 180s 2s/step - loss: 0.3702 - accura
cy: 0.8548 - val_loss: 0.9700 - val_accuracy: 0.5852
Epoch 6/50
110/110 [==============================] - 169s 2s/step - loss: 0.3543 - accura
cy: 0.8631 - val_loss: 0.9009 - val_accuracy: 0.6045
Epoch 7/50
110/110 [==============================] - 170s 2s/step - loss: 0.3128 - accura
cy: 0.8787 - val_loss: 0.8634 - val_accuracy: 0.6284
Epoch 8/50
110/110 [==============================] - 172s 2s/step - loss: 0.2715 - accura
cy: 0.8960 - val_loss: 0.8527 - val_accuracy: 0.6648
Epoch 9/50
110/110 [==============================] - 389s 4s/step - loss: 0.2587 - accura
cy: 0.9111 - val_loss: 0.7205 - val_accuracy: 0.7125
Epoch 10/50
110/110 [==============================] - 169s 2s/step - loss: 0.2320 - accura
cy: 0.9119 - val_loss: 0.6513 - val_accuracy: 0.7568
Epoch 11/50
110/110 [==============================] - 171s 2s/step - loss: 0.2041 - accura
cy: 0.9236 - val_loss: 0.7230 - val_accuracy: 0.7511
Epoch 12/50
110/110 [==============================] - 2351s 22s/step - loss: 0.1791 - accu
racy: 0.9290 - val_loss: 0.7397 - val_accuracy: 0.7409
Epoch 13/50
110/110 [==============================] - 234s 2s/step - loss: 0.1811 - accura
cy: 0.9324 - val_loss: 1.2216 - val_accuracy: 0.6330
Epoch 14/50
110/110 [==============================] - 168s 2s/step - loss: 0.1384 - accura
cy: 0.9483 - val_loss: 0.8489 - val_accuracy: 0.7580
Epoch 15/50
110/110 [==============================] - 169s 2s/step - loss: 0.1408 - accura
cy: 0.9457 - val_loss: 0.8261 - val_accuracy: 0.7648
Epoch 16/50
110/110 [==============================] - 733s 7s/step - loss: 0.1515 - accura
cy: 0.9477 - val_loss: 1.0765 - val_accuracy: 0.6898
Epoch 17/50
110/110 [==============================] - 168s 2s/step - loss: 0.1240 - accura
cy: 0.9545 - val_loss: 0.8903 - val_accuracy: 0.7648
Epoch 18/50
110/110 [==============================] - 168s 2s/step - loss: 0.1133 - accura
cy: 0.9548 - val_loss: 1.1069 - val_accuracy: 0.7284
```

```
Epoch 19/50
110/110 [==============================] - 172s 2s/step - loss: 0.1134 - accura
cy: 0.9563 - val_loss: 1.0151 - val_accuracy: 0.7557
Epoch 20/50
110/110 [==============================] - 176s 2s/step - loss: 0.1244 - accura
cy: 0.9582 - val_loss: 1.0402 - val_accuracy: 0.7352
Epoch 21/50
110/110 [==============================] - 176s 2s/step - loss: 0.0974 - accura
cy: 0.9670 - val_loss: 1.2663 - val_accuracy: 0.6989
Epoch 22/50
110/110 [==============================] - 180s 2s/step - loss: 0.0809 - accura
cy: 0.9716 - val_loss: 1.2417 - val_accuracy: 0.7034
Epoch 23/50
110/110 [==============================] - 722s 7s/step - loss: 0.0754 - accura
cy: 0.9719 - val_loss: 1.2075 - val_accuracy: 0.7341
Epoch 24/50
110/110 [==============================] - 183s 2s/step - loss: 0.0728 - accura
cy: 0.9730 - val_loss: 0.9247 - val_accuracy: 0.7477
Epoch 25/50
110/110 [==============================] - 170s 2s/step - loss: 0.0749 - accura
cy: 0.9730 - val_loss: 1.1902 - val_accuracy: 0.7614
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 254, 254, 32)      896

 max_pooling2d (MaxPooling2D  (None, 127, 127, 32)     0
 )

 conv2d_1 (Conv2D)           (None, 125, 125, 64)      18496

 max_pooling2d_1 (MaxPooling  (None, 62, 62, 64)       0
 2D)

 conv2d_2 (Conv2D)           (None, 60, 60, 128)       73856

 max_pooling2d_2 (MaxPooling  (None, 30, 30, 128)      0
 2D)

 flatten (Flatten)           (None, 115200)            0

 dense (Dense)               (None, 128)               14745728

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 4)                 516

=================================================================
Total params: 14,839,492
Trainable params: 14,839,492
Non-trainable params: 0
_________________________________________________________________
```

Evaluate the model

In [43]:
```
# Evaluate on the validation set
val_loss, val_accuracy = model.evaluate(validation_generator)
print(f"Validation Loss: {val_loss}")
print(f"Validation Accuracy: {val_accuracy}")
```

```
28/28 [==============================] - 12s 389ms/step - loss: 0.8261 - accura
cy: 0.7648
Validation Loss: 0.8261425495147705
Validation Accuracy: 0.7647727131843567
```

In [44]:
```
# Get predictions for the validation set
predictions = model.predict(validation_generator)

# Convert the predicted probabilities into predicted class labels
predicted_classes = np.argmax(predictions, axis=1)

# Get the true class labels from the validation set
true_classes = validation_generator.classes
```

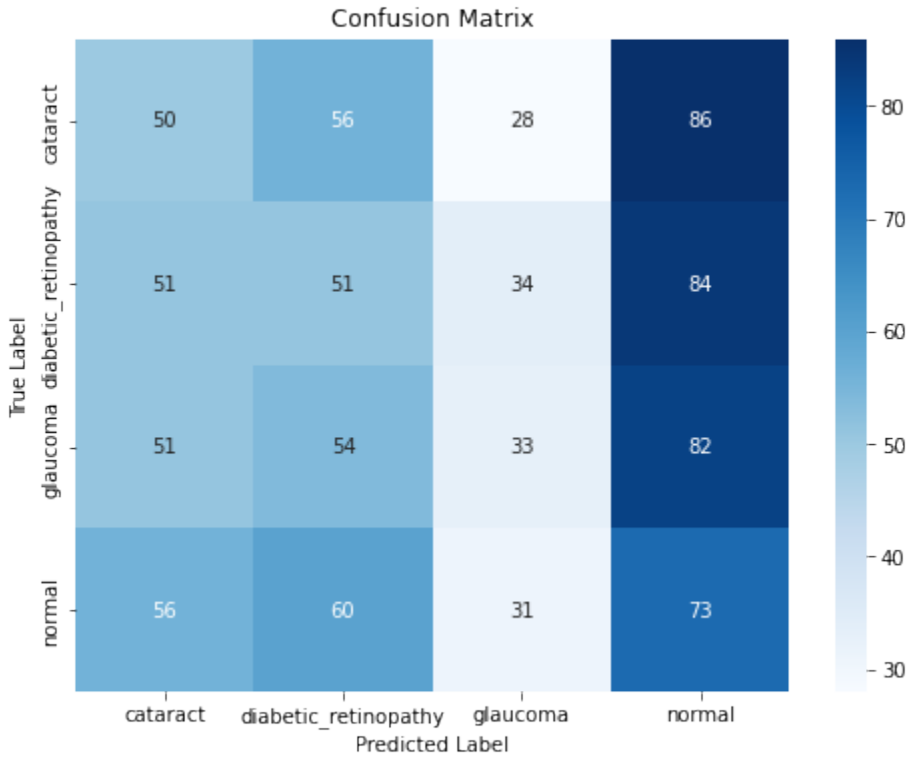
In [45]:
```
# Print predictions (probabilities for each class)
print(f"Predictions (probabilities): \n{predictions}")
```

```
Predictions (probabilities):
[[3.0514155e-07 9.9999714e-01 2.3622717e-06 2.2054908e-07]
 [7.5654894e-01 9.6597780e-08 3.2569066e-02 2.1088186e-01]
 [8.7732598e-20 1.0000000e+00 3.9252652e-18 1.6208705e-23]
 ...
 [8.6755544e-01 7.9791178e-09 1.2219074e-01 1.0253876e-02]
 [9.0896571e-01 1.2537373e-08 6.3272808e-03 8.4707022e-02]
 [3.1967947e-04 1.7858409e-06 3.0859975e-02 9.6881860e-01]]
```

In [46]:
```
from sklearn.metrics import classification_report, confusion_matrix

# Generate the classification report
class_labels = list(validation_generator.class_indices.keys())
report = classification_report(true_classes, predicted_classes, target_names=c
print(report)

# Generate confusion matrix
conf_matrix = confusion_matrix(true_classes, predicted_classes)
print(conf_matrix)
```

```
                    precision    recall  f1-score   support

          cataract       0.24      0.23      0.23       220
diabetic_retinopathy       0.23      0.23      0.23       220
          glaucoma       0.26      0.15      0.19       220
            normal       0.22      0.33      0.27       220

          accuracy                           0.24       880
         macro avg       0.24      0.24      0.23       880
      weighted avg       0.24      0.24      0.23       880

[[50 56 28 86]
 [51 51 34 84]
 [51 54 33 82]
 [56 60 31 73]]
```

In [47]:
```
import seaborn as sns
import matplotlib.pyplot as plt

# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap='Blues', xticklabels=class_
plt.ylabel('True Label')
plt.xlabel('Predicted Label')
plt.title('Confusion Matrix')
plt.show()
```



In [48]:
```
import matplotlib.pyplot as plt

# relevant metrics from the training history
```

```
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

# Determine the number of epochs
epochs_range = range(len(acc))

# Plot training and validation accuracy
plt.figure(figsize=(8, 8))
plt.subplot(1, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

# Plot training and validation loss
plt.subplot(1, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')

plt.show()
```