Tugas 4 MA4072 - Pembelajaran Mendalam

oleh:
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Akan dibuat tiga model dengan arsitektur berbeda untuk memprediksi penyakit Katarak berdasarkan Fundus mata.

1. Model MLP
2. Model CNN dengan Arsitektur VGG11
3. Model RNN dengan Arsitektur LSTM

Ketiga model ini akan dilatih dan diuji menggunakan dataset Ocular Disease Recognition (ODIR) yang diperoleh dari https://www.kaggle.com/datasets/andrewmvd/ocular-disease-recognition-odir5k. Data yang dipertimbangkan adalah Fundus kanan atau Fundus kiri Pasien

Perlu dicatat: untuk rerun Colab ini, diperlukan kaggle API dari pengguna dan ditaruh di direktori /content/ pada runtime e.g. /content/kaggle.json. Tutorial mendapatkannya bisa mengikuti di https://medium.com/analytics-vidhya/how-to-download-kaggle-datasets-into-google-colab-via-google-drive-dcb348d7af07

File Download

In [ ]:
```
!pip install kaggle
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: kaggle in /usr/local/lib/python3.7/dist-packages (1.5.12)
Requirement already satisfied: certifi in /usr/local/lib/python3.7/dist-packages (from kaggle) (2022.5.18.1)
Requirement already satisfied: urllib3 in /usr/local/lib/python3.7/dist-packages (from kaggle) (1.24.3)
Requirement already satisfied: tqdm in /usr/local/lib/python3.7/dist-packages (from kaggle) (4.64.0)
Requirement already satisfied: python-slugify in /usr/local/lib/python3.7/dist-packages (from kaggle) (6.1.2)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.7/dist-packages (from kaggle) (2.8.2)
Requirement already satisfied: requests in /usr/local/lib/python3.7/dist-packages (from kaggle) (2.23.0)
Requirement already satisfied: six ≥ 1.10 in /usr/local/lib/python3.7/dist-packages (from kaggle) (1.15.0)
Requirement already satisfied: text-unidecode ≥ 1.3 in /usr/local/lib/python3.7/dist-packages (from python-slugify→kaggle) (1.3)
Requirement already satisfied: idna<3, ≥ 2.5 in /usr/local/lib/python3.7/dist-packages (from requests→kaggle) (2.10)
Requirement already satisfied: chardet<4, ≥ 3.0.2 in /usr/local/lib/python3.7/dist-packages (from requests→kaggle) (3.0.4)
```

In [ ]:
```
!mkdir ~/.kaggle
```

```
mkdir: cannot create directory ‘/root/.kaggle’: File exists
```

In [ ]:
```
!cp kaggle.json ~/.kaggle/
```

In [ ]:
```
!chmod 600 ~/.kaggle/kaggle.json
```

In [ ]:
```
!kaggle datasets download andrewmvd/ocular-disease-recognition-odir5k
```

```
Downloading ocular-disease-recognition-odir5k.zip to /content
 98% 1.59G/1.62G [00:49<00:00, 32.9MB/s]
100% 1.62G/1.62G [00:49<00:00, 35.3MB/s]
```

In [ ]:
```
!unzip ocular-disease-recognition-odir5k.zip
```

Setup

Import

In [ ]:
```
import pandas as pd
# import cv2
# import os.path
# from google.colab.patches import cv2_imshow
import numpy as np
import random
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler
# from functools import lru_cache, wraps
import torch.utils.data
import torchvision
import sklearn.metrics
from sklearn.model_selection import train_test_split
from PIL import Image
```

Seed

In [ ]:
```
GLOBAL_SEED = 13520157+10118011
torch.manual_seed(GLOBAL_SEED)
torch.cuda.manual_seed(GLOBAL_SEED)
random.seed(GLOBAL_SEED)
np.random.seed(GLOBAL_SEED)
```

Global Utilities

In [ ]:
```
scaler = StandardScaler()
def print_eval(cf_matrix, classes):
    fpm = np.sum(cf_matrix, axis=0)
    fnm = np.sum(cf_matrix, axis=1)
    rec = [(cf_matrix[i][i]) / (fnm[i] + 1e-10) for i in range(len(cf_mat
    prec = [(cf_matrix[i][i]) / (fpm[i] + 1e-10)for i in range(len(cf_mat
    f1 = [2 * prec[i] * rec[i] / (prec[i] + rec[i] + 1e-10) for i in rang
    raw_m = np.vstack((rec, prec, f1))
    acc = np.trace(cf_matrix) / (np.sum(cf_matrix) + 1e-10)
    print(f"\nTotal Accuracy: {acc:.4f}")
    print(pd.DataFrame(raw_m, index = ["Recall", "Precision", "F1 Score"]
def filters(row):
  try:
    Image.open(row['filepath'])
    if ("cataract" in row['Left-Diagnostic Keywords'] and "left" in row['
      return True
    if ("normal" in row['Left-Diagnostic Keywords'] and "left" in row['fi
      return True
    return False
  except:
    return False
def labelling(row):
  if ("cataract" in row['Left-Diagnostic Keywords'] and "left" in row['fi
    return 1
  elif ("normal" in row['Left-Diagnostic Keywords'] and "left" in row['fi
    return 0
```

Load and Cleaning Data

In [ ]:
```
df = pd.read_csv("/content/full_df.csv")
df.dropna(inplace=True)
df['filepath'] = df['filepath'].str.slice_replace(start=0, stop=66, repl=
df = df[['Patient Age', 'Patient Sex', 'Left-Diagnostic Keywords', 'Right
df = df.loc[df.apply(filters, axis=1), :]
df['labels'] = df.apply(labelling, axis=1)
df.reset_index(drop=True, inplace=True)
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:6: SettingWi
thCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-do
cs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

In [ ]:
```
df_picked = pd.concat([df.loc[df['labels'] == 0, :].sample(n=300), df.loc
df_picked.reset_index(drop=True, inplace=True)
```

In [ ]:
```
df_picked
```

Out[ ]:

	Patient Age	Patient Sex	Left-Diagnostic Keywords	Right-Diagnostic Keywords	filepath	labels
0	25	Male	normal fundus	normal fundus	/content /preprocessed_images /2642_left.jpg	0
1	72	Male	normal fundus	normal fundus	/content /preprocessed_images /2883_left.jpg	0
2	56	Male	normal fundus	normal fundus	/content /preprocessed_images /2659_left.jpg	0
3	69	Male	normal fundus	normal fundus	/content /preprocessed_images /2513_right.jpg	0
4	63	Female	normal fundus	normal fundus	/content /preprocessed_images /2422_left.jpg	0
...	...	...	...	...	...	...
595	76	Female	cataract	normal fundus	/content /preprocessed_images /2136_left.jpg	1
596	70	Male	lens dust, cataract	cataract, lens dust	/content /preprocessed_images /2251_right.jpg	1
597	69	Male	cataract	cataract	/content /preprocessed_images /2246_left.jpg	1
598	64	Female	cataract	cataract	/content /preprocessed_images /2108_left.jpg	1
599	68	Female	cataract	cataract	/content /preprocessed_images /2219_right.jpg	1

600 rows × 6 columns

Train and Testing Split

In [ ]:
```
df_train, df_test = train_test_split(df_picked, test_size=0.2, random_sta
df_train.reset_index(drop=True, inplace=True)
df_test.reset_index(drop=True, inplace=True)
```

In [ ]:
```
df_train
```

Out[ ]:

	Patient Age	Patient Sex	Left-Diagnostic Keywords	Right-Diagnostic Keywords	filepath	labels
0	60	Female	normal fundus	normal fundus	/content/preprocessed_images/3210_left.jpg	0
1	56	Male	normal fundus	normal fundus	/content/preprocessed_images/2659_left.jpg	0
2	44	Male	normal fundus	macular epiretinal membrane	/content/preprocessed_images/140_left.jpg	0
3	51	Female	normal fundus	normal fundus	/content/preprocessed_images/3431_right.jpg	0
4	80	Female	lens dust, normal fundus	normal fundus	/content/preprocessed_images/3037_right.jpg	0
...	...	...	...	...	...	...
475	76	Male	lens dust, cataract	cataract, lens dust	/content/preprocessed_images/2244_right.jpg	1
476	56	Female	normal fundus	normal fundus	/content/preprocessed_images/2438_right.jpg	0
477	64	Male	cataract	cataract	/content/preprocessed_images/2240_right.jpg	1
478	63	Male	cataract	normal fundus	/content/preprocessed_images/2175_left.jpg	1
479	50	Male	normal fundus	normal fundus	/content/preprocessed_images/3423_right.jpg	0

480 rows × 6 columns

In [ ]:
```
df_test
```

Out[ ]:

	Patient Age	Patient Sex	Left-Diagnostic Keywords	Right-Diagnostic Keywords	filepath	labels
0	48	Male	normal fundus	cataract	/content/preprocessed_images/2218_right.jpg	1
1	48	Male	normal fundus	normal fundus	/content/preprocessed_images/2723_left.jpg	0
2	52	Male	normal fundus	normal fundus	/content/preprocessed_images/3050_left.jpg	0
3	54	Female	cataract	cataract	/content/preprocessed_images/2134_right.jpg	1
4	54	Female	normal fundus	epiretinal membrane	/content/preprocessed_images/60_left.jpg	0
...	...	...	...	...	...	...
115	43	Male	normal fundus	chorioretinal atrophy	/content/preprocessed_images/69_left.jpg	0
116	63	Female	lens dust, normal fundus	normal fundus, lens dust	/content/preprocessed_images/3046_right.jpg	0
117	81	Female	cataract	cataract	/content/preprocessed_images/2128_left.jpg	1
118	64	Female	normal fundus	normal fundus	/content/preprocessed_images/2944_left.jpg	0
119	65	Female	cataract	cataract	/content/preprocessed_images/477_right.jpg	1

120 rows × 6 columns

Dataset

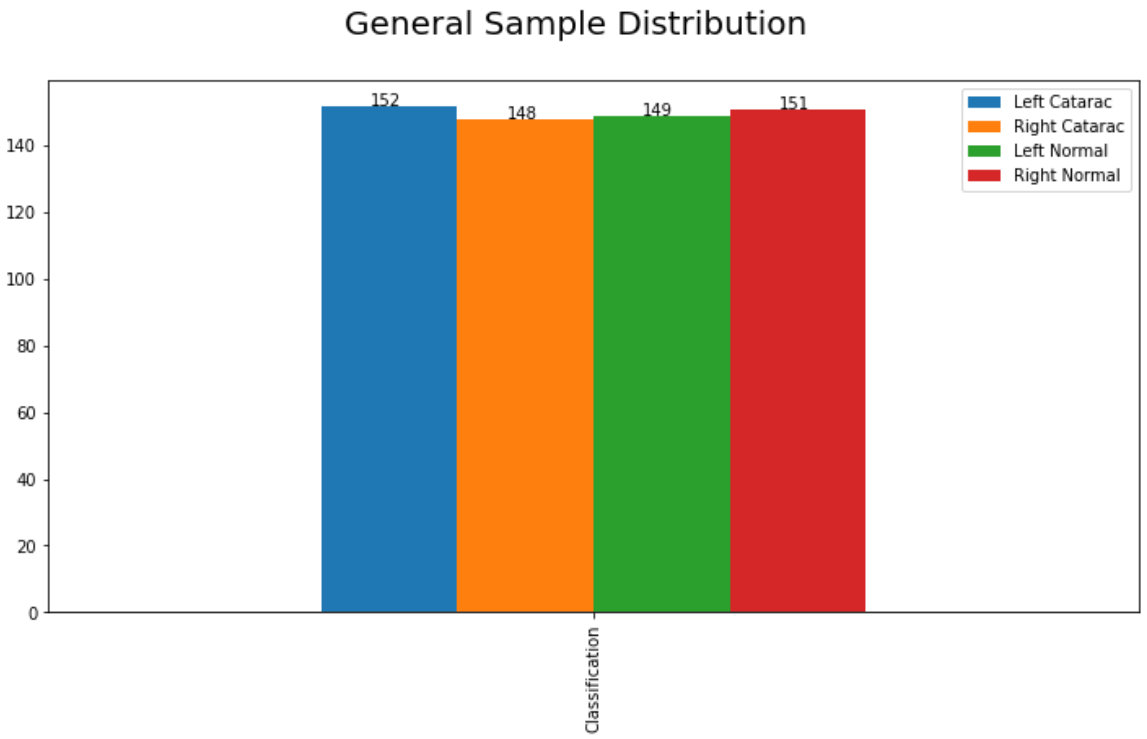
In [ ]:
```python
# Transformation
class CustomResize(object):
  def __init__(self, size):
    self.size = size
  def __call__(self, sample):
    img, imgLabel = sample['img'],  sample['labels']
    pad = torchvision.transforms.functional.resize(img, self.size)
    return {'img': pad, 'labels': imgLabel}

class CustomCenterCrop(object):
  def __init__(self, size):
    self.size = size
  def __call__(self, sample):
    img, imgLabel = sample['img'],  sample['labels']
    cr = torchvision.transforms.functional.center_crop(img, self.size)
    return {'img': cr, 'labels': imgLabel}

class RegularToNormalizedFlattenTensor(object):
  def __call__(self, sample):
    img, imgLabel = sample['img'],  sample['labels']
    timg = torchvision.transforms.functional.pil_to_tensor(img).float()
    timg = torchvision.transforms.functional.normalize(timg, mean=(0.5),
    flat = torch.flatten(timg)
    return {'img': flat, 'labels': imgLabel}

class RegularToNormalizedMergedTensor(object):
  def __call__(self, sample):
    img, imgLabel = sample['img'],  sample['labels']
    timg = torchvision.transforms.functional.pil_to_tensor(img).float()
    timg = torchvision.transforms.functional.normalize(timg, mean=(0.5),
    return {'img': timg, 'labels': imgLabel}

class RGBtoGS(object):
  def __call__(self, sample):
    img, imgLabel = sample['img'], sample['labels']
    gimg = torch.reshape(torchvision.transforms.functional.rgb_to_graysca
    return {'img': gimg, 'labels': imgLabel}

class EyeDataset(torch.utils.data.Dataset):
  def __init__(self, dataframe, transform=None):
    self.detail_csv = dataframe
    self.transform = transform
  def __len__(self):
    return len(self.detail_csv)
  def __getitem__(self, idx):
    if torch.is_tensor(idx):
      idx = idx.tolist()
    img = Image.open(self.detail_csv.iloc[idx, df.columns.get_loc('filepa
    imgLabel = self.detail_csv.iloc[idx, df.columns.get_loc('labels')]
    sample = {'img': img, 'labels': imgLabel}
    if self.transform:
      sample = self.transform(sample)
    return sample
```

General Data Information

General Distribution

In [ ]:
```
leftcat = len(df_picked.loc[(df_picked['Left-Diagnostic Keywords'].str.co
rightcat = len(df_picked.loc[df_picked['Right-Diagnostic Keywords'].str.c
leftnorm = len(df_picked.loc[df_picked['Left-Diagnostic Keywords'].str.co
rightnorm = len(df_picked.loc[df_picked['Right-Diagnostic Keywords'].str.
fig, ax = plt.subplots(figsize=(12, 6))
fig.suptitle('General Sample Distribution', fontsize=20)
pd.DataFrame({'Left Catarac': leftcat, 'Right Catarac': rightcat, 'Left N
for p in ax.patches:
    ax.annotate(str(p.get_height()), xy=(p.get_x()+0.045, p.get_height())
fig.show()
print(f"Left Catarac: {leftcat}, Right Catarac: {rightcat}, Left Normal:
```

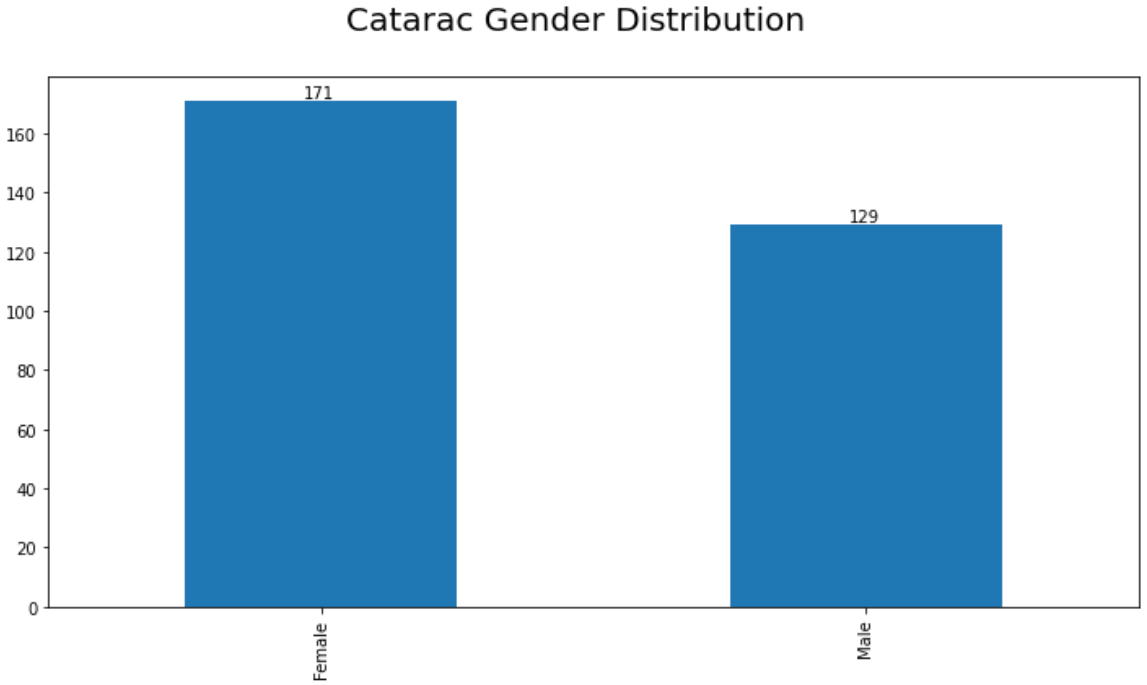
```
Left Catarac: 152, Right Catarac: 148, Left Normal: 149, Right Norm: 151
```



Cataracs

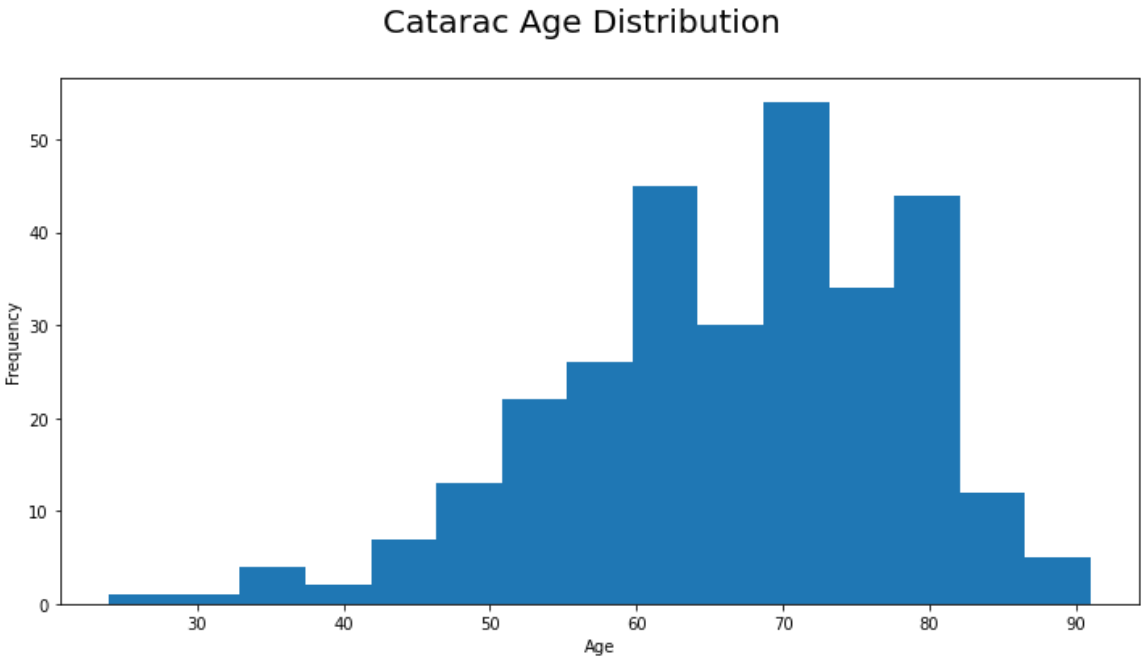
Gender

In [ ]:
```
fig, ax = plt.subplots(figsize=(12, 6))
fig.suptitle('Catarac Gender Distribution', fontsize=20)
df_picked.loc[(df_picked['Left-Diagnostic Keywords'].str.contains("catara
for p in ax.patches:
    ax.annotate(str(p.get_height()), xy=(p.get_x()+0.219, p.get_height()+
fig.show()
```



Age

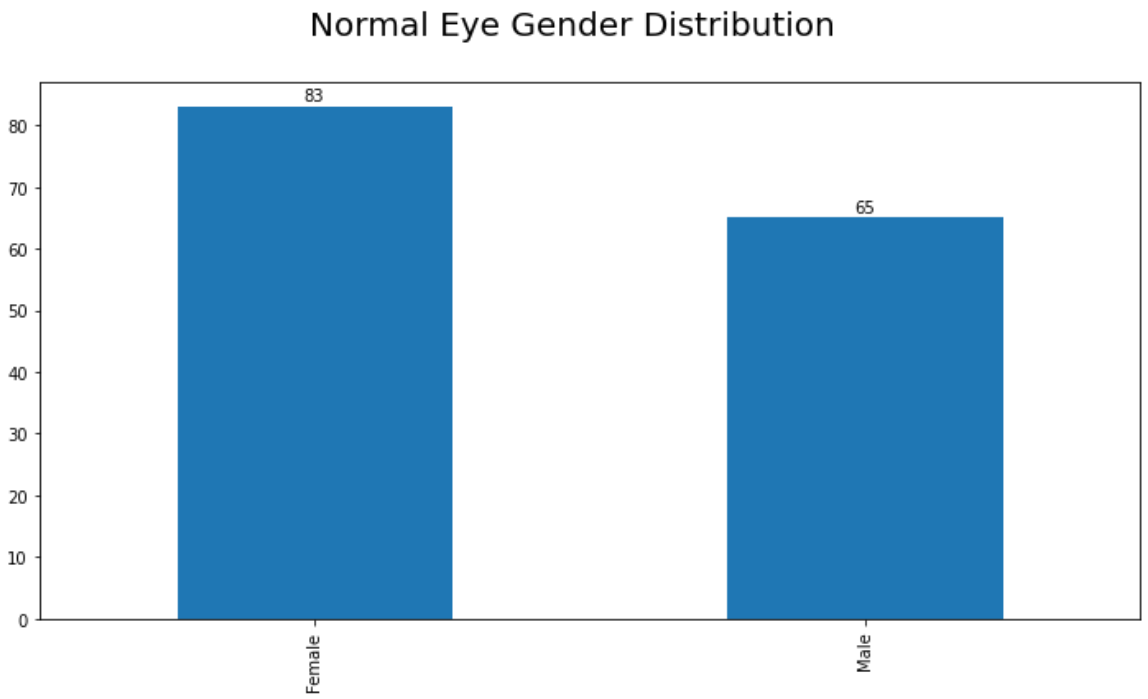
In [ ]:
```
fig, ax = plt.subplots(figsize=(12, 6))
fig.suptitle('Catarac Age Distribution', fontsize=20)
df_picked.loc[(df_picked['Left-Diagnostic Keywords'].str.contains("catara
ax.set_xlabel("Age")
fig.show()
```



Normal

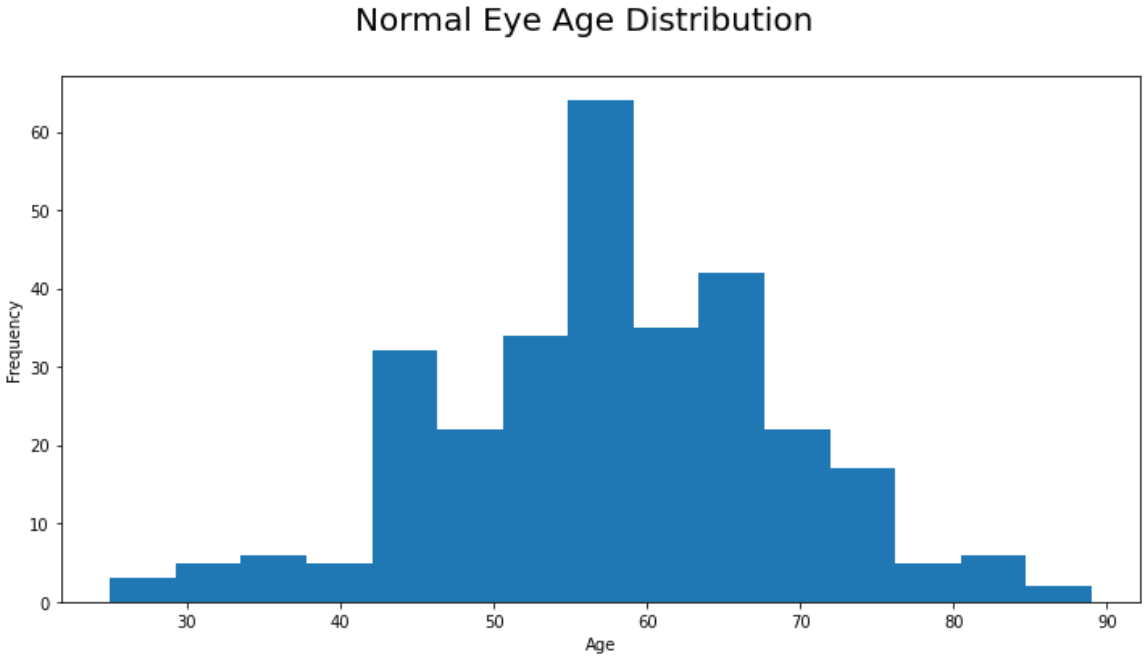
Gender

In [ ]:
```
fig, ax = plt.subplots(figsize=(12, 6))
fig.suptitle('Normal Eye Gender Distribution', fontsize=20)
df_picked.loc[(df_picked['Left-Diagnostic Keywords'].str.contains("normal
for p in ax.patches:
    ax.annotate(str(p.get_height()), xy=(p.get_x()+0.23, p.get_height()+1
fig.show()
```



Age

In [ ]:
```
fig, ax = plt.subplots(figsize=(12, 6))
fig.suptitle('Normal Eye Age Distribution', fontsize=20)
df_picked.loc[(df_picked['Left-Diagnostic Keywords'].str.contains("normal
ax.set_xlabel("Age")
fig.show()
```



Model

MLP Approach

MLP Model

In [ ]:
```
class MLPModel(torch.nn.Module):
  def __init__(self, dataframe):
    super(MLPModel, self).__init__()
    torch.manual_seed(GLOBAL_SEED)
    # DATASET LOADER
    self.dataset = EyeDataset(dataframe=dataframe,
                        transform=torchvision.transforms.Compose([
                        CustomResize(128),
                        CustomCenterCrop((128, 128)),
                        RegularToNormalizedFlattenTensor()
                      ]))
    # LAYERING
    self.relu = torch.nn.ReLU()
    self.softmax = torch.nn.Softmax(dim=1)
    self.sigmoid = torch.nn.Sigmoid()
    insize = self.dataset[0]['img'].size(dim=0)
    self.l1 = torch.nn.Linear(insize, 128)
    self.d1 = torch.nn.Dropout(p=0.25)
    self.bnorm1 = torch.nn.BatchNorm1d(128)
    self.l2 = torch.nn.Linear(128, 64)
    self.bnorm2 = torch.nn.BatchNorm1d(64)
    self.l3 = torch.nn.Linear(64, 32)
    self.bnorm3 = torch.nn.BatchNorm1d(32)
    self.lo = torch.nn.Linear(32, 1)
  def forward(self, x):
    x = self.relu(self.bnorm1(self.l1(x)))
    x = self.relu(self.bnorm2(self.l2(x)))
    x = self.relu(self.bnorm3(self.l3(x)))
    x = self.d1(x)
    x = self.lo(x)
    return x
```

Training

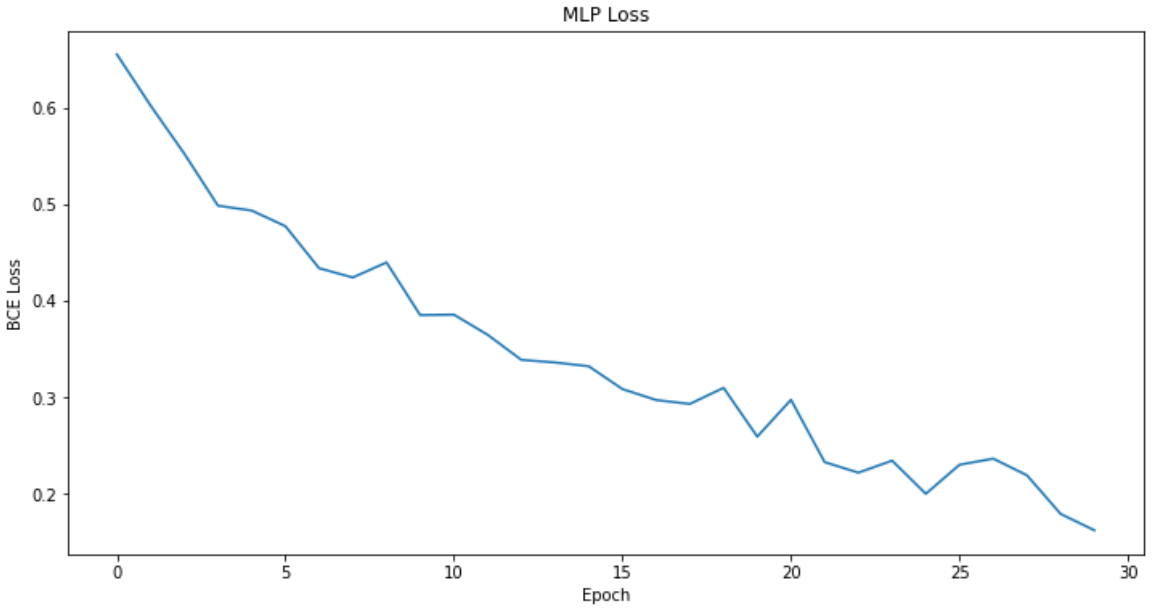
In [ ]:

```
dataframe = df_train
batch_size = 32
epoch = 30
xlogger = np.array([])
ylogger = np.array([])
counter = 0


mlp_model = MLPModel(dataframe)
loader = torch.utils.data.DataLoader(mlp_model.dataset, batch_size=batch_
criterion = torch.nn.BCEWithLogitsLoss()
optim = torch.optim.NAdam(mlp_model.parameters(), lr=1e-3)
sched = torch.optim.lr_scheduler.ReduceLROnPlateau(optim, patience=3, thr
if torch.cuda.is_available():
  mlp_model.to('cuda')
for e in range(epoch):
  acculoss = 0.0
  accstep = 0
  for i, batch in enumerate(loader):
      bx, by = batch['img'], batch['labels']
      if torch.cuda.is_available():
        bx, by = bx.to('cuda'), by.to('cuda')
      out = mlp_model.forward(bx)
      loss = criterion(out, by.unsqueeze(1).float())
      optim.zero_grad()
      loss.backward()
      optim.step()
      accstep += 1
      acculoss += loss.detach().item()
      # if ((i+1)%5 == 0):
      #     with torch.no_grad():
      #       print(f"Epoch: {e+1}; Batch: {i+1}; Loss: {loss}")
      #       xlogger = np.append(xlogger, counter)
      #       ylogger = np.append(ylogger, loss.item())
      #       counter += 1
  print(f"Epoch: {e+1}; Loss: {acculoss/accstep}")
  xlogger = np.append(xlogger, counter)
  ylogger = np.append(ylogger, acculoss/accstep)
  counter += 1
  sched.step(acculoss/accstep)
```

```
Epoch: 1; Loss: 0.6555738329887391
Epoch: 2; Loss: 0.6024779359499614
Epoch: 3; Loss: 0.5525592029094696
Epoch: 4; Loss: 0.4985385457674662
Epoch: 5; Loss: 0.49352105259895324
Epoch: 6; Loss: 0.4773142913977305
Epoch: 7; Loss: 0.43364712794621785
Epoch: 8; Loss: 0.4240441521008809
Epoch: 9; Loss: 0.4396765410900116
Epoch: 10; Loss: 0.38500726024309795
Epoch: 11; Loss: 0.38548091650009153
Epoch: 12; Loss: 0.36460493008295697
Epoch: 13; Loss: 0.3385884195566177
Epoch: 14; Loss: 0.33587873180707295
Epoch: 15; Loss: 0.331928159793218
Epoch: 16; Loss: 0.3082391271988551
Epoch: 17; Loss: 0.2968727469444275
Epoch: 18; Loss: 0.292848664522171
Epoch: 19; Loss: 0.3095363328854243
Epoch: 20; Loss: 0.25892120202382407
Epoch: 21; Loss: 0.29717039068539935
Epoch: 22; Loss: 0.23244941333929697
Epoch: 23; Loss: 0.22149761865536371
Epoch: 24; Loss: 0.23402495086193084
Epoch: 25; Loss: 0.19960506856441498
Epoch: 26; Loss: 0.22977172334988913
Epoch: 27; Loss: 0.23607937892278036
Epoch: 28; Loss: 0.21880115469296774
Epoch: 29; Loss: 0.17871997952461244
Epoch: 30; Loss: 0.16175269683202106
```

Stats

In [ ]:
```python
# SHOW GRAPH
plt.figure(figsize=(12, 6))
plt.title(f"MLP Loss")
plt.figure(1).patch.set_facecolor("white")
plt.xlabel("Epoch")
plt.ylabel("BCE Loss")
plt.plot(xlogger, ylogger)
plt.show()
```



In [ ]:
```
test_set = EyeDataset(dataframe=df_test,
                      transform=torchvision.transforms.Compose([
                      CustomResize(128),
                      CustomCenterCrop((128, 128)),
                      RegularToNormalizedFlattenTensor()
                     ]))
loader = torch.utils.data.DataLoader(test_set, batch_size=len(test_set),
with torch.no_grad():
  classes = ["NORMAL", "CATARACS"]
  for batch in loader:
      bx, by = batch['img'], batch['labels']
      if torch.cuda.is_available():
        bx = bx.to('cuda')
      out = mlp_model.forward(bx)
      outenc = torch.round(torch.flatten(torch.sigmoid(out)))
      cf_matrix = sklearn.metrics.confusion_matrix(by, outenc.cpu())
      df_cm = pd.DataFrame(cf_matrix, index = [i+" (A)" for i in classes]
      print(df_cm)
```

```
              NORMAL (P)  CATARACS (P)
NORMAL (A)            45            12
CATARACS (A)          15            48
```

In [ ]:
```
print_eval(cf_matrix, classes)
```

```
Total Accuracy: 0.7750
             NORMAL  CATARACS
Recall     0.789474  0.761905
Precision  0.750000  0.800000
F1 Score   0.769231  0.780488
```

CNN Approach (VGG)

CNN Model

In [ ]:

```
# Gajadi GoogLeNet kena overfit
# class InceptionBlock(torch.nn.Module):
#   def __init__(self, in_channels, c1, c2, c3, c4):
#     super(InceptionBlock, self).__init__()
#     torch.manual_seed(GLOBAL_SEED)
#     self.relu = torch.nn.ReLU()
#     self.p1_1 = torch.nn.Conv2d(in_channels, c1, kernel_size=1)
#     self.p2_1 = torch.nn.Conv2d(in_channels, c2[0], kernel_size=1)
#     self.p2_2 = torch.nn.Conv2d(c2[0], c2[1], kernel_size=3, padding=1)
#     self.p3_1 = torch.nn.Conv2d(in_channels, c3[0], kernel_size=1)
#     self.p3_2 = torch.nn.Conv2d(c3[0], c3[1], kernel_size=5, padding=2)
#     self.p4_1 = torch.nn.MaxPool2d(kernel_size=3, stride=1, padding=1)
#     self.p4_2 = torch.nn.Conv2d(in_channels, c4, kernel_size=1)
#   def forward(self, x):
#     p1 = torch.nn.functional.relu(self.p1_1(x))
#     p2 = self.relu(self.p2_2(self.relu(self.p2_1(x))))
#     p3 = self.relu(self.p3_2(self.relu(self.p3_1(x))))
#     p4 = self.relu(self.p4_2(self.p4_1(x)))
#     return torch.cat((p1, p2, p3, p4), dim=1)

# class CNNModel(torch.nn.Module):
#   def __init__(self, dataframe):
#     super(CNNModel, self).__init__()
#     torch.manual_seed(GLOBAL_SEED)
#     # DATASET LOADER
#     self.dataset = EyeDataset(dataframe=dataframe,
#                         transform=torchvision.transforms.Compose([
#                         CustomResize(256),
#                         CustomCenterCrop(224),
#                         RegularToNormalizedMergedTensor()
#                       ]))
#     # LAYERING
#     in_ch = self.dataset[0]['img'].size(dim=0)
#     # STAGE 1 Conv+ReLU+MaxPool
#     self.s1 = torch.nn.Sequential(torch.nn.Conv2d(in_ch, 64, kernel_siz
#                     torch.nn.ReLU(),
#                     torch.nn.MaxPool2d(kernel_size=3, stride=2, padding=
#     # STAGE 2 Double Conv+ReLU and MaxPool
#     self.s2 = torch.nn.Sequential(torch.nn.Conv2d(64, 64, kernel_size=1
#                     torch.nn.ReLU(),
#                     torch.nn.Conv2d(64, 192, kernel_size=3, padding=1),
#                     torch.nn.ReLU(),
#                     torch.nn.MaxPool2d(kernel_size=3, stride=2, padding=
#     # STAGE 3 Double Inception Block + MaxPool
#     self.s3 = torch.nn.Sequential(InceptionBlock(192, 64, (96, 128), (1
#                     InceptionBlock(256, 128, (128, 192), (32, 96), 64),
#                     torch.nn.MaxPool2d(kernel_size=3, stride=2, padding=
#     # STAGE 4 Quintuple Inception Block + MaxPool
#     self.s4 = torch.nn.Sequential(InceptionBlock(480, 192, (96, 208), (
#                     InceptionBlock(512, 160, (112, 224), (24, 64), 64),
#                     InceptionBlock(512, 128, (128, 256), (24, 64), 64),
#                     InceptionBlock(512, 112, (144, 288), (32, 64), 64),
#                     InceptionBlock(528, 256, (160, 320), (32, 128), 128)
#                     torch.nn.MaxPool2d(kernel_size=3, stride=2, padding=
#     # STAGE 5 Double Inception Block + Adaptive Avg Pool
#     self.s5 = torch.nn.Sequential(InceptionBlock(832, 256, (160, 320),
#                     InceptionBlock(832, 384, (192, 384), (48, 128), 128)
#                     torch.nn.AdaptiveAvgPool2d((1,1)),
#                     torch.nn.Flatten())
#     # Output Layer
#     self.lo = torch.nn.Linear(1024, 1)
#     self.d1 = torch.nn.Dropout(p=0.5)
#     # torch.nn.init.xavier_normal_(self.lo.weight)
```

```
#     # torch.nn.init.xavier_normal_(self.lo.weight)
#   def forward(self, x):
#     x = self.s5(self.s4(self.s3(self.s2(self.s1(x)))))
#     x = self.d1(x)
#     return self.lo(x)

class CNNModel(torch.nn.Module):
  def applyw(self, w):
      if type(w) == torch.nn.Conv2d:
        torch.nn.init.xavier_uniform_(w.weight, gain=torch.nn.init.calcula

  def __init__(self, dataframe):
    super(CNNModel, self).__init__()
    torch.manual_seed(GLOBAL_SEED)
    # DATASET LOADER
    self.dataset = EyeDataset(dataframe=dataframe,
                      transform=torchvision.transforms.Compose([
                      CustomResize(256),
                      CustomCenterCrop((224, 224)),
                      RegularToNormalizedMergedTensor()
                    ]))
    self.in_ch = self.dataset[0]['img'].size(dim=0)
    self.conv_layers = torch.nn.Sequential(
        torch.nn.Conv2d(self.in_ch, 64, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.MaxPool2d(kernel_size=2, stride=2),
        torch.nn.Conv2d(64, 128, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.MaxPool2d(kernel_size=2, stride=2),
        torch.nn.Conv2d(128, 256, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.Conv2d(256, 256, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.MaxPool2d(kernel_size=2, stride=2),
        torch.nn.Conv2d(256, 512, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.Conv2d(512, 512, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.MaxPool2d(kernel_size=2, stride=2),
        torch.nn.Conv2d(512, 512, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.Conv2d(512, 512, kernel_size=3, padding=1),
        torch.nn.ReLU(),
        torch.nn.MaxPool2d(kernel_size=2, stride=2),
        torch.nn.Flatten()
    )
    # fully connected linear layers
    self.linear_layers = torch.nn.Sequential(
        torch.nn.Linear(512*7*7, 4096),
        torch.nn.ReLU(),
        torch.nn.Dropout(0.5),
        torch.nn.Linear(4096, 4096),
        torch.nn.ReLU(),
        torch.nn.Dropout(0.5),
        torch.nn.Linear(4096, 1)
    )

  def forward(self, x):
    return self.linear_layers(self.conv_layers(x))
```

Training

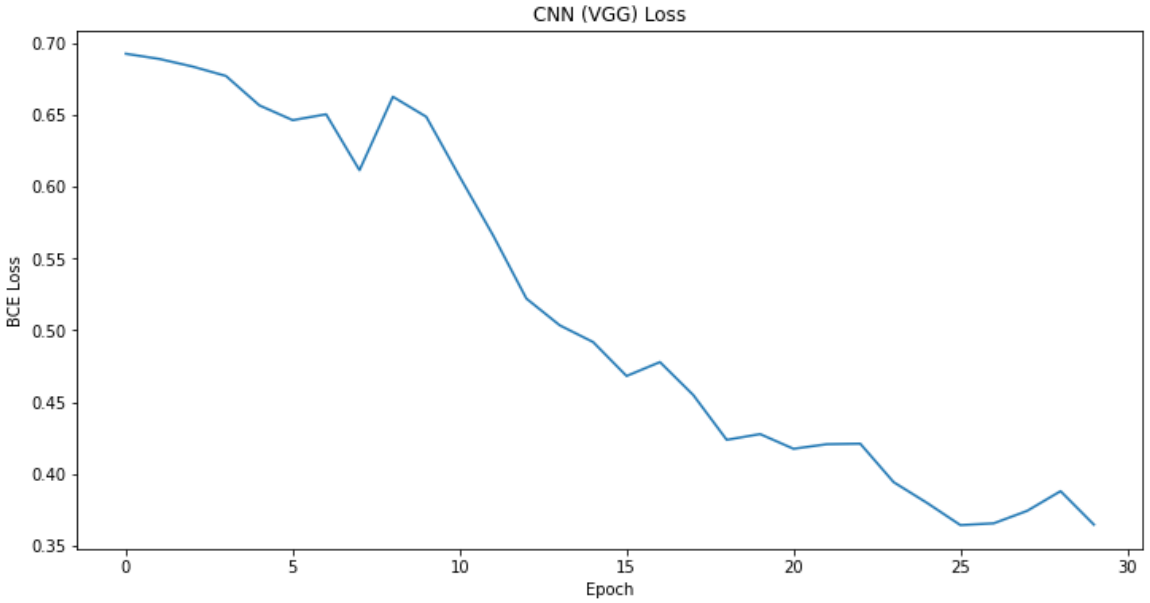
In [ ]:

```
dataframe = df_train
batch_size = 32
epoch = 30
xlogger = np.array([])
ylogger = np.array([])
counter = 0


cnn_model = CNNModel(dataframe)
loader = torch.utils.data.DataLoader(cnn_model.dataset, batch_size=batch_
criterion = torch.nn.BCEWithLogitsLoss()
optim = torch.optim.SGD(cnn_model.parameters(), lr=0.001, momentum=0.9,
                        weight_decay=0.0005)
if torch.cuda.is_available():
  cnn_model.to('cuda')
for e in range(epoch):
  acculoss = 0.0
  accstep = 0
  for i, batch in enumerate(loader):
      optim.zero_grad()
      bx, by = batch['img'], batch['labels']
      if torch.cuda.is_available():
        bx, by = bx.to('cuda'), by.to('cuda')
      out = cnn_model.forward(bx)
      loss = criterion(out, by.unsqueeze(1).float())
      loss.backward()
      optim.step()
      accstep += 1
      acculoss += loss.item()
  print(f"Epoch: {e+1}; Loss: {acculoss/accstep}")
  xlogger = np.append(xlogger, counter)
  ylogger = np.append(ylogger, acculoss/accstep)
  counter += 1
```

```
Epoch: 1; Loss: 0.6923396468162537
Epoch: 2; Loss: 0.6887384454409281
Epoch: 3; Loss: 0.6834265549977621
Epoch: 4; Loss: 0.6768775741259258
Epoch: 5; Loss: 0.6564265171686808
Epoch: 6; Loss: 0.6461218436559041
Epoch: 7; Loss: 0.650216015179952
Epoch: 8; Loss: 0.6112921953201294
Epoch: 9; Loss: 0.6624187390009563
Epoch: 10; Loss: 0.6484756151835124
Epoch: 11; Loss: 0.606783386071523
Epoch: 12; Loss: 0.5660408794879913
Epoch: 13; Loss: 0.5219585160414378
Epoch: 14; Loss: 0.5033439715703328
Epoch: 15; Loss: 0.4916908125082652
Epoch: 16; Loss: 0.4680925210316976
Epoch: 17; Loss: 0.47778066794077556
Epoch: 18; Loss: 0.4548188805580139
Epoch: 19; Loss: 0.42366792559623717
Epoch: 20; Loss: 0.4276837209860484
Epoch: 21; Loss: 0.41745562354723614
Epoch: 22; Loss: 0.4206336756547292
Epoch: 23; Loss: 0.4210062106450399
Epoch: 24; Loss: 0.3942320783933004
Epoch: 25; Loss: 0.3797900378704071
Epoch: 26; Loss: 0.3643382539351781
Epoch: 27; Loss: 0.3655871589978536
Epoch: 28; Loss: 0.3742581238349279
Epoch: 29; Loss: 0.38796561360359194
Epoch: 30; Loss: 0.3646557370821635
```

Stats

In [ ]:
```python
# SHOW GRAPH
plt.figure(figsize=(12, 6))
plt.title(f"CNN (VGG) Loss")
plt.figure(1).patch.set_facecolor("white")
plt.xlabel("Epoch")
plt.ylabel("BCE Loss")
plt.plot(xlogger, ylogger)
plt.show()
```



In [ ]:
```
test_set =  EyeDataset(dataframe=df_test,
                       transform=torchvision.transforms.Compose([
                       CustomResize(256),
                       CustomCenterCrop((224, 224)),
                       RegularToNormalizedMergedTensor()
                      ]))
loader = torch.utils.data.DataLoader(test_set, batch_size=len(test_set),
with torch.no_grad():
  classes = ["NORMAL", "CATARACS"]
  for batch in loader:
      bx, by = batch['img'], batch['labels']
      if torch.cuda.is_available():
        bx = bx.to('cuda')
      out = cnn_model.forward(bx)
      outenc = torch.round(torch.flatten(torch.sigmoid(out)))
      cf_matrix = sklearn.metrics.confusion_matrix(by, outenc.cpu())
      df_cm = pd.DataFrame(cf_matrix, index = [i+" (A)" for i in classes]
      print(df_cm)
```

```
              NORMAL (P)  CATARACS (P)
NORMAL (A)            40            17
CATARACS (A)           5            58
```

In [ ]:
```
print_eval(cf_matrix, classes)
```

```
Total Accuracy: 0.8167
             NORMAL  CATARACS
Recall     0.701754  0.920635
Precision  0.888889  0.773333
F1 Score   0.784314  0.840580
```

RNN Approach (LSTM)

RNN Model

In [ ]:

```
class RNNModel(torch.nn.Module):
  def __init__(self, dataframe, input_dim, hidden_dim, layer_dim, output_
    super(RNNModel, self).__init__()
    torch.manual_seed(GLOBAL_SEED)
    # DATASET LOADER
    self.dataset = EyeDataset(dataframe=dataframe,
                      transform=torchvision.transforms.Compose([
                      CustomResize(input_dim),
                      CustomCenterCrop((input_dim, input_dim)),
                      RegularToNormalizedMergedTensor()
                    ]))
    self.hidden_dim = hidden_dim
    self.layer_dim = layer_dim
    self.lstmR = torch.nn.LSTM(input_dim, hidden_dim, layer_dim, batch_fi
    self.lstmG = torch.nn.LSTM(input_dim, hidden_dim, layer_dim, batch_fi
    self.lstmB = torch.nn.LSTM(input_dim, hidden_dim, layer_dim, batch_fi
    self.fc = torch.nn.Linear(3*hidden_dim, output_dim)
    self.d1 = torch.nn.Dropout(p=0.5)

  def forward(self, x):
    h0 = torch.zeros(self.layer_dim, x.size(0), self.hidden_dim).requires
    c0 = torch.zeros(self.layer_dim, x.size(0), self.hidden_dim).requires
    h1 = torch.zeros(self.layer_dim, x.size(0), self.hidden_dim).requires
    c1 = torch.zeros(self.layer_dim, x.size(0), self.hidden_dim).requires
    h2 = torch.zeros(self.layer_dim, x.size(0), self.hidden_dim).requires
    c2 = torch.zeros(self.layer_dim, x.size(0), self.hidden_dim).requires
    if torch.cuda.is_available():
      h0 = h0.to('cuda')
      c0 = c0.to('cuda')
      h1 = h1.to('cuda')
      c1 = c1.to('cuda')
      h2 = h2.to('cuda')
      c2 = c2.to('cuda')

    outR, (h0n, c0n) = self.lstmR(x[:,0,:,:], (h0.detach(), c0.detach()))
    outG, (h1n, c1n) = self.lstmG(x[:,1,:,:], (h1.detach(), c1.detach()))
    outB, (h2n, c2n) = self.lstmB(x[:,2,:,:], (h2.detach(), c2.detach()))
    out = self.fc(torch.cat((outR[:, -1, :], outG[:, -1, :], outB[:, -1,
    return out
```

Training

In [ ]:

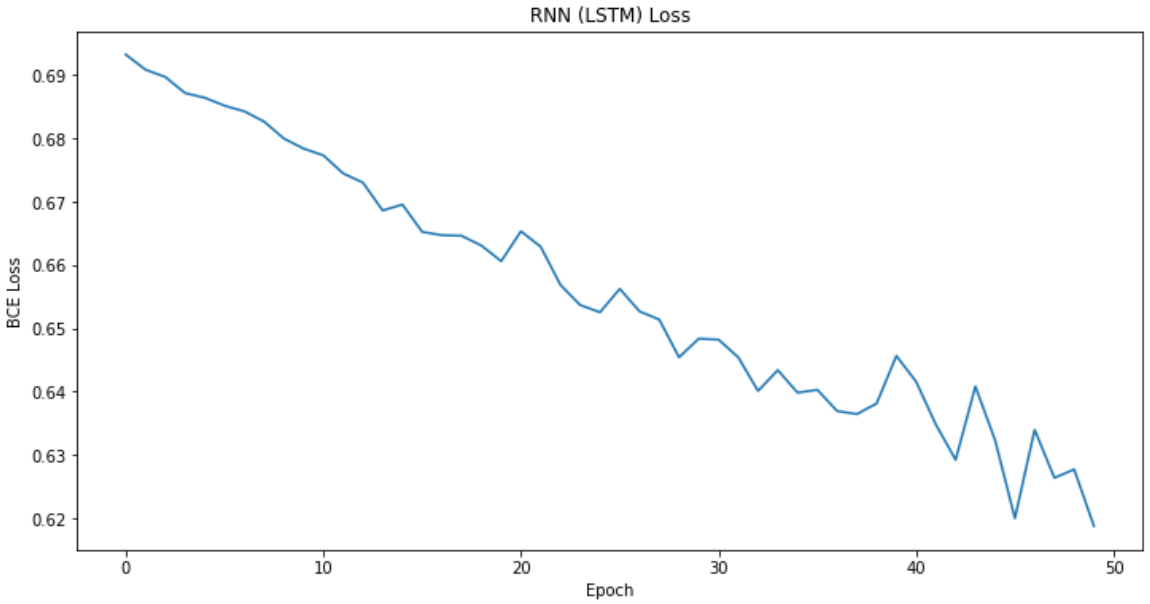
```
dataframe = df_train
batch_size = 32
epoch = 50
xlogger = np.array([])
ylogger = np.array([])
counter = 0


rnn_model = RNNModel(dataframe, 224, batch_size, 2, 1)
loader = torch.utils.data.DataLoader(rnn_model.dataset, batch_size=batch_
criterion = torch.nn.BCEWithLogitsLoss()
optim = torch.optim.SGD(rnn_model.parameters(), lr=0.1)
if torch.cuda.is_available():
  rnn_model.to('cuda')
for e in range(epoch):
  acculoss = 0.0
  accstep = 0
  for i, batch in enumerate(loader):
      optim.zero_grad()
      bx, by = batch['img'], batch['labels']
      if torch.cuda.is_available():
        bx, by = bx.to('cuda'), by.to('cuda')
      out = rnn_model.forward(bx)
      loss = criterion(out, by.unsqueeze(1).float())
      loss.backward()
      optim.step()
      accstep += 1
      acculoss += loss.item()
  print(f"Epoch: {e+1}; Loss: {acculoss/accstep}")
  xlogger = np.append(xlogger, counter)
  ylogger = np.append(ylogger, acculoss/accstep)
  counter += 1
```

```
Epoch: 1; Loss: 0.6932337045669555
Epoch: 2; Loss: 0.6908448576927185
Epoch: 3; Loss: 0.6896891395250956
Epoch: 4; Loss: 0.6871532638867696
Epoch: 5; Loss: 0.6864095012346904
Epoch: 6; Loss: 0.685160752137502
Epoch: 7; Loss: 0.6842683315277099
Epoch: 8; Loss: 0.6826538483301798
Epoch: 9; Loss: 0.679977027575175
Epoch: 10; Loss: 0.6783825914065044
Epoch: 11; Loss: 0.677316443125407
Epoch: 12; Loss: 0.6744725545247395
Epoch: 13; Loss: 0.673015566666921
Epoch: 14; Loss: 0.668613851070404
Epoch: 15; Loss: 0.6695548733075459
Epoch: 16; Loss: 0.6652405222256979
Epoch: 17; Loss: 0.6647122939427693
Epoch: 18; Loss: 0.6646215558052063
Epoch: 19; Loss: 0.6630696495374043
Epoch: 20; Loss: 0.660612940788269
Epoch: 21; Loss: 0.6653397719065348
Epoch: 22; Loss: 0.6628859996795654
Epoch: 23; Loss: 0.6568632404009501
Epoch: 24; Loss: 0.6536799470583597
Epoch: 25; Loss: 0.6525469064712525
Epoch: 26; Loss: 0.6562415719032287
Epoch: 27; Loss: 0.6526901523272196
Epoch: 28; Loss: 0.6513897538185119
Epoch: 29; Loss: 0.6454277316729228
Epoch: 30; Loss: 0.6483809987703959
Epoch: 31; Loss: 0.6482260584831238
Epoch: 32; Loss: 0.6454303582509359
Epoch: 33; Loss: 0.6401219844818116
Epoch: 34; Loss: 0.6434089064598083
Epoch: 35; Loss: 0.6398479302724203
Epoch: 36; Loss: 0.6403021017710367
Epoch: 37; Loss: 0.6369543592135112
Epoch: 38; Loss: 0.6364569703737895
Epoch: 39; Loss: 0.6381398240725199
Epoch: 40; Loss: 0.6456618507703146
Epoch: 41; Loss: 0.6415817062060039
Epoch: 42; Loss: 0.6348019003868103
Epoch: 43; Loss: 0.6292526483535766
Epoch: 44; Loss: 0.6408363143603008
Epoch: 45; Loss: 0.6323234518369039
Epoch: 46; Loss: 0.6200155019760132
Epoch: 47; Loss: 0.633997400601705
Epoch: 48; Loss: 0.6264004151026408
Epoch: 49; Loss: 0.6277339061101278
Epoch: 50; Loss: 0.618783462047577
```

Stats

In [ ]:

```
# SHOW GRAPH
plt.figure(figsize=(12, 6))
plt.title(f"RNN (LSTM) Loss")
plt.figure(1).patch.set_facecolor("white")
plt.xlabel("Epoch")
plt.ylabel("BCE Loss")
plt.plot(xlogger, ylogger)
plt.show()
```



In [ ]:
```
test_set =  EyeDataset(dataframe=df_test,
                       transform=torchvision.transforms.Compose([
                       CustomResize(224),
                       CustomCenterCrop((224, 224)),
                       RegularToNormalizedMergedTensor()
                      ]))
loader = torch.utils.data.DataLoader(test_set, batch_size=len(test_set),
with torch.no_grad():
  classes = ["NORMAL", "CATARACS"]
  for batch in loader:
      bx, by = batch['img'], batch['labels']
      if torch.cuda.is_available():
        bx = bx.to('cuda')
      out = rnn_model.forward(bx)
      outenc = torch.round(torch.flatten(torch.sigmoid(out)))
      cf_matrix = sklearn.metrics.confusion_matrix(by, outenc.cpu())
      df_cm = pd.DataFrame(cf_matrix, index = [i+" (A)" for i in classes]
      print(df_cm)
```

```
               NORMAL (P)  CATARACS (P)
NORMAL (A)             23            34
CATARACS (A)           27            36
```

In [ ]:
```
print_eval(cf_matrix, classes)
```

```
Total Accuracy: 0.4917
             NORMAL  CATARACS
Recall     0.403509  0.571429
Precision  0.460000  0.514286
F1 Score   0.429907  0.541353
```