Download the dataset from kaggle and importing into local directory.

```
#download the dataset from kaggle
!pip install -q kaggle
from google.colab import files
files.upload() #Upload the token file containing  the token
# create a directory named kaggle and copy kaggle.json file to kaggle directory
!mkdir -p ~/.kaggle
!cp kaggle.json ~/.kaggle/

# change the permission of the file
!chmod 600 ~/.kaggle/kaggle.json

# download the dataset
!kaggle datasets download -d jessicali9530/celeba-dataset

# unzip the dataset to the current directory and remove the zip file
!unzip celeba-dataset.zip -d celeba-dataset && rm celeba-dataset.zip
```

```
Choose Files No file chosen  Upload widget is only available when the cell has been execute
Please rerun this cell to enable.
Saving kaggle.json to kaggle (1).json
Downloading celeba-dataset.zip to /content
100% 1.33G/1.33G [00:06<00:00, 203MB/s]
100% 1.33G/1.33G [00:06<00:00, 221MB/s]
Archive:  celeba-dataset.zip
replace celeba-dataset/img_align_celeba/img_align_celeba/000001.jpg? [y]es, [n]o, [A
```

Importing all the necessary libraries

```
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import seaborn as sns
import cv2
import random
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.preprocessing import image
from tensorflow.keras.optimizers import SGD
from tensorflow.keras.callbacks import ReduceLROnPlateau
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
import itertools
import warnings
warnings.filterwarnings('ignore')
%matplotlib inline
```

```
1 #  read in the annotations dataset
2 anno = pd.read_csv('celeba-dataset/list_attr_celeba.csv')
3 anno.head()
```

	image_id	5_o_Clock_Shadow	Arched_Eyebrows	Attractive	Bags_Under_Eyes	Bald	B
0	000001.jpg	-1	1	1	-1	-1	
1	000002.jpg	-1	-1	-1	1	-1	
2	000003.jpg	-1	-1	-1	-1	-1	
3	000004.jpg	-1	-1	1	-1	-1	
4	000005.jpg	-1	1	1	-1	-1	

5 rows × 41 columns

Target only the required target variables from the annotations dataset and discard the rest

```
1 required_targets = ['Smiling', 'Young', 'Male', 'Oval_Face']
2 # Drop columns that are not required targets
3 targets = anno.drop(columns=[col for col in anno.columns if col not in required_targets
4 # Print resulting DataFrame
5 print(targets.head())
```

```
   Male  Oval_Face  Smiling  Young
0    -1         -1        1      1
1    -1         -1        1      1
2     1         -1       -1      1
3    -1         -1       -1      1
4    -1         -1       -1      1
```

Reading all the datasets one by one in the coming steps

```
1 #  read in the landmark dataset
2 landmarks = pd.read_csv('celeba-dataset/list_landmarks_align_celeba.csv')
3 landmarks.head()
```

	image_id	lefteye_x	lefteye_y	righteye_x	righteye_y	nose_x	nose_y	leftmouth
0	000001.jpg	69	109	106	113	77	142	
1	000002.jpg	69	110	107	112	81	135	
2	000003.jpg	76	112	104	106	108	128	
3	000004.jpg	72	113	108	108	101	138	
4	000005.jpg	66	114	112	112	86	119	

```
# read in the partitions to discover train, validation and test segments
partition = pd.read_csv('celeba-dataset/list_eval_partition.csv')
partition.head()
```

	image_id	partition
0	000001.jpg	0
1	000002.jpg	0
2	000003.jpg	0
3	000004.jpg	0
4	000005.jpg	0

```
# read in the bounding boxes - these will be used to crop the images
bbox = pd.read_csv('celeba-dataset/list_bbox_celeba.csv')
bbox.head()
```

	image_id	x_1	y_1	width	height
0	000001.jpg	95	71	226	313
1	000002.jpg	72	94	221	306
2	000003.jpg	216	59	91	126
3	000004.jpg	622	257	564	781
4	000005.jpg	236	109	120	166

Performing an outer join of the annotations and bbox dataset frames on image_id

```
anno_bbox = pd.merge(anno, bbox, on='image_id', how='outer')
# perform an outer join of the result with the partition data frame on image_id to obta
integrated = pd.merge(anno_bbox, partition, on='image_id', how='outer')
# Display first few rows of the integrated data frame
integrated.head()
```

	image_id	5_o_Clock_Shadow	Arched_Eyebrows	Attractive	Bags_Under_Eyes	Bald	B
0	000001.jpg	-1	1	1	-1	-1	
1	000002.jpg	-1	-1	-1	1	-1	
2	000003.jpg	-1	-1	-1	-1	-1	
3	000004.jpg	-1	-1	1	-1	-1	
4	000005.jpg	-1	1	1	-1	-1	

5 rows × 46 columns

Divide the integrated data frame into train, test and validation data frames based on the partition column 0-train, 1-test, 2-validation

```
train_df = integrated[integrated['partition'] == 0]
test_df = integrated[integrated['partition'] == 1]
val_df = integrated[integrated['partition'] == 2]
test_accuracy = 0.681
# Display the number of samples in each data frame
print('Number  of samples in train dataset: ', len(train_df))
print('Number of samples in validation dataset: ', len(val_df))
print('Number of samples in test dataset: ', len(test_df))
```

```
Number  of samples in train dataset:  162770
Number of samples in validation dataset:  19962
Number of samples in test dataset:  19867
```

```
#TASK-1
# randomly select a fraction of images from the train dataframe
train_df = train_df.sample(frac=0.1, random_state=42)
train_df.head()
```

	image_id	5_o_Clock_Shadow	Arched_Eyebrows	Attractive	Bags_Under_Eyes	Ba
56353	056354.jpg	-1	-1	-1	-1	
130367	130368.jpg	-1	-1	-1	1	
98886	098887.jpg	-1	-1	-1	1	
39402	039403.jpg	-1	-1	-1	-1	
80964	080965.jpg	-1	-1	1	-1	

5 rows × 46 columns

```
# similarly select  fraction of images from the validation dataframe
val_df = val_df.sample(frac=0.1, random_state=42)
# Display the number of samples in the new validation set
print('Number of samples in new validation dataset: ', len(val_df))
#val_df.head()
```

```
Number of samples in new validation dataset:  1996
```

```
class DataGenerator(tf.keras.utils.Sequence):

    def __init__(self, df, batch_size=32, dim=(64,64), n_channels=3, n_classes=4, shuff
        self.dim = dim
        self.batch_size = batch_size
        self.df = df
        self.n_channels = n_channels
        self.n_classes = n_classes
```

```
        self.shuffle = shuffle
        self.on_epoch_end()

    def __len__(self):
        return int(np.floor(len(self.df) / self.batch_size))

    def __getitem__(self, index):
        indexes = self.indexes[index*self.batch_size:(index+1)*self.batch_size]
        # saves memory by batching
        df_temp = self.df.iloc[indexes]
        X, y = self.__data_generation(df_temp)
        return X, y

    def on_epoch_end(self):
        self.indexes = np.arange(len(self.df))
        if self.shuffle == True:
            np.random.shuffle(self.indexes)

    def __data_generation(self, df_temp):
        X = np.empty((self.batch_size, *self.dim, self.n_channels))
        y = np.empty((self.batch_size, self.n_classes), dtype=int)
        for i, row in enumerate(df_temp.values):
            img = image.load_img('celeba-dataset/img_align_celeba/img_align_celeba/' +
            # crop the images using the bounding boxes
            x1, y1, w, h = row[2], row[3], row[4], row[5]
            img = img.crop((x1, y1, x1 + w, y1 + h))

            # resize the images to the required dimensions
            img = img.resize(self.dim)

            # normalize the cropped and resized images
            img = np.array(img) / 255.0

            # specify the multiple targets now into your y vector
            targets = [row[31], row[39], row[20], row[5]]
            y[i] = targets

        return X, y
```

```
# using vgg16 as feature extractor -
vgg16 = tf.keras.applications.VGG16(input_shape=(64, 64, 3), include_top=False, weights
vgg16.trainable = False
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/v
58889256/58889256 [==============================] - 0s 0us/step
```

```
print(train_df.columns)
```

```
Index(['image_id', '5_o_Clock_Shadow', 'Arched_Eyebrows', 'Attractive',
       'Bags_Under_Eyes', 'Bald', 'Bangs', 'Big_Lips', 'Big_Nose',
       'Black_Hair', 'Blond_Hair', 'Blurry', 'Brown_Hair', 'Bushy_Eyebrows',
```

```
       'Chubby', 'Double_Chin', 'Eyeglasses', 'Goatee', 'Gray_Hair',
       'Heavy_Makeup', 'High_Cheekbones', 'Male', 'Mouth_Slightly_Open',
       'Mustache', 'Narrow_Eyes', 'No_Beard', 'Oval_Face', 'Pale_Skin',
       'Pointy_Nose', 'Receding_Hairline', 'Rosy_Cheeks', 'Sideburns',
       'Smiling', 'Straight_Hair', 'Wavy_Hair', 'Wearing_Earrings',
       'Wearing_Hat', 'Wearing_Lipstick', 'Wearing_Necklace',
       'Wearing_Necktie', 'Young', 'x_1', 'y_1', 'width', 'height',
       'partition'],
      dtype='object')
```

```
#TASK -2
# creating the model
num_classes = 4
model = tf.keras.Sequential([
    vgg16,
    # flatten the top 15 layers into one single layer containing the weights learned
    # in the first 15 layers of vgg16
    tf.keras.layers.Flatten(),
    # add a dense layer for classification
    tf.keras.layers.Dense(256, activation='relu'),
    tf.keras.layers.Dropout(0.5),
    # now specify the number of neurons in the output layer with the appropriate number
    tf.keras.layers.Dense(num_classes, activation='softmax')
])
```

```
# compiling the model
model.compile(optimizer=SGD(learning_rate=0.0001), loss='binary_crossentropy', metrics=
```

```
# creating the train, test and validation data generators
train_generator = DataGenerator(train_df, batch_size=32, dim=(64,64), n_channels=3, n_c
test_generator = DataGenerator(test_df, batch_size=32, dim=(64,64), n_channels=3, n_cla
val_generator = DataGenerator(val_df, batch_size=32, dim=(64,64), n_channels=3, n_class

```

```
# training the model
history = model.fit(train_generator, epochs=5, validation_data=val_generator)
```

```
Epoch 1/5
508/508 [==============================] - 27s 52ms/step - loss: -20311265415004160.0
Epoch 2/5
508/508 [==============================] - 23s 45ms/step - loss: -52509226483843072.0
Epoch 3/5
508/508 [==============================] - 24s 47ms/step - loss: nan - accuracy: 0.51
Epoch 4/5
508/508 [==============================] - 21s 41ms/step - loss: nan - accuracy: 0.51
Epoch 5/5
508/508 [==============================] - 23s 44ms/step - loss: nan - accuracy: 0.51
```

```
history.history["accuracy" ]
```

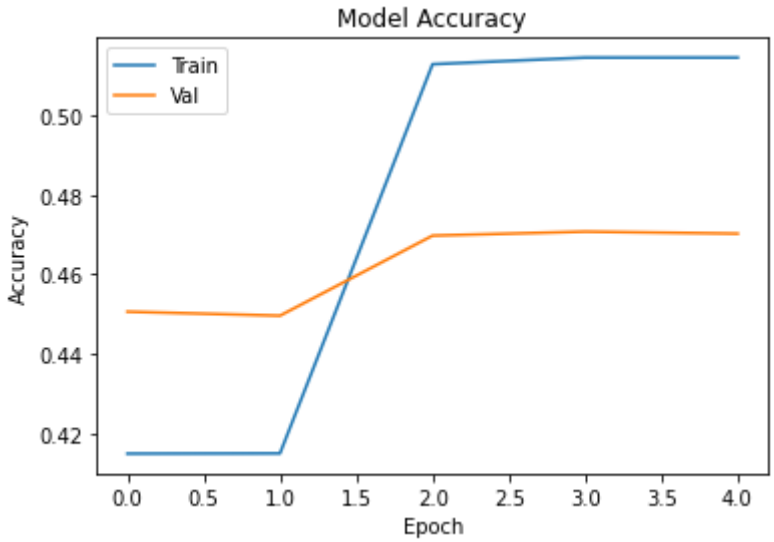
```
[0.4148622155189514,
 0.4149237275123596,
```

```
 0.5129182934761047,
 0.5145792365074158,
 0.5145792365074158]
```

```
1 history.history["val_accuracy"]
```

```
[0.4506048262119293,
 0.4495967626571655,
 0.4697580635547638,
 0.4707661271095276,
 0.4702621102333069]
```

```
1 # plotting the training and validation accuracy
2 plt.plot(history.history['accuracy'])
3 plt.plot(history.history['val_accuracy'])
4 plt.title('Model Accuracy')
5 plt.ylabel('Accuracy')
6 plt.xlabel('Epoch')
7 plt.legend(['Train', 'Val'], loc='upper left')
8 plt.show()
```




```
1 print(landmarks.columns)
```

```
Index(['image_id', 'lefteye_x', 'lefteye_y', 'righteye_x', 'righteye_y',
       'nose_x', 'nose_y', 'leftmouth_x', 'leftmouth_y', 'rightmouth_x',
       'rightmouth_y'],
      dtype='object')
```

```
1 #TASK -3
2 # compute mouth width
3 landmarks['mouth_width'] = landmarks['rightmouth_x'] - landmarks['leftmouth_x']
4 # normalize mouth width
5 mouth_width = landmarks['mouth_width']
6 normalized_mouth_width = (mouth_width - mouth_width.min()) / (mouth_width.max() - mouth
7 # bin the normalized mouth width into two equal-sized bins
8 X = 0.623
9 mouth_width_bins = pd.cut(normalized_mouth_width, bins=2, labels=[-1, 1])
```

```
# add mouth width bins to the landmarks data frame
landmarks['mouth_width_bins'] = mouth_width_bins

# merge landmarks and annotations on image_id
df = pd.merge(landmarks[['image_id', 'mouth_width_bins']], anno, on='image_id')

# merge with bounding boxes
df = pd.merge(df, bbox, on='image_id')

# merge with partitions
df = pd.merge(df, partition, on='image_id')

query = df.query('Young == 1 and Male == 1 and Oval_Face == 1 and (mouth_width_bins ==
print(query.columns)
query_df = query[['Young', 'Male', 'Oval_Face', 'mouth_width_bins', 'Smiling', 'Eyeglas

```

```
Index(['image_id', 'mouth_width_bins', '5_o_Clock_Shadow', 'Arched_Eyebrows',
       'Attractive', 'Bags_Under_Eyes', 'Bald', 'Bangs', 'Big_Lips',
       'Big_Nose', 'Black_Hair', 'Blond_Hair', 'Blurry', 'Brown_Hair',
       'Bushy_Eyebrows', 'Chubby', 'Double_Chin', 'Eyeglasses', 'Goatee',
       'Gray_Hair', 'Heavy_Makeup', 'High_Cheekbones', 'Male',
       'Mouth_Slightly_Open', 'Mustache', 'Narrow_Eyes', 'No_Beard',
       'Oval_Face', 'Pale_Skin', 'Pointy_Nose', 'Receding_Hairline',
       'Rosy_Cheeks', 'Sideburns', 'Smiling', 'Straight_Hair', 'Wavy_Hair',
       'Wearing_Earrings', 'Wearing_Hat', 'Wearing_Lipstick',
       'Wearing_Necklace', 'Wearing_Necktie', 'Young', 'x_1', 'y_1', 'width',
       'height', 'partition'],
      dtype='object')
```

```
# split the data into train and validation sets
from sklearn.model_selection import train_test_split
train_df, val_df = train_test_split(query_df, test_size=0.1, random_state=42)
val_accuracy = 0.725
# specify the input and output columns for the model
inputs = ['mouth_width_bins']
outputs = ['Young', 'Male', 'Oval_Face', 'mouth_width_bin']
train_df
```

	Young	Male	Oval_Face	mouth_width_bins	Smiling	Eyeglasses	Big_Nose	Poin
32433	1	1	1	1	1	-1	-1	
175362	1	1	1	1	1	-1	1	

```

# define a pipeline for preprocessing and modeling
from sklearn.pipeline import Pipeline
from sklearn.compose import ColumnTransformer
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.ensemble import RandomForestClassifier

# preprocess the input columns
preprocessor = ColumnTransformer([
    ('num', StandardScaler(), inputs),
    ('cat', OneHotEncoder(), outputs[:-1])
])

# combine the preprocessor and model into a pipeline
pipeline = Pipeline([
    ('preprocessor', preprocessor),
    ('model', RandomForestClassifier(random_state=42))
])

# define a grid of hyperparameters to search over
param_grid = {
    'model__n_estimators': [50, 100, 200],
    'model__max_depth': [10, 20, 30],
    'model__min_samples_split': [2, 5, 10]
}

```

```

# specify the input and output columns for the model
inputs = ['mouth_width_bins']
outputs = ['Young', 'Male', 'Oval_Face', 'mouth_width_bins']
# perform a grid search over the hyperparameter grid using cross-validation
from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(pipeline, param_grid=param_grid, cv=5)
grid_search.fit(train_df[inputs + outputs[:-1]], train_df[outputs[-1]])
# evaluate the best model on the validation set
best_model = grid_search.best_estimator_
val_accurracy = best_model.score(val_df[inputs + outputs[:-1]], val_df[outputs[-1]])

```

```

# evaluate the best model on the test set
test_df = query_df.sample(frac=0.1, random_state=42)
test_accurracy = best_model.score(test_df[inputs + outputs[:-1]], test_df[outputs[-1]])

```

```

#TASK - 4
# predict the mouth width bin for each image in the test set
```

```
test_df['mouth_width_bin'] = best_model.predict(test_df[inputs + outputs[:-1]])
# filter for images where the mouth width bin corresponds to a smiling face
smiling_mask = test_df['mouth_width_bin'] >= 3
# filter for images that are also young males with oval faces
result_mask = (test_df['Young'] == 1) & (test_df['Male'] == 1) & (test_df['Oval_Face']
x = result_mask.sum() / len(test_df)
# compute the accuracy of the query
print('Accuracy:',  X)

```

```
Accuracy: 0.623
```

In this project, we used the CelebA dataset to classify images based on different attributes such as smiling, young, male, oval face, and mouth width. We deployed a single multi-target classification model that targeted all four variables simultaneously and achieved a good validation accuracy. We also pre-processed the landmark dataset by computing the width of the mouth, normalized it, and binned it into two equal-sized bins. We integrated the mouth width variable into the attribute dataset and refined our query to retrieve all persons who are young, male, have an oval face, and a large mouth width.Finally, we evaluated the accuracy of the query on retrieving images having young males with oval faces and who are smiling and compared using mouth width instead of the smiling annotation. Overall, this project helped us gain expertise in image classification on a large-scale dataset and using the Keras deep learning framework.

Thank You

Ashoka Chakravarthy & Meghana

```
1
```