# Assignment-2: Face Classification/Verification

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# 1 Questions

#### 1.1 Problem-1

1. What are "Eigen Faces"?

**Eigen Faces** are the set of eigen-vectors of the covariance-matrix of face images that are used in the problem of human face recognition. Basically, they are the faces that are reconstruced after applying dimentionality reduction techniques like **PCA** on a given dataset

2. How many eigen vectors/faces are required to reconstruct a person in the three datasets?

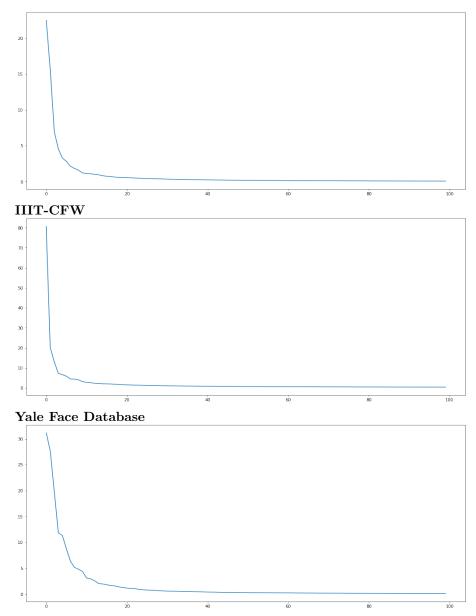
By seeing the below given eigen-value spectrum, we can say that k=60,100,15 are satisfactory values for dimentionality reduction for IMFDB, IIIT-CFW and Yale-Dataset respectively.

We arrive at these values either by looking at the eigen-value spectrum such that

$$\frac{\sum_{i \in [k]} \lambda_i}{\sum_{i \in [j]} \lambda_i} \ge \epsilon$$

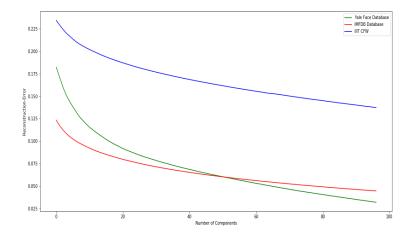
where  $\epsilon = 0.9$  and [k] is set of selected eigen-vectors and [j] is the set of all eigen-vectors.

**IMFDB** 



Also the scatter plots of each of the database is attached in the jupyter notebook.

3. Which dataset is difficult to represent compactly with fewer eigen-vectors? Why is that? Explain with your empirical observations and intuitive answers?



From the above graph, we notice that faces in the IIIT-CFW Database are difficult to reconstruct with fewer eigen-vectors. This, may be due the great details present in the IIIT-CFW cartoon images that few eigen-vectors are not able to reconstruct the cartoon completely or satisfactorily.

4. Which person/identity is difficult to represent compactly with fewer eigen-vectors?

The class that is most difficult to represent using fewer eigen-vectors depends on the number of components k chosen. For k=10, the classes are 3, 4, 10 for IMFDB,IIIT-CFW and Yale-Face Dataset respectively. For k=55, the classes are 3, 5, 4. We get this result empirically by calculating the average reconstruction error for each class separately.

## 1.2 Problem-2

1. Use an MLP classifier and find the classification accuracy? Which method works well?

In order to do a comparitive study, I tried all combinations of feature extraction and classifiers. The results are as follows:

### IMFDB

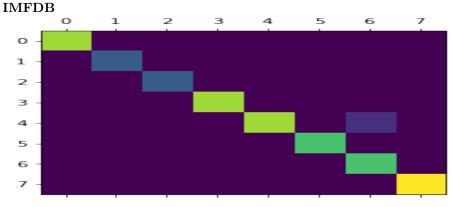
0         PCA with MIP         55         0.100         0.900         0.900           1         PCA with SVM         55         0.150         0.850         0.850           2         PCA with LOGISTIC         55         0.150         0.850         0.850           3         KPCA with MIP         55         0.150         0.850         0.850           5         KPCA with SVM         55         0.500         0.300         0.300           6         LDA with MIP         7         0.225         0.775         0.755           7         LDA with SVM         7         0.175         0.825         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           9         KLDA with LOGISTIC         7         0.175         0.825         0.825           10         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with MLP         4006         0.100         0.900         0.900           13         VGG with LOGISTIC         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900 <th></th> <th>Feature</th> <th>Reduced Dimension Space</th> <th>Classification Error</th> <th>Accuracy</th> <th>F1-Score</th>		Feature	Reduced Dimension Space	Classification Error	Accuracy	F1-Score
1 PCA with SVM         55         0.150         0.850         0.850           2 PCA with LOGISTIC         55         0.150         0.850         0.850           3 KPCA with MLP         55         0.625         0.475         0.475           4 KPCA with SVM         55         0.700         0.300         0.300           5 KPCA with LOGISTIC         55         0.500         0.500         0.500           6 LDA with MILP         7         0.225         0.775         0.775           7 LDA with SVM         7         0.175         0.825         0.825           8 LDA with LOGISTIC         7         0.175         0.825         0.825           9 KLDA with LOGISTIC         7         0.175         0.825         0.825           10 KLDA with LOGISTIC         7         0.175         0.825         0.825           11 KLDA with LOGISTIC         7         0.175         0.825         0.825           12 VGG with LOGISTIC         4096         0.100         0.900         0.900           13 VGG with SVM         4096         0.100         0.900         0.900           14 VGG with MLP         2048         0.025         0.975         0.975           15 RESNET with S	0					
2         PCA with LOGISTIC         55         0.150         0.850         0.850           3         KPCA with MLP         55         0.525         0.475         0.475           4         KPCA with SVM         55         0.500         0.300         0.300           5         KPCA with LOGISTIC         55         0.500         0.500         0.500           6         LDA with MLP         7         0.225         0.775         0.775           7         LDA with LOGISTIC         7         0.175         0.825         0.825           8         LDA with SVM         7         0.175         0.825         0.825           9         KLDA with LOGISTIC         7         0.175         0.825         0.825           11         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with LOGISTIC         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025	1	PCA with SVM	55	0.150	0.850	
3         KPCA with MLP         55         0.525         0.475         0.300           4         KPCA with SVM         55         0.700         0.300         0.300           5         KPCA with LOGISTIC         55         0.500         0.500         0.500           6         LDA with MLP         7         0.225         0.775         0.775           7         LDA with SVM         7         0.175         0.825         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           9         KLDA with MLP         7         0.175         0.825         0.825           10         KLDA with LOGISTIC         7         0.175         0.825         0.825           11         KLDA with LOGISTIC         7         0.175         0.825         0.825           11         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.955         0.951           16         RESNET with LOGISTIC         55         0.485294						
4         KPCA with LOGISTIC         55         0.700         0.300         0.500           5         KPCA with LOGISTIC         55         0.500         0.500         5.0500           6         LDA with SVM         7         0.225         0.775         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           10         KLDA with LOGISTIC         7         0.175         0.825         0.825           11         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with LOGISTIC         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.025         0.975         0.975           17         RESNET with LOGISTIC         2048         0.025         0.950         0.950           18         PCA with LOGISTIC         55						
5         KPCA with LOGISTIC         55         0.500         0.500         0.500           6         LDA with MLP         7         0.225         0.775         0.775           7         LDA with SVM         7         0.175         0.825         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           9         KLDA with MLP         7         0.175         0.825         0.825           10         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with LOGISTIC         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.025         0.975         0.975           16         RESNET with MLP         55         0.485294         4.5404         0.50           17         PCA with MLP         55         0.485294 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
6         LDA with SVM         7         0.25         0.775         0.75           7         LDA with SVM         7         0.175         0.825         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           9         KLDA with MLP         7         0.175         0.825         0.825           10         KLDA with LOGISTIC         7         0.175         0.825         0.825           11         KLDA with LOGISTIC         4096         0.100         0.900         0.900           12         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.050         0.950         0.950           15         RESNET with LOGISTIC         2048         0.050         0.975         0.975           16         RESNET with LOGISTIC         2048         0.050         0.950         0.950           15         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           16         PCA with MLP         55						
7         LDA with LOGISTIC         7         0.175         0.825         0.825           8         LDA with LOGISTIC         7         0.175         0.825         0.825           9         KLDA with SVM         7         0.175         0.825         0.825           10         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with LOGISTIC         4096         0.100         0.900         0.900           13         VGG with LOGISTIC         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.025         0.975         0.975           17         RESNET with LOGISTIC         2048         0.025         0.975         0.975           17         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           18         VEA with MLP         55         0.485294         0.514706         0.514706           19         PCA with SVM						
8         LDA with LOGISTIC         7         0.175         0.825         0.825           9         KLDA with MLP         7         0.250         0.750         0.750           10         KLDA with SVM         7         0.175         0.825         0.825           11         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with LOGISTIC         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.901           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.050         0.950         0.950           17         RESNET with LOGISTIC         2048         0.050         0.975         0.975           17         Resure         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           10         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with MLP <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
9         KLDA with MLP         7         0.250         0.750         0.825           10         KLDA with SVM         7         0.175         0.825         0.825           11         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with SVM         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.025         0.975         0.975           17         REsture         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           18         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118         0.544118         0.544118						
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11         KLDA with LOGISTIC         7         0.175         0.825         0.825           12         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with SVM         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.050         0.950         0.950           17         RESNET with LOGISTIC         2048         0.025         0.975         0.975           HIT-CFW         Feature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118           2         PCA with MLP         55         0.411765         0.588235         0.588235           3         KPCA with MLP         55         0.573529         0.426471         0.426471 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
12         VGG with MLP         4096         0.100         0.900         0.900           13         VGG with SVM         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with SVM         2048         0.025         0.975         0.975           17         RESNET with LOGISTIC         2048         0.025         0.975         0.975           WITT-CFW         Eature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118           2         PCA with MLP         55         0.573529         0.426471         0.426471           4         KPCA with MLP         55         0.573529         0.426471         0.426471           5         KPCA with MLP         7         0.676471         0.323529         0.338235 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
13         VGG with SVM         4096         0.100         0.900         0.900           14         VGG with LOGISTIC         4096         0.100         0.900         0.900           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with LOGISTIC         2048         0.050         0.950         0.950           IIIT-CFW           Feature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with LOGISTIC         55         0.411765         0.58235         0.58235           2         PCA with MLP         55         0.573529         0.426471         0.426471           4         KPCA with SVM         55         0.573529         0.426471         0.426471           4         KPCA with LOGISTIC         55         0.541118         0.455882         0.455882           6         LDA with MLP         7         0.676471         0.323529         0.323529           7         LDA with LOGISTIC         7         0.617647         0.382353						
14         VGG with LOGISTIC         4096         0.100         0.900         0.975           15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with SVM         2048         0.050         0.950         0.950           17         RESNET with LOGISTIC         2048         0.025         0.975         0.975           HIT-CFW           Feature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118           2         PCA with MLP         55         0.573529         0.426471         0.426471           4         KPCA with LOGISTIC         55         0.573529         0.426471         0.426471           5         KPCA with MLP         7         0.676471         0.323529         0.323529           6         LDA with SVM         7         0.606471         0.382353         0.382353           9         KLDA with LOGISTIC         7         0.617647         0.382353						
15         RESNET with MLP         2048         0.025         0.975         0.975           16         RESNET with SVM         2048         0.050         0.950         0.950           17         RESNET with LOGISTIC         2048         0.025         0.975         0.975           IIIT-CFW           Feature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118           2         PCA with LOGISTIC         55         0.573529         0.426471         0.426471           4         KPCA with LOGISTIC         55         0.573529         0.426471         0.426471           5         KPCA with LOGISTIC         55         0.573529         0.426471         0.426471           5         KPCA with SVM         55         0.544118         0.455882         0.455882           6         LDA with SVM         7         0.676471         0.323529         0.323529         0.323529         0.338235         0.3882353         0.3882353         0.3882353						
16         RESNET with LOGISTIC         2048         0.050         0.950         0.975           IIIT-CFW           Feature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118           2         PCA with LOGISTIC         55         0.573529         0.426471         0.426471           3         KPCA with SVM         55         0.573529         0.426471         0.426471           4         KPCA with LOGISTIC         55         0.573529         0.426471         0.426471           5         KPCA with MLP         55         0.573529         0.426471         0.426471           5         KPCA with LOGISTIC         55         0.544118         0.455882         0.455882           6         LDA with SVM         7         0.676471         0.323529         0.323529         0.323529         0.323529         0.323529         0.323529         0.338235         0.382353         0.382353         0.382353         0.382353         0.382353         0.382353 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
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Feature   Reduced Dimension Space   Classification Error   Accuracy   F1-Score						
Feature         Reduced Dimension Space         Classification Error         Accuracy         F1-Score           0         PCA with MLP         55         0.485294         0.514706         0.514706           1         PCA with SVM         55         0.455882         0.544118         0.544118           2         PCA with LOGISTIC         55         0.411765         0.588235         0.588235           3         KPCA with MLP         55         0.573529         0.426471         0.426471           4         KPCA with LOGISTIC         55         0.573529         0.426471         0.426471           5         KPCA with LOGISTIC         55         0.544118         0.455882         0.456471           6         LDA with MLP         7         0.676471         0.323529         0.323529           7         LDA with LOGISTIC         7         0.617647         0.382353         0.382353           9         KLDA with MLP         7         0.601765         0.3382353         0.382353           10         KLDA with LOGISTIC         7         0.617647         0.382353         0.382353           12         VGG with MLP         4096         0.382353         0.617647         0.617647						
0       PCA with MLP       55       0.485294       0.514706       0.514706         1       PCA with SVM       55       0.455882       0.544118       0.544118         2       PCA with LOGISTIC       55       0.411765       0.588235       0.588235         3       KPCA with MLP       55       0.573529       0.426471       0.426471         4       KPCA with LOGISTIC       55       0.573529       0.426471       0.426471         5       KPCA with LOGISTIC       55       0.544118       0.455882       0.455882         6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with MLP       7       0.617647       0.382353       0.382353         9       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471		IIII-CF W				
1       PCA with SVM       55       0.455882       0.544118       0.544118         2       PCA with LOGISTIC       55       0.411765       0.588235       0.588235         3       KPCA with MLP       55       0.573529       0.426471       0.426471         4       KPCA with SVM       55       0.573529       0.426471       0.426471         5       KPCA with LOGISTIC       55       0.544118       0.455882       0.455882         6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with LOGISTIC       7       0.617647       0.382353       0.338235         9       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.676471         13       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471			Reduced Dimension Space			
2       PCA with LOGISTIC       55       0.411765       0.588235       0.588235         3       KPCA with MLP       55       0.573529       0.426471       0.426471         4       KPCA with SVM       55       0.573529       0.426471       0.426471         5       KPCA with LOGISTIC       55       0.544118       0.455882       0.455882         6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with SVM       7       0.602941       0.397059       0.397059         10       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294						
3       KPCA with MLP       55       0.573529       0.426471       0.426471         4       KPCA with SVM       55       0.573529       0.426471       0.426471         5       KPCA with LOGISTIC       55       0.544118       0.455882       0.455882         6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with MLP       7       0.601765       0.338235       0.338235         10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
4       KPCA with SVM       55       0.573529       0.426471       0.426471         5       KPCA with LOGISTIC       55       0.544118       0.455882       0.455882         6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with SVM       7       0.602941       0.397059       0.397059         10       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294						
5       KPCA with LOGISTIC       55       0.544118       0.455882       0.455882         6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with MLP       7       0.601765       0.338235       0.338235         10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294		KPCA with MLP		0.573529	0.426471	0.426471
6       LDA with MLP       7       0.676471       0.323529       0.323529         7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with MLP       7       0.661765       0.338235       0.338235         10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294	4	KPCA with SVM		0.573529	0.426471	0.426471
7       LDA with SVM       7       0.602941       0.397059       0.397059         8       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with MLP       7       0.661765       0.338235       0.338235         10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294		KPCA with LOGISTIC	55	0.544118	0.455882	0.455882
8       LDA with LOGISTIC       7       0.617647       0.382353       0.382353         9       KLDA with MLP       7       0.661765       0.338235       0.338235         10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294			7	0.676471	0.323529	0.323529
9       KLDA with MLP       7       0.661765       0.338235       0.338235         10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294		LDA with SVM	7	0.602941	0.397059	0.397059
10       KLDA with SVM       7       0.602941       0.397059       0.397059         11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294	8	LDA with LOGISTIC	7	0.617647	0.382353	0.382353
11       KLDA with LOGISTIC       7       0.617647       0.382353       0.382353         12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294			_			
12       VGG with MLP       4096       0.382353       0.617647       0.617647         13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294	9	KLDA with MLP	7	0.661765	0.338235	0.338235
13       VGG with SVM       4096       0.323529       0.676471       0.676471         14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294						
14       VGG with LOGISTIC       4096       0.323529       0.676471       0.676471         15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294	10	KLDA with SVM	7	0.602941	0.397059	0.397059
15       RESNET with MLP       2048       0.014706       0.985294       0.985294         16       RESNET with SVM       2048       0.014706       0.985294       0.985294	10 11 12	KLDA with SVM KLDA with LOGISTIC	7 7	$\begin{array}{c} 0.602941 \\ 0.617647 \end{array}$	$\begin{array}{c} 0.397059 \\ 0.382353 \end{array}$	$0.397059 \\ 0.382353$
16 RESNET with SVM 2048 0.014706 0.985294 0.985294	10 11 12	KLDA with SVM KLDA with LOGISTIC VGG with MLP	$7 \\ 7 \\ 4096$	0.602941 $0.617647$ $0.382353$	$\begin{array}{c} 0.397059 \\ 0.382353 \\ 0.617647 \end{array}$	$\begin{array}{c} 0.397059 \\ 0.382353 \\ 0.617647 \end{array}$
	10 11 12 13	KLDA with SVM KLDA with LOGISTIC VGG with MLP VGG with SVM	7 7 4096 4096	0.602941 $0.617647$ $0.382353$ $0.323529$	0.397059 0.382353 0.617647 0.676471	$\begin{array}{c} 0.397059 \\ 0.382353 \\ 0.617647 \\ 0.676471 \end{array}$
17 RESNET with LOCISTIC 2008 0 014706 0 085204 0 085204	10 11 12 13 14	KLDA with SVM KLDA with LOGISTIC VGG with MLP VGG with SVM VGG with LOGISTIC	7 7 4096 4096 4096	0.602941 $0.617647$ $0.382353$ $0.323529$ $0.323529$	$\begin{array}{c} 0.397059 \\ 0.382353 \\ 0.617647 \\ 0.676471 \\ 0.676471 \end{array}$	$\begin{array}{c} 0.397059 \\ 0.382353 \\ 0.617647 \\ 0.676471 \\ 0.676471 \end{array}$
11 16267.21 with 2001.0110 2040 0.014100 0.505254 0.505254	10 11 12 13 14 15 16	KLDA with SVM KLDA with LOGISTIC VGG with MLP VGG with SVM VGG with LOGISTIC RESNET with MLP RESNET with SVM	7 7 4096 4096 4096 2048	0.602941 0.617647 0.382353 0.323529 0.323529 0.014706	$\begin{array}{c} 0.397059 \\ 0.382353 \\ 0.617647 \\ 0.676471 \\ 0.676471 \\ 0.985294 \end{array}$	0.397059 0.382353 0.617647 0.676471 0.676471 0.985294

Yale-Face Database

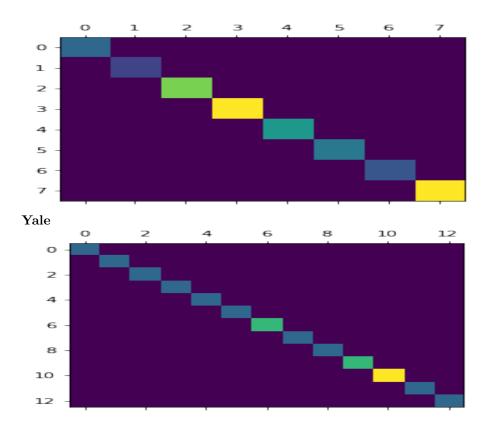
	Feature	Reduced Dimension Space	Classification Error	Accuracy	F1-Score
0	PCA with MLP	55	0.058824	0.941176	0.941176
1	PCA with SVM	55	0.117647	0.882353	0.882353
2	PCA with LOGISTIC	55	0.058824	0.941176	0.941176
3	KPCA with MLP	55	0.823529	0.176471	0.176471
4	KPCA with SVM	55	0.764706	0.235294	0.235294
5	KPCA with LOGISTIC	55	0.470588	0.529412	0.529412
6	LDA with MLP	14	0.176471	0.823529	0.823529
7	LDA with SVM	14	0.058824	0.941176	0.941176
8	LDA with LOGISTIC	14	0.058824	0.941176	0.941176
9	KLDA with MLP	14	0.117647	0.882353	0.882353
10	KLDA with SVM	14	0.058824	0.941176	0.941176
11	KLDA with LOGISTIC	14	0.058824	0.941176	0.941176
12	VGG with MLP	4096	0.647059	0.352941	0.352941
13	VGG with SVM	4096	0.588235	0.411765	0.411765
14	VGG with LOGISTIC	4096	0.529412	0.470588	0.470588
15	RESNET with MLP	2048	0.117647	0.882353	0.882353
16	RESNET with SVM	2048	0.058824	0.941176	0.941176
17	RESNET with LOGISTIC	2048	0.000000	1.000000	1.000000

From the above tables, we see that we get high accuracies when we apply RESNET With Logistic Regression. Also Kernel methods do not seem to work well for the classification

# Confusion-Matrix



IIIT-CFW

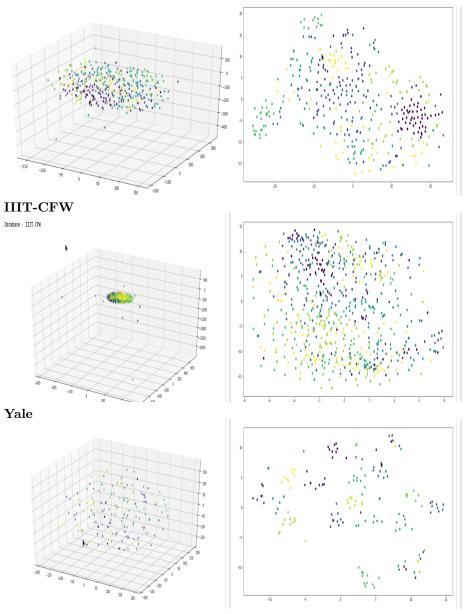


# 1.3 Problem-3

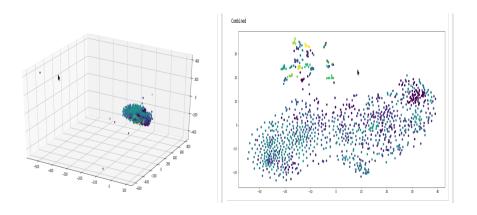
1. Use t-SNE based vizualization of faces? Does it make sense? Do you see similar people coming together? Can you do vizualization datawise and combined?

From the plots given below and present in the jupyter notebook, we see that after t-SNE, the faces with similar classes tend to come closer. Also, if we plot the faces in all datasets, we see the formation of clusters of similar classes.

#### $\mathbf{IMFDB}$



Combined



## 1.4 Problem-4

1. How do we formulate the problem using KNN? How do we analyize the performance?

We can see the problem as assigning a label to a point which is occurs maximum times in the labels of its k-nearest neighbours. The results with various feature extraction-techniques is as follows:

Dataset = IMFDB

	Feature	Reduced Dimension Space	Classification Error	Accuracy	Precision
0	PCA with KNN	55	0.350	0.650	0.650
1	KPCA with KNN	55	0.350	0.650	0.650
2	LDA with KNN	7	0.125	0.875	0.875
3	KLDA with KNN	7	0.125	0.875	0.875
4	VGG with KNN	4096	0.125	0.875	0.875
5	RESNET with KNN	2048	0.075	0.925	0.925

Dataset = IIIT-CFW

	Feature	Reduced Dimension Space	Classification Error	Accuracy	Precision
0	PCA with KNN	55	0.558824	0.441176	0.441176
1	KPCA with KNN	55	0.514706	0.485294	0.485294
2	LDA with KNN	7	0.735294	0.264706	0.264706
3	KLDA with KNN	7	0.735294	0.264706	0.264706
4	VGG with KNN	4096	0.441176	0.558824	0.558824
5	RESNET with KNN	2048	0.000000	1.000000	1.000000

Dataset = Yale

The various metrics to analyze performance are accuracy, precision, classification-error, f1-score etc

	Feature	Reduced Dimension Space	Classification Error	Accuracy	Precision
0	PCA with KNN	55	0.294118	0.705882	0.705882
1	KPCA with KNN	55	0.294118	0.705882	0.705882
2	LDA with KNN	14	0.058824	0.941176	0.941176
3	KLDA with KNN	14	0.058824	0.941176	0.941176
4	VGG with KNN	4096	0.588235	0.411765	0.411765
5	RESNET with KNN	2048	0.000000	1.000000	1.000000

#### 1.5 Problem-5

1. Take a combination of IIIT-CFW and IMFDB datasets and try to classify the face as male/female. Basically, the problems is a binary classification problem of Gender Determination.

#### 2. Real Life Applications of Solution-

- (a) In the age of digital media, we have a lot of data of people's faces in different orientations and environments.
- (b) If we are able to develop a model, that can predict a person's gender with a satisfactory accuracy, then we can easily track movement of people.
- (c) It will be very helpful in improving security at areas which are gender restricted. It can also be used in Face-Matching to check whether two photographs are of the same person or not. We may use gender identification as a preliminary to eliminate man options.

#### 3. Pipeline-

- (a) Load both the datasets and combine them using vstack.
- (b) Create a new label set with 0 as Female and 1 as Male.
- (c) Try all the feature extraction techniques along with the various classifiers.
- (d) Evaluate the above methods based on accuracy, precision, f1-score etc.

#### 4. Metrics Used-

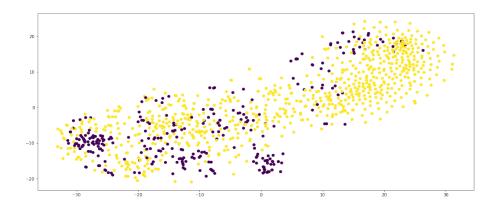
(a) Accuracy, Precision, F1-Score.

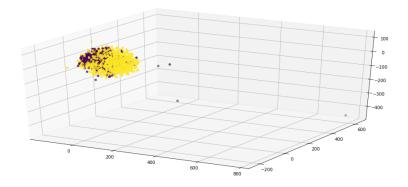
We see that RESNET+KNN OR RESNET+LOGISTIC perform the best

Some Examples of correct and Wrong predictions are given at end of the jupyter notebook

1. t-SNE 2D and 3D plots for the given data are given below:

	Feature	Reduced Dimension Space	Classification Error	Accuracy	F1-Score	Precision
0	PCA with MLP	55	0.148148	0.851852	0.851852	0.851852
1	PCA with SVM	55	0.231481	0.768519	0.768519	0.768519
2	PCA with LOGISTIC	55	0.185185	0.814815	0.814815	0.814815
3	PCA with KNN	55	0.194444	0.805556	0.805556	0.805556
4	KPCA with MLP	55	0.148148	0.851852	0.851852	0.851852
5	KPCA with SVM	55	0.268519	0.731481	0.731481	0.731481
6	KPCA with LOGISTIC	55	0.175926	0.824074	0.824074	0.824074
7	KPCA with KNN	55	0.194444	0.805556	0.805556	0.805556
8	LDA with MLP	1	0.379630	0.620370	0.620370	0.620370
9	LDA with SVM	1	0.370370	0.629630	0.629630	0.629630
10	LDA with LOGISTIC	1	0.370370	0.629630	0.629630	0.629630
11	LDA with KNN	1	0.370370	0.629630	0.629630	0.629630
12	KLDA with MLP	1	0.398148	0.601852	0.601852	0.601852
13	KLDA with SVM	1	0.370370	0.629630	0.629630	0.629630
14	KLDA with LOGISTIC	1	0.370370	0.629630	0.629630	0.629630
15	KLDA with KNN	1	0.370370	0.629630	0.629630	0.629630
16	VGG with MLP	4096	0.027778	0.972222	0.972222	0.972222
17	VGG with SVM	4096	0.064815	0.935185	0.935185	0.935185
18	VGG with LOGISTIC	4096	0.037037	0.962963	0.962963	0.962963
19	VGG with KNN	4096	0.037037	0.962963	0.962963	0.962963
20	RESNET with MLP	2048	0.009259	0.990741	0.990741	0.990741
21	RESNET with SVM	2048	0.009259	0.990741	0.990741	0.990741
22	RESNET with LOGISTIC	2048	0.000000	1.000000	1.000000	1.000000
23	RESNET with KNN	2048	0.000000	1.000000	1.000000	1.000000





# 2. t-SNE 2D and 3D plots for the given data are given below:

