CS 669 / DS 403

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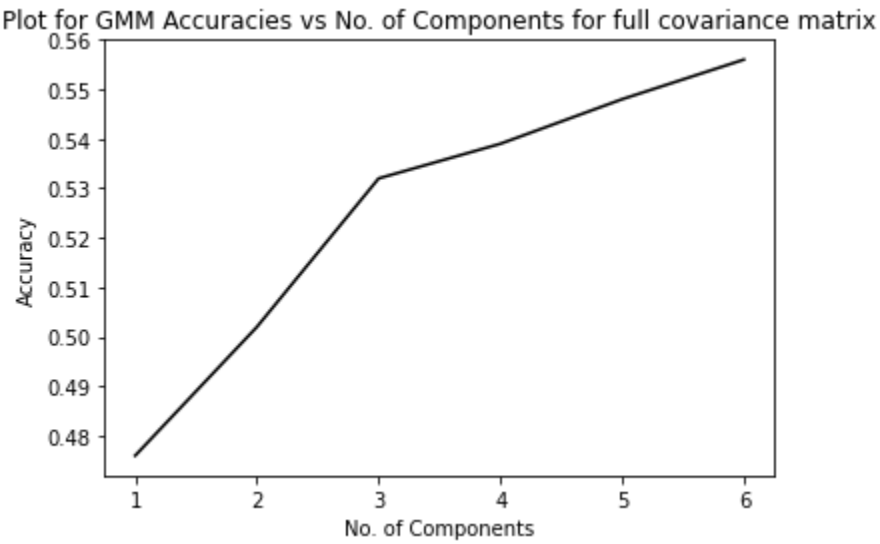
Assignment 2

Google Colab Link-
https://colab.research.google.com/drive/1KsZAZURaoCt4o1KjfwSrZNRaYgUC6dEc?usp=sharing

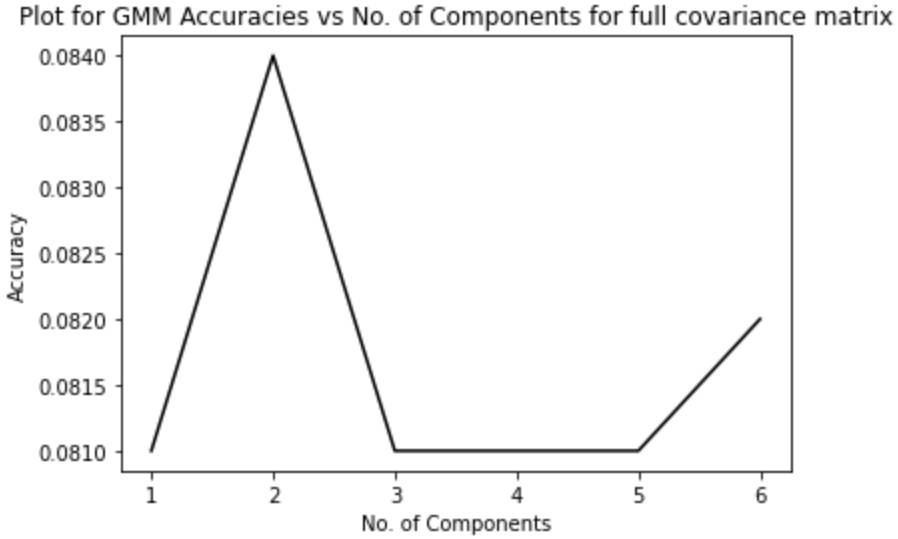
Q1)
Accuracy table for GMM

Accuracy	**pb_test (full covariance matrix)**	**yt_test (full covariance matrix)**	**pb_test (diag covariance matrix)**	**yt_test (diag covariance matrix)**
For q=1	**0.476**	**0.081**	**0.33**	**0.083**
For q=2	**0.502**	**0.084**	**0.339**	**0.091**
For q=3	**0.532**	**0.081**	**0.349**	**0.089**
For q=4	**0.539**	**0.081**	**0.362**	**0.086**
For q=5	**0.548**	**0.081**	**0.372**	**0.089**
For q=6	**0.556**	**0.082**	**0.373**	**0.087**

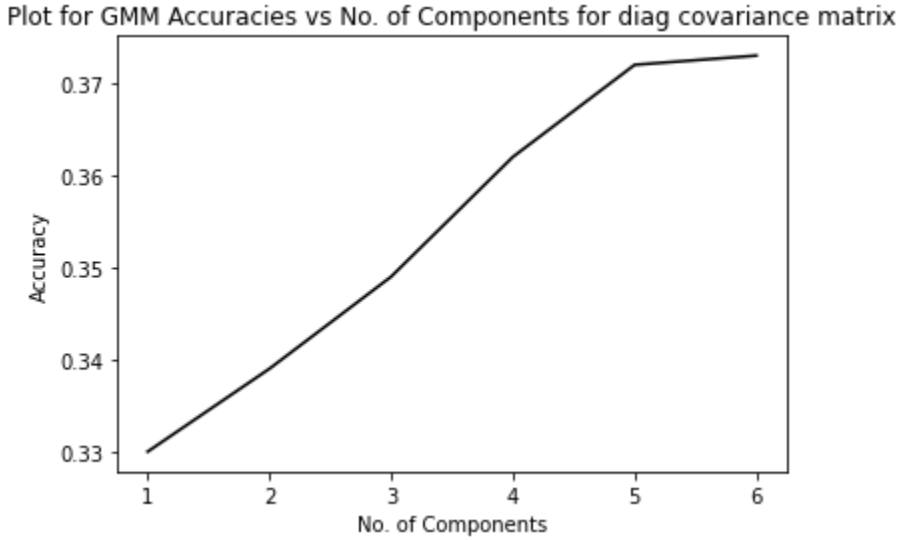
Plot for GMM Accuracies vs No. of Components for full Covariance Matrix PB_Test



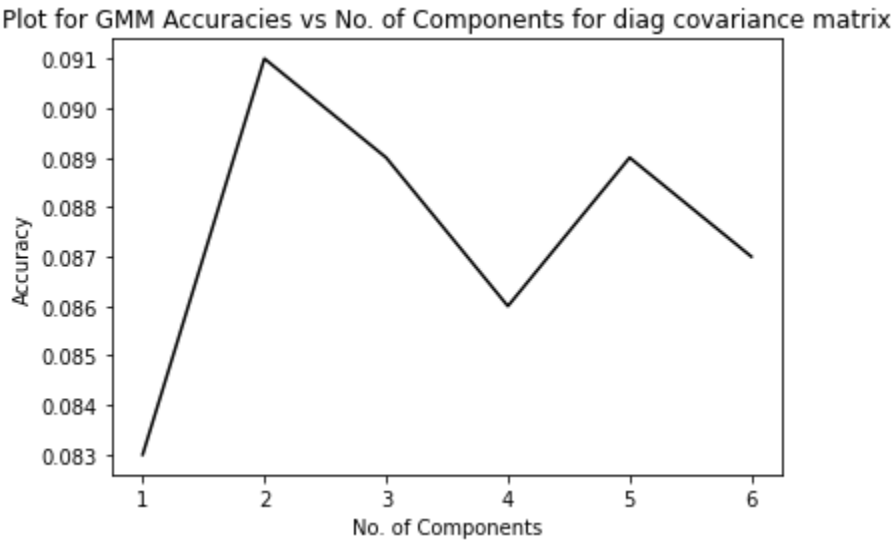
Plot for GMM Accuracies vs No. of Components for full Covariance Matrix YT_Test



Plot for GMM Accuracies vs No. of Components for Diag Covariance Matrix PB_Test



Plot for GMM Accuracies vs No. of Components for Diag Covariance Matrix YT_Test

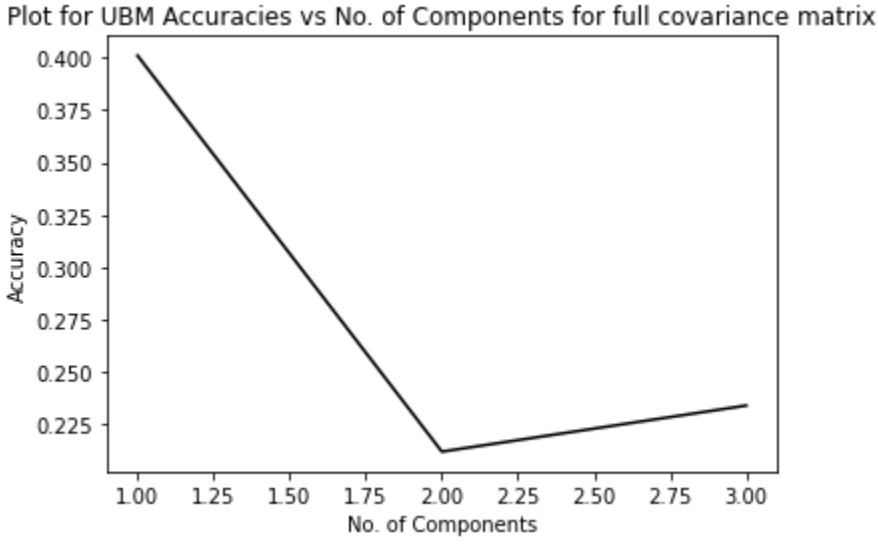


Q2)

Accuracy table for UBM

Accuracy	pb_test (full covariance matrix)	yt_test (full covariance matrix)	pb_test (diag covariance matrix)	yt_test (diag covariance matrix)
For q=1	0.401	0.073	0.303	0.080
For q=2	0.212	0.063	0.303	0.080
For q=3	0.234	0.081	0.334	0.079

Plot for UBM Accuracies vs No. of Components for full Covariance Matrix PB_Test



For **q = 1** the accuracy for PB_test is **0.401** for full covariance matrix

The Confusion Matrix is shown below :

```
[[13311  4044  4531  1076   540  2438  3281  2405  4552  1922  1594  2021]
 [ 2800 27850   802  1305   256   772  2561  1121  2961   915  1803   408]
 [ 3922   469 17695   117   468  3897  3725  3067  3220   525  1890  3038]
 [  341   317   956 28722  3142  1621   448   931   520  4856  1933  2825]
 [ 1373  1674  2739 10857  4350  3338   897  4454  1973  6590  2974  1912]
 [ 1649  2712  3433  2104  1677 19072  1523  1301  2349  2164  2220  2645]
 [ 3051  2724  2446  1461   387  1164 14506  2320  5135   595  3346  1761]
 [ 4490   615  1910   498   645   508  1225 18737  2090  2148  1791  1406]
 [ 4414  3424  4065  1067   688  2727  1271  2247 18187  1580  2467  1665]
 [  134   316   126 22462  2677  1083    33   635   508 19796  1116   703]
 [  536  4249   445  4787  1692  2219  1135   894  2114  1703 19286  4631]
 [ 3039  1722  6068  7119  1767  5393  2863  2243  2703  2827  4760
6656]]
```

For **q = 2** the accuracy for PB_test is **0.212** for full covariance matrix

The Confusion Matrix is shown below :

```
[[    0     0 16002     0     0     0     0     0 18811  6902     0     0]
 [    0    60  5377     0     0     0   103    16 29693  8259    46     0]
 [    0     0 31784     0     0     0     0     0  8479  1770     0     0]
 [    0     0  3849   120     0     0     0     1  4596 38043     1     2]
 [    0     0  7228     1     0     0     1     5  9151 26745     0     0]
 [    0     0 14227     7     0     0     0     0 16260 12355     0     0]
 [    0     0 18866     0     0     0    97    13 15589  4331     0     0]
 [    0     0 10575     0     0     0     0     0 11264 14224     0     0]
 [    0     0  8560     1     0     0     0     0 30627  4614     0     0]
 [    0     0   386    43     0     0     0     0  1922 47238     0     0]
 [    0     0  4517     0     0     0     1     0 22521 16652     0     0]
 [    0     0 16329     0     0     0     1     0 13650 17180     0
0]]
```

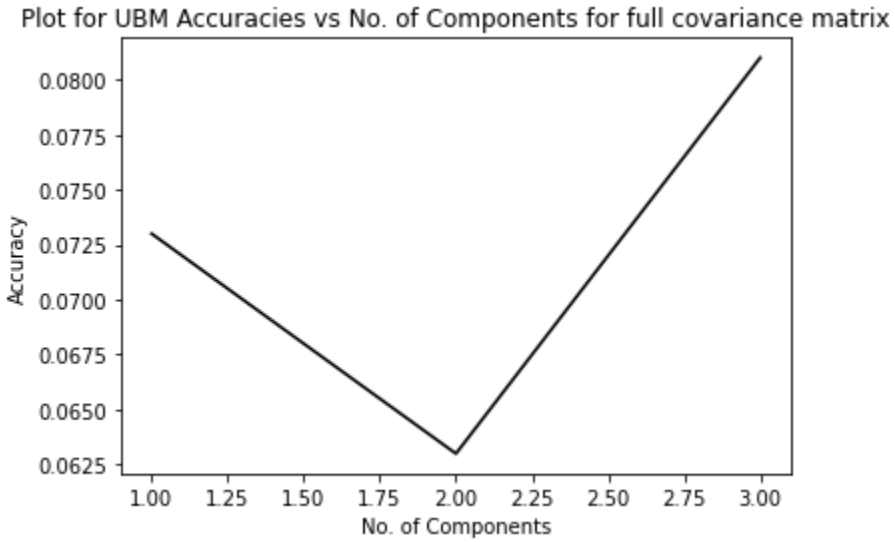
For **q = 3** the accuracy for PB_test is **0.234** for full covariance matrix

The Confusion Matrix is shown below :

```
[[    1  7424     0     0     0  4669  8001     0 13604     0     0  8016]
 [    0 30591     0     0     1  1132  4333     0  5078     0     0  2419]
 [    0   746     0     0     0  9051 11733     0 12274     0     0  8229]
 [    0  2382     0   427    30  3364   979     5  1365    15     0 38045]
 [    0  3350     0    16     0  6914  2613     3  4786     2     0 25447]
 [    0  3515     0    29     5 21753  3639     0  4737     1     0  9170]
 [    0  3760     0     2     0  1722 18844     0  8799     0     0  5769]
 [    0  3163     0     0     0  1297  4540     0  9010     1     0 18052]
 [    0  4565     1     1     0  4059  3323     0 26270     1     0  5582]
 [    0  2674     0   394    35  5213   129     0  2318    36     0 38790]
```

```
 [    0  7854     0     0     0  4259  3254     0  4893     1     0 23430]
 [    0  2971     0     4     0  7859  6561     0  5999     0     0
23766]]
```

Plot for UBM Accuracies vs No. of Components for full Covariance Matrix YT_Test



For **q = 1** the accuracy for YT_test is **0.073** for full covariance matrix

```
The Confusion Matrix is shown below :
[[ 8862  8626  5140   207    64  1695  2849  5468  3059   586   522  1040]
 [ 4531  5220  6749   125   123  1204  5999  5794  2919   265  1085   580]
 [ 5085 10906  3376    71   380  2722  7070  3174  2368   250  3335  1180]
 [ 2242  2856  3667   350   589  2182 10626  8405  1232   821  3582  2175]
 [ 5635  8959  1481    13    40  6915  5846  3927  4007   453  1116   903]
 [ 6928  5036  5155   109   107  1696  3980  9388  3061   550   363  1085]
 [ 2332 10864   927  2224   709  1564  3083  7210  3055  2391  3222  1338]
 [ 5657 13542  3177    61   186  1393  6186  3724  2186   567   944  2200]
 [ 6158  5775  5437   124   108   862  2407 12473  2803   331  1282   791]
 [ 4782  1366  4052    39    80   260  2066 12425  8921   262   976   995]
 [ 2545  6452   452  3008   735   694  1836  9172  2626  5550  1840  1427]
 [ 2983  6380  2156  1077  1289  2100  4615  9930  1753  2078  3825
2239]]
```

For **q = 2** the accuracy for YT_test is **0.063** for full covariance matrix

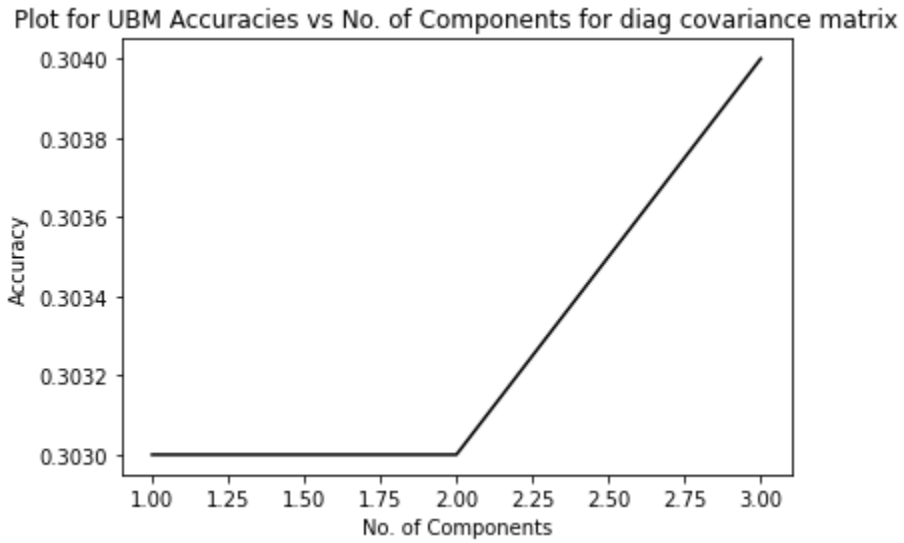
```
The Confusion Matrix is shown below :
[[    0 10355 10906     0     0  2447  4502  6570     0   904   622  1812]
 [    0  6448 11132     0     0  1322  7815  5687     0   410   809   971]
```

```
 [    0 12627  6325     0     0  2723 10005  3482     0   327  2534  1894]
 [    2  2566  6215     0     0  1653 12473  8670     0   980  3536  2632]
 [    0 12529  4899     0     0  7307  8102  4404     0   290   841   923]
 [    0  6901  9974     0     0  1376  6157  9499     0   953   482  2116]
 [    0 11616  1718     0     0  2173  4667  7549     0  4018  3880  3298]
 [    0 12136  6297     0     0  1464  9836  3425     0   853  1012  4800]
 [    0  7702  8696     0     0   724  3271 13871     0   884  1266  2137]
 [    0  3051 11091     0     0   697  3194 14117     0   398  1492  2184]
 [    0  6779  1814     0     0   814  3093  7970     0 10199  2516  3152]
 [    0  6195  4663     0     0  2224  5847 10920     0  2779  3951
3846]]
```

For **q = 3** the accuracy for YT_test is **0.081** for full covariance matrix

```
The Confusion Matrix is shown below :
[[    8     2   109     0     0     1    42    33 32761  5161     0     1]
 [   10     1    23     0     0     2    64    29 30390  4073     0     2]
 [    1     2     2     0     0     0    73     9 36177  3652     1     0]
 [    2     1   136     1     0    46   667   116 28069  9685     4     0]
 [    0     2     1     1     0     1    28     9 35004  4248     1     0]
 [    0     0     5     0     0     0    11    65 32960  4417     0     0]
 [    0     6     2     0     0     0     5     1 24392 14513     0     0]
 [    0     5    24     0     0     2   110    47 35983  3651     0     1]
 [    0     0     5     0     0     0    19   112 32293  6122     0     0]
 [    1     0     1     0     0     0    25   130 31188  4879     0     0]
 [    0     1     0     0     0     0     3     0 15747 20586     0     0]
 [    1     3     7     1     0     0    11     6 21027 19367     2
0]]
```

Plot for UBM Accuracies vs No. of Components for Diag Covariance Matrix PB_Test



For **q = 1** the accuracy for PB_test is **0.303** for diag covariance matrix

The Confusion Matrix is shown below :

```
[[ 8342  3713  7022  1731   262  4232   976  3527  3863  2458  3393  2196]
 [ 3134 20392  1912  2218   127  2043  1129  2231  3820  1230  4469   849]
 [ 3422   602 15178   726   312  6429   950  3193  3037  1309  3333  3542]
 [ 1154   592  2560 23757  1570  2835   167  1320  1048  6702  3271  1636]
 [ 2172  1522  4279 10480  1752  4732   281  4150  2184  6413  3663  1503]
 [ 1165  2073  5958  2603   861 16067   546  1928  2442  2453  4246  2507]
 [ 2509  2425  4059  2949   255  2839  5916  4621  4204  1299  5596  2224]
 [ 4398   972  3990  1253   143   970   399 16241  1855  2925  1928   989]
 [ 3576  3221  7009  1082   299  3567   503  2550 14613  1388  3965  2029]
 [ 1332   803  2558 19153  1260  3204    51  1940  1475 14573  2499   741]
 [  801  4242  2095  6198   603  5019   538  1566  2255  1918 16154  2302]
 [ 2122  1741  5867  8536  1084  6638  1245  3320  2403  3584  6382
4238]]
```

For **q = 2** the accuracy for PB_test is **0.303** for diag covariance matrix

The Confusion Matrix is shown below :

```
[[ 8722  3355  7187  1728   255  4241  1129  3404  3837  2197  3502  2158]
 [ 3364 20023  1965  2247   134  2003  1197  2108  3799  1167  4720   827]
 [ 3472   456 15868   685   231  6478  1084  3065  2965   997  3238  3494]
 [ 1239   633  2650 23731  1703  2670   180  1353  1012  6365  3559  1517]
 [ 2207  1447  4445 10698  1874  4503   327  4121  2135  6082  3827  1465]
 [ 1268  1947  6266  2570   882 15808   622  1912  2397  2245  4520  2412]
 [ 2632  2322  4157  2808   281  2785  6265  4490  4000  1128  5921  2107]
 [ 4357  1055  4034  1365   138   984   407 16184  1811  2670  2058  1000]
 [ 3720  3301  7230  1084   319  3634   589  2565 14009  1315  4137  1899]
 [ 1451   884  2669 19057  1382  2950    55  1974  1422 14332  2716   697]
 [  842  4135  2081  6492   685  4576   602  1513  2204  1729 16582  2250]
 [ 2143  1784  5983  8643  1119  6467  1333  3212  2304  3320  6783
4069]]
```

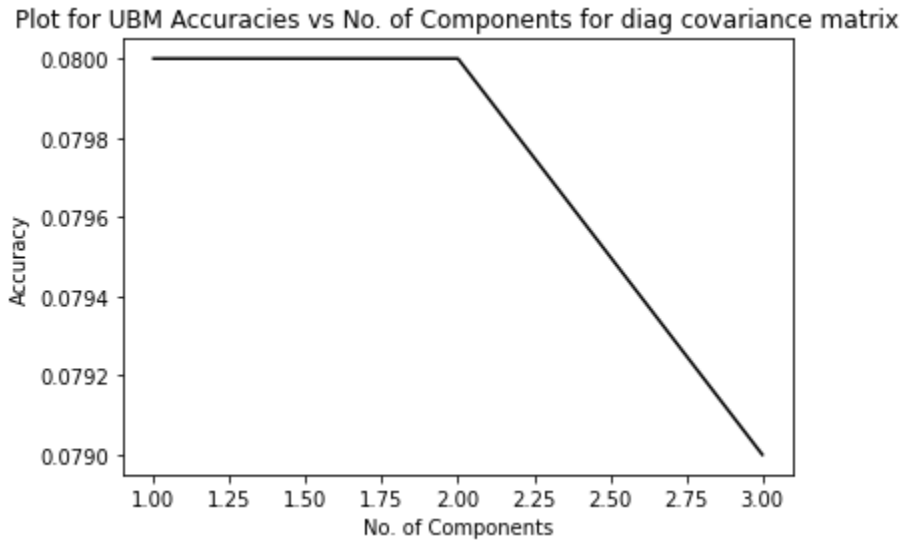
For **q = 3** the accuracy for PB_test is **0.304** for diag covariance matrix

The Confusion Matrix is shown below :

```
[[ 8592  3667  7216  1728   260  4315  1148  3689  3679  2015  3264  2142]
 [ 3303 20288  1904  2221   138  2136  1223  2326  3725  1120  4410   760]
 [ 3412   483 16290   616   284  6565  1013  3257  2820   881  2909  3503]
 [ 1114   697  2473 23991  1658  2970   157  1435   986  6625  3016  1490]
 [ 2039  1553  4424 10786  1854  4862   267  4203  2063  6194  3518  1368]
 [ 1152  1989  6036  2616   945 16363   582  2037  2322  2240  4103  2464]
 [ 2642  2489  4056  2692   293  2959  6130  5078  3977  1110  5475  1995]
 [ 4170  1241  3971  1343   160  1101   405 16588  1613  2678  1909   884]
 [ 3675  3340  7251  1110   360  3816   580  2800 13726  1295  3874  1975]
```

```
 [ 1242   857  2407 19373  1442  3603    42  2186  1365 14145  2316   611]
 [  828  4410  1970  6774   717  5089   521  1618  2153  1814 15712  2085]
 [ 2088  1879  5941  8827  1180  6771  1327  3506  2232  3297  6057
4055]]
```

Plot for UBM Accuracies vs No. of Components for Diag Covariance Matrix YT_Test



For **q = 1** the accuracy for YT_test is **0.08** for diag covariance matrix

```
The Confusion Matrix is shown below :
[[ 5571  7005  6345   713    98  3148  1671  4562  4125   665  2498  1717]
 [ 3389  4819  7374   493    31  3339  2808  4778  3279   380  2692  1212]
 [ 2764  8789  4327   741   175  4321  2466  3008  3534   506  7248  2038]
 [ 1664  3023  4631  2649   220  3554  5453  5911  1792   788  5612  3430]
 [ 3525  6140  2963  1330    24  7939  2095  3625  3965  1066  4006  2617]
 [ 3421  4943  6033   583    67  3173  1832  7528  4016   815  2416  2631]
 [ 2334  7613  2482  3860   264  2279  2086  6072  3342  1862  5169  1556]
 [ 3823 10715  4067   468    67  3763  4870  3661  2489   760  2914  2226]
 [ 5838  4767  5322   610    82  1848  1132  9350  3989   712  2829  2072]
 [ 3894  2023  6828   427   123   680  1199  9287  7801   639  1718  1605]
 [ 2821  4962  1384  5639   594   928  1178  8182  2677  3341  3122  1509]
 [ 2346  4750  3847  3928   447  2318  2205  8112  2150  2509  5148
2665]]
```

For **q = 2** the accuracy for YT_test is **0.08** for diag covariance matrix

```
The Confusion Matrix is shown below :
[[ 5645  6916  6172   635   103  3328  1836  4454  4075   605  2713  1636]
 [ 3455  4699  7756   471    38  3403  2971  4434  3068   305  2852  1142]
 [ 2951  8329  4511   723   171  4354  2731  2852  3290   452  7526  2027]
```

```
 [ 1692  3161  4618  2559   211  3643  5749  5625  1627   645  5975  3222]
 [ 3417  6559  3085  1247    36  8113  2186  3495  3526   960  4264  2407]
 [ 3471  4764  6231   565    67  3267  2104  7419  3786   736  2536  2512]
 [ 2493  7389  2600  3882   274  2245  2251  5825  3215  1669  5546  1530]
 [ 3747 10127  4182   430    79  3983  5756  3428  2253   670  3125  2043]
 [ 5853  4815  5454   578    86  1913  1290  9241  3714   637  3036  1934]
 [ 3864  2053  7108   395   120   708  1347  9377  7193   560  1905  1594]
 [ 2919  5018  1504  5264   561   989  1308  8519  2516  2895  3376  1468]
 [ 2437  4940  3781  3787   455  2279  2479  7777  2091  2226  5596
2577]]
```

For **q = 3** the accuracy for YT_test is **0.079** for diag covariance matrix

```
The Confusion Matrix is shown below :
[[ 5463  6932  6402   639   127  3364  1857  4832  3873   589  2463  1577]
 [ 3467  4685  7879   458    45  3474  2917  4720  2959   286  2573  1131]
 [ 2925  8511  4561   694   205  4460  2662  3265  3140   396  7074  2024]
 [ 1640  3146  4818  2526   284  3731  5658  6152  1561   703  5371  3137]
 [ 3547  6460  3168  1204    34  8324  2249  3932  3420   794  3806  2357]
 [ 3491  4709  6406   546    70  3329  2071  7808  3638   688  2293  2409]
 [ 2341  7561  2540  3929   327  2448  2202  6089  3155  1742  5170  1415]
 [ 3792 10125  4287   412    86  3911  5731  3750  2259   675  2761  2034]
 [ 5831  4962  5626   521    95  1939  1284  9556  3498   581  2824  1834]
 [ 3838  2142  7176   334   131   755  1337  9829  6990   521  1728  1443]
 [ 2779  4973  1522  5383   683  1063  1348  8570  2479  3177  3087  1273]
 [ 2257  5011  3898  3723   509  2562  2485  8303  1983  2243  5057
2394]]
```

Observations & Inferences

- **On comparing both the systems we can observe that system 1 i.e,(Gaussian Mixture Model) performs better than system 2 i.e,(Universal Background Model- Gaussian Mixture Model) in terms of accuracy. The reason for this is that for system 1, we were developing a GMM model for each of the given languages. Each iteration of the E-step and M-step of the GMM updates the Mean Vector, Covariance Matrix, and Weight of each component. While only the mean vector is subject to MAP Adaptation in the case of UBM-GMM, the component weights and covariance matrix are retained across all classes and languages. It follows that System1 performs better than System2 in label prediction for test data.**

- **As with the diagonal covariance matrix, the accuracy of the GMM model increases when the number of mixtures is increased, as well as when the full covariance matrix is used.**

- **The diagonal covariance matrix should be used instead of the entire covariance matrix in the GMM model since it achieves a higher level of accuracy.**
- **Since the speaker in the audio file for Prasar Bharti adheres to one language throughout the audio file, the accuracy reached for the pb test is higher than that of the yt test. This is because the language that the speaker uses in the audio file for Youtube changes frequently.**
- **Punjabi and Gujarati have a high score in the confusion matrix, which indicates that they are related and easily confused. They also have comparable dialects.**