Computer Science Department, UNR

CS 791Y: Mathematical Methods for Computer Vision
(CS 790Q: Machine Learning)

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Comparison of LLE and PCA in Face Recognition

Project Interim Report

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Contents

1 Overview of the problem

Face recognition is a challenging topic in computer vision and image processing research areas. A common method to deal with this problem is first to train a (large number of) set of face images, usually normalized, and then to test the face images in question against those stored train images.

A face image in the image space can be seen as a point in a space of high dimension, the value of which equals to the product of image width times its height. This image space of high dimension is usually redundant for the expression of the face images, and thus can be reduced to another image space with lower dimensionality. Two methods have been used for the reduction of space dimensionality: Principal Component Analysis (PCA) and Locally Linear Embedding (LLE).

PCA has already been used for face recognition and obtained relatively good results. LLE for face recognition seems, at the moment, seems to be a relatively new subject. In this course project, we will try to use the local linearity and global non-linearity of the LLE's tranformation in face recognition, and compare LLE results with those obtained through PCA.

2 AR face database

We use *AR Face Database* in our project. This database was created by Aleix Martinez and Robert Benavente, and can be downloaded, upon the authors' permission, at `http://http://rvl1.ecn.purdue.edu/~aleix/aleix_face_DB.html`.

Tha AR face database contains over $4,000$ color face images corresponding to 70 men and 56 women. There are 26 images for each person in frontal view with different facial expressions, illumination conditions, and occlusions (sun glasses and scarf), and with two sessions separated by two weeks for same pictures. Or specifically, those face images are named as s-xxx-yy.raw:

- s: F—female, M—male.
- xxx: unique person identifier as digit numbers.
- yy: image features defined as following:
  - 01: Neutral expression.
  - 02: Smile.
  - 03: Anger.
  - 04: Scream.
  - 05: Left light on.
  - 06: Right light on.
  - 07: All side lights on.
  - 08: wearing sun glasses.
  - 09: Wearing sun glasses and left light on.
  - 10: Wearing sun glasses and right light on.
  - 11: wearing scarf.
  - 12: Wearing scarf and left light on.
  - 13: Wearing scarf and right light on.
  - 14 to 26: the second session with same conditions as 01 to 13.

In fact, we used the normoralized images of the face images. The normalized images have the same names as the above indicated but in *pgm* format with the size of 60x85 pixels.

3 What I have done so far

First I modified the PCA codes so that they can get input images for a certain defined image directory with the above file names, and the program can print out some kind of meaningful output.

Then, I have managed to run the LLE original matlab code and got results that are very close to the LLE authos' results with some examples. The problems with my previous unstable results lies in:

- Not setting a random *state* for a random function which I ignored.
- Not realizing the importance of a regularization factor, *tol* in the original code. When it was changed to 0.01 instead of 0.001, close results are obtained.
- Matlab has different implemenation/interpretation for solving eigenvalue problem between its older and current versions.

Also I wrote a matlab code that can read from specified image directory the images and then calculate the embeddings for the input (training) image space. Then test the other images against those image embeddings by mapping testing images onto the embedding space. I used the Non-parametric model mapping recommended in the paper. Those preliminary results are in next section.

4 Preliminary results

4.1 PCA Results

With PCA, I had the following results:

```
Script started on Fri Nov 28 16:38:07 2003
```

```
[b_yi@chicken PCA]$ ./RecognizeFace TrainSetFileNames TestSetFileNames 5
***************PCA Face Recognition***************
There are 19 training images:
     ----training   1:  M-006-01.pgm
     ----training   2:  M-007-02.pgm
     ----training   3:  M-006-03.pgm
     ----training   4:  M-007-04.pgm
     ----training   5:  M-006-05.pgm
     ----training   6:  M-007-06.pgm
     ----training   7:  M-006-07.pgm
     ----training   8:  M-007-08.pgm
     ----training   9:  M-006-09.pgm
     ----training  10:  M-007-10.pgm
     ----training  11:  M-006-11.pgm
     ----training  12:  M-007-12.pgm
     ----training  13:  M-006-13.pgm
     ----training  14:  M-007-14.pgm
     ----training  15:  M-006-15.pgm
     ----training  16:  M-007-16.pgm
     ----training  17:  M-006-17.pgm
     ----training  18:  M-007-18.pgm
     ----training  19:  M-006-19.pgm

There are 19 testing images:
     ----testing   1:  M-006-01.pgm
```

```
    ----testing   2:  M-006-02.pgm
    ----testing   3:  M-006-03.pgm
    ----testing   4:  M-006-04.pgm
    ----testing   5:  M-006-05.pgm
    ----testing   6:  M-006-06.pgm
    ----testing   7:  M-006-07.pgm
    ----testing   8:  M-006-08.pgm
    ----testing   9:  M-006-09.pgm
    ----testing  10:  M-006-10.pgm
    ----testing  11:  M-006-11.pgm
    ----testing  12:  M-006-12.pgm
    ----testing  13:  M-006-13.pgm
    ----testing  14:  M-006-14.pgm
    ----testing  15:  M-006-15.pgm
    ----testing  16:  M-006-16.pgm
    ----testing  17:  M-006-17.pgm
    ----testing  18:  M-006-18.pgm
    ----testing  19:  M-006-19.pgm


************* Testing Results  ****************
Testing image   1:  M-006-01.pgm
    The 5 most similar images are:
        M-006-01.pgm (with distance: 2.867701e-06)
        M-006-03.pgm (with distance: 5.901730e+05)
        M-006-15.pgm (with distance: 3.055535e+06)
```

```
        M-006-17.pgm (with distance: 5.047455e+06)

        M-007-16.pgm (with distance: 7.073582e+06)


Testing image   2:  M-006-02.pgm

     The 5 most similar images are:

        M-006-01.pgm (with distance: 1.896611e+05)

        M-006-03.pgm (with distance: 1.106888e+06)

        M-006-15.pgm (with distance: 2.492115e+06)

        M-006-17.pgm (with distance: 5.254893e+06)

        M-007-02.pgm (with distance: 7.800299e+06)


Testing image   3:  M-006-03.pgm

     The 5 most similar images are:

        M-006-03.pgm (with distance: 1.832766e-06)

        M-006-01.pgm (with distance: 5.901727e+05)

        M-006-15.pgm (with distance: 5.635663e+06)

        M-006-17.pgm (with distance: 5.999275e+06)

        M-007-16.pgm (with distance: 7.536627e+06)


Testing image   4:  M-006-04.pgm

     The 5 most similar images are:

        M-006-03.pgm (with distance: 1.843232e+06)

        M-006-01.pgm (with distance: 2.116935e+06)

        M-006-17.pgm (with distance: 2.826935e+06)

        M-007-04.pgm (with distance: 5.540024e+06)
```

```
        M-006-15.pgm (with distance: 6.124306e+06)


Testing image   5:  M-006-05.pgm

     The 5 most similar images are:

          M-006-05.pgm (with distance: 9.897152e-06)

          M-007-18.pgm (with distance: 9.469537e+06)

          M-006-03.pgm (with distance: 1.334883e+07)

          M-006-01.pgm (with distance: 1.368118e+07)

          M-006-15.pgm (with distance: 1.485872e+07)


Testing image   6:  M-006-06.pgm

     The 5 most similar images are:

          M-006-19.pgm (with distance: 2.285052e+06)

          M-006-07.pgm (with distance: 8.904606e+06)

          M-007-06.pgm (with distance: 1.006459e+07)

          M-006-03.pgm (with distance: 2.063751e+07)

          M-006-05.pgm (with distance: 2.221928e+07)


Testing image   7:  M-006-07.pgm

     The 5 most similar images are:

          M-006-07.pgm (with distance: 4.729683e-05)

          M-006-19.pgm (with distance: 1.311651e+07)

          M-006-05.pgm (with distance: 1.650699e+07)

          M-007-06.pgm (with distance: 2.417780e+07)

          M-007-18.pgm (with distance: 2.732217e+07)
```

```
Testing image   8:  M-006-08.pgm

     The 5 most similar images are:

          M-006-01.pgm (with distance: 6.425035e+06)

          M-006-03.pgm (with distance: 7.141568e+06)

          M-006-09.pgm (with distance: 9.878616e+06)

          M-007-08.pgm (with distance: 1.023277e+07)

          M-007-02.pgm (with distance: 1.158481e+07)


Testing image   9:  M-006-09.pgm

     The 5 most similar images are:

          M-006-09.pgm (with distance: 3.506449e-05)

          M-006-05.pgm (with distance: 1.726805e+07)

          M-006-01.pgm (with distance: 1.777003e+07)

          M-006-03.pgm (with distance: 1.799394e+07)

          M-006-15.pgm (with distance: 2.271107e+07)


Testing image  10:  M-006-10.pgm

     The 5 most similar images are:

          M-007-10.pgm (with distance: 1.573539e+07)

          M-006-09.pgm (with distance: 1.675080e+07)

          M-006-03.pgm (with distance: 1.724765e+07)

          M-006-19.pgm (with distance: 1.726272e+07)

          M-006-01.pgm (with distance: 1.872914e+07)
```

```
Testing image  11:  M-006-11.pgm

     The 5 most similar images are:

          M-006-11.pgm (with distance: 2.603892e-05)

          M-006-13.pgm (with distance: 1.487193e+07)

          M-007-12.pgm (with distance: 1.654335e+07)

          M-006-01.pgm (with distance: 1.979736e+07)

          M-007-04.pgm (with distance: 2.035803e+07)


Testing image  12:  M-006-12.pgm

     The 5 most similar images are:

          M-006-11.pgm (with distance: 7.294065e+06)

          M-007-12.pgm (with distance: 1.315594e+07)

          M-006-13.pgm (with distance: 1.584151e+07)

          M-006-01.pgm (with distance: 1.598821e+07)

          M-006-15.pgm (with distance: 1.603912e+07)


Testing image  13:  M-006-13.pgm

     The 5 most similar images are:

          M-006-13.pgm (with distance: 8.736341e-06)

          M-006-11.pgm (with distance: 1.487190e+07)

          M-006-15.pgm (with distance: 2.344935e+07)

          M-006-01.pgm (with distance: 2.381486e+07)

          M-006-03.pgm (with distance: 2.541626e+07)


Testing image  14:  M-006-14.pgm
```

```
    The 5 most similar images are:

        M-006-15.pgm (with distance: 2.404401e+05)

        M-006-01.pgm (with distance: 1.962416e+06)

        M-006-03.pgm (with distance: 4.040666e+06)

        M-006-17.pgm (with distance: 4.469299e+06)

        M-007-16.pgm (with distance: 6.877905e+06)


Testing image  15:  M-006-15.pgm

    The 5 most similar images are:

        M-006-15.pgm (with distance: 4.579876e-06)

        M-006-01.pgm (with distance: 3.055534e+06)

        M-006-17.pgm (with distance: 4.877402e+06)

        M-006-03.pgm (with distance: 5.635665e+06)

        M-007-16.pgm (with distance: 8.353235e+06)


Testing image  16:  M-006-16.pgm

    The 5 most similar images are:

        M-006-15.pgm (with distance: 8.755798e+05)

        M-006-01.pgm (with distance: 1.236054e+06)

        M-006-03.pgm (with distance: 2.542833e+06)

        M-006-17.pgm (with distance: 3.164981e+06)

        M-007-16.pgm (with distance: 5.929124e+06)


Testing image  17:  M-006-17.pgm

    The 5 most similar images are:
```

```
        M-006-17.pgm (with distance: 7.535086e-06)
        M-006-15.pgm (with distance: 4.877400e+06)
        M-006-01.pgm (with distance: 5.047457e+06)
        M-006-03.pgm (with distance: 5.999278e+06)
        M-007-04.pgm (with distance: 8.614320e+06)


Testing image  18:  M-006-18.pgm
    The 5 most similar images are:
        M-006-05.pgm (with distance: 2.528206e+06)
        M-007-18.pgm (with distance: 5.709802e+06)
        M-006-15.pgm (with distance: 8.810099e+06)
        M-006-01.pgm (with distance: 1.199777e+07)
        M-006-17.pgm (with distance: 1.328190e+07)


Testing image  19:  M-006-19.pgm
    The 5 most similar images are:
        M-006-19.pgm (with distance: 3.630856e-05)
        M-007-06.pgm (with distance: 8.303457e+06)
        M-006-07.pgm (with distance: 1.311648e+07)
        M-006-15.pgm (with distance: 1.860064e+07)
        M-006-01.pgm (with distance: 2.199158e+07)


Script done on Fri Nov 28 16:38:18 2003
```

4.2 LLE results

I obtained following LLE results with matlab. The same training/testing images as the PCA's are used.

Interpretations: for example the first row: the first testing image (M-006-01.pgm) is most close to the 3rd training image (M–006–03.pgm), second close to the 17th traing image (M–006–17.pgm), and third close to the 15th training image (M–006–15.pgm). And so on.

The distances part has the same meaning.

```
------- LLE Face Recognition---------------------

----- The Rows are for testing image numbers----

------The colums are for the training images-------


****** The similiarity from testing image to training images------


  Columns 1 through 12


     3    17    15     4     9    14     5     8     2     1    19    13

    15    17     1     3     2     9     8     5    19     4    14    16

     1    15     2    17     9    16     8     3    19    12     5    11

     3    17     4    15    14    13     8     5     9     2    19    10

     9     5     7     2    18     8    19    17    16    15    14     4

    19     7     6    10    15    17     9     1     5     2     8     3

     7    19     5     9     6    18    10    17     8     2     4    14

     2     1     9    16    15     8    17     5    12    19     4     3
```

9	5	2	8	17	18	15	16	14	7	4	1
19	6	10	2	7	9	8	17	15	5	4	16
11	12	13	2	8	17	9	4	14	15	16	3
11	13	12	17	8	4	2	14	3	9	15	19
11	13	12	17	2	15	8	3	4	9	14	19
15	17	1	2	3	8	9	19	16	4	5	14
1	15	2	17	8	9	16	3	19	12	5	4
17	3	15	4	2	8	14	1	9	5	19	10
17	15	3	4	8	2	14	9	1	5	19	10
9	5	18	17	8	2	14	4	15	3	7	19
19	6	10	7	17	2	8	9	15	5	4	14

Columns 13 through 19

10	6	16	11	18	12	7
10	12	11	6	13	7	18
4	10	14	7	6	18	13
6	1	18	11	16	12	7
1	12	3	6	10	11	13
12	11	16	4	14	13	18
15	3	12	11	16	13	1
14	11	7	10	18	6	13
3	19	12	11	10	6	13
14	1	3	12	18	11	13
5	19	1	10	6	18	7

5	10	6	16	1	18	7
5	1	10	6	16	18	7
10	6	12	11	7	13	18
10	14	11	6	7	18	13
13	6	16	11	12	18	7
6	16	13	11	12	18	7
16	1	6	10	12	11	13
16	3	1	12	18	11	13

****** The distances from testing image to training images------

Columns 1 through 7

0.3530	0.5941	1.6341	5.0550	6.4978	6.5595	6.5804
0.3756	1.3521	1.7513	3.0442	5.5902	5.9341	7.3015
0.1664	2.3536	4.3199	4.6536	6.1244	6.8431	7.2208
0.6882	1.8912	3.5133	4.3656	4.7524	7.1065	7.3627
0.7036	1.8197	3.9002	5.0878	5.5876	5.6198	6.4599
1.1073	3.9262	6.0914	6.4420	6.5565	7.5482	7.5701
0.7650	5.5362	5.6742	7.5963	9.4366	10.3090	11.6667
2.0346	2.2489	2.5525	3.1865	3.4593	3.9447	4.4511
0.1085	1.2896	4.2430	4.6469	4.6803	5.3239	5.6887
1.3003	3.2364	3.3345	4.2244	4.3174	4.4014	4.5630
0.9636	1.9235	5.4101	6.4364	6.5934	7.0735	7.5360

1.5797	3.2312	3.5361	6.8757	7.4127	7.6020	7.7414
2.1854	3.8340	3.8788	4.8997	6.3845	6.4035	6.4684
0.1650	1.0447	1.5291	2.9475	4.4233	4.4847	5.2240
0.4532	1.6924	3.1038	3.5769	5.5828	5.6512	5.7492
0.1667	0.9118	1.0126	4.2893	5.0159	5.1094	5.7485
0.0498	1.0068	1.3839	3.4029	3.9226	3.9303	4.6962
0.6319	0.7129	4.4472	4.5290	5.2573	5.4832	5.6200
0.5663	2.2064	2.6913	4.2490	6.0976	6.1310	6.2935

Columns 8 through 14

6.6313	6.6505	6.7708	7.9754	9.0155	11.1155	11.8310
7.7701	7.9471	9.3280	11.0945	11.1708	12.1978	13.5610
9.6000	10.2552	10.3007	10.4986	13.0603	13.3045	13.5826
7.6020	8.4990	8.6160	9.6081	11.5582	11.7577	12.0444
6.5653	6.7401	7.3954	8.2219	8.4950	8.5753	9.2927
7.5771	8.2240	8.9298	10.6358	11.4301	12.3063	12.7526
14.7244	14.7637	15.0189	15.4736	15.6292	16.4274	17.1584
6.5792	7.3505	8.9614	9.4624	9.7978	9.8198	10.7065
6.4005	6.5537	6.5760	6.8441	7.2482	7.3755	7.8404
4.8047	5.3816	5.5726	6.6521	7.5362	7.5821	8.4545
8.2768	8.2859	8.6323	8.9962	9.6850	9.7856	9.8484
7.7789	8.4155	8.6170	8.9770	9.6613	9.9847	10.8050
6.4870	7.0431	7.2921	7.5515	8.0605	8.7574	9.3182
6.9446	7.3326	7.3538	8.0661	8.8805	9.2351	11.0588

8.6325	9.0087	9.7762	9.9298	11.0680	11.4383	12.3672
5.7749	5.8819	6.6091	7.1084	9.4574	9.7664	10.3995
5.3587	5.7391	6.4456	6.7702	8.3982	9.4187	9.7352
5.8108	6.1951	6.2329	6.4958	7.3779	8.6610	9.4477
6.5254	6.7929	7.1326	7.7891	9.0167	10.0958	10.3814

Columns 15 through 19

13.6408	14.4301	15.4268	15.7718	16.6948
13.7296	13.7307	14.4503	15.5971	19.6569
14.6236	15.5893	16.0181	21.1583	21.7439
13.6693	16.1998	16.2556	18.3334	18.9793
10.1201	10.3925	10.4497	11.2836	16.1491
13.3149	13.9065	15.7181	17.0992	18.9655
17.3584	17.4306	18.2880	18.7817	19.8717
11.1275	11.2160	12.5415	13.0947	19.4935
9.3233	10.9378	11.6281	11.9281	14.2997
9.2392	9.6256	10.1129	11.0794	14.0377
10.5872	10.8882	11.3893	13.1026	14.1761
10.9462	11.3761	12.3208	13.4887	15.0205
9.7917	10.1592	10.4004	13.9554	13.9686
11.3030	12.7402	14.7156	15.4184	17.1615
12.5648	13.7957	15.0387	19.2884	20.2657
11.3642	13.6962	14.3006	14.5830	15.9018
9.7688	12.8851	13.0479	13.1797	15.3585

11.1427	11.3179	12.1618	13.1087	13.2498
10.6272	11.4278	12.0764	12.3741	14.2182

5 What I will do

- Using different regularization factor to test its influence.
- It seems that the embeddings from ascending and descending eigenvalues have very small influence. I'll delve into this problem to see if it is a code bug and LLE's rotation-invariant feature.
- Design experiments with different combinations of large number of images for both PCA and LLE.
- **My question: what is good to use LLE's mapping to the embedding? Because for mapping an untrained image to embedding, I have calculated or defined its neighbors in the training data. After the mapping, the new point in embedding space with new closest neighbors will change? Or to what degree?**
- If I have time, I will have interests in one of the *open problems* proposed in the paper: the relationship between K and d.