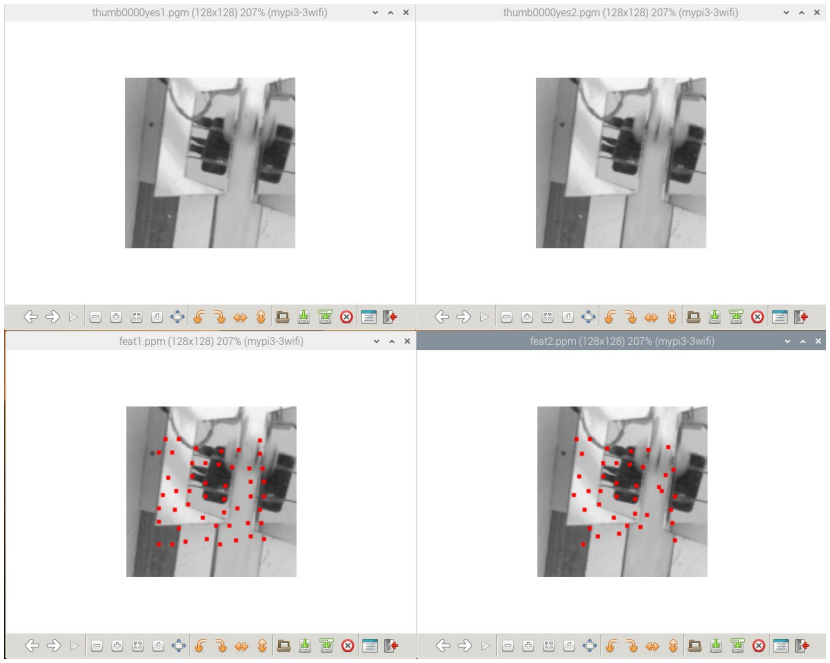
**********Draft**********

Principal component analysis (PCA)

08/31/19

**********Draft**********

Looking the feature extraction from ultibo_numlib/klt. Converted the 4 test images bmp images to pgm which was the format that was used.
Modified example1.c to use thumb0000yes1.pgm and thumb0000yes2.pgm



feat1.txt
Feel free to place comments here.

!!!
!!! Warning: This is a KLT data file. Do not modify below this line !!!

```
------------------------------
KLT Feature List
------------------------------

nFeatures = 100

feature | (x,y)=val
--------+-----------------
      0 | ( 59, 42)=12494
      1 | ( 49, 52)=11437
      2 | ( 71, 33)=11096
      3 | ( 39, 91)=10412
      4 | ( 59, 67)=10405
      5 | (100, 77)= 9171
      6 | ( 73, 69)= 8453
      7 | ( 24, 86)= 8441
      8 | ( 52, 31)= 7226
      9 | ( 49, 42)= 5225
     10 | ( 67, 89)= 3450
     11 | ( 74, 59)= 3192
     12 | (100, 35)= 2280
     13 | (101, 87)= 2264
     14 | ( 59, 57)= 1547
     15 | (103, 99)= 1533
     16 | (100, 25)= 1514
     17 | ( 46, 73)= 1183
     18 | (103, 67)= 1166
     19 | ( 79, 45)= 1089
     20 | ( 84, 32)= 1085
     21 | ( 47, 63)=  906
     22 | (102, 46)=  836
     23 | ( 39, 24)=  757
     24 | ( 34,103)=  730
     25 | ( 69, 43)=  473
     26 | ( 57, 83)=  468
     27 | ( 31, 53)=  407
     28 | ( 24, 34)=  270
     29 | ( 24, 76)=  236
     30 | ( 92, 46)=  210
     31 | ( 73, 79)=  168
     32 | (103, 56)=  145
     33 | ( 27, 66)=  130
     34 | ( 29, 24)=   97
     35 | ( 93, 56)=   80
     36 | ( 24,103)=   65
     37 | ( 93, 97)=   52
     38 | ( 36, 77)=   44
     39 | ( 77, 89)=   40
     40 | ( 44,101)=   28
```

41 | (60, 99)= 25
42 | (34, 34)= 21
43 | (93, 67)= 15
44 | (91, 87)= 13
45 | (70,103)=   5
46 | (82,100)=   4
47 | (83, 76)=   4
48 | (37, 63)=   1
49 | (-1, -1)= -1
50 | (-1, -1)= -1
51 | (-1, -1)= -1
52 | (-1, -1)= -1
53 | (-1, -1)= -1
54 | (-1, -1)= -1
55 | (-1, -1)= -1
56 | (-1, -1)= -1
57 | (-1, -1)= -1
58 | (-1, -1)= -1
59 | (-1, -1)= -1
60 | (-1, -1)= -1
61 | (-1, -1)= -1
62 | (-1, -1)= -1
63 | (-1, -1)= -1
64 | (-1, -1)= -1
65 | (-1, -1)= -1
66 | (-1, -1)= -1
67 | (-1, -1)= -1
68 | (-1, -1)= -1
69 | (-1, -1)= -1
70 | (-1, -1)= -1
71 | (-1, -1)= -1
72 | (-1, -1)= -1
73 | (-1, -1)= -1
74 | (-1, -1)= -1
75 | (-1, -1)= -1
76 | (-1, -1)= -1
77 | (-1, -1)= -1
78 | (-1, -1)= -1
79 | (-1, -1)= -1
80 | (-1, -1)= -1
81 | (-1, -1)= -1
82 | (-1, -1)= -1
83 | (-1, -1)= -1
84 | (-1, -1)= -1
85 | (-1, -1)= -1
86 | (-1, -1)= -1
87 | (-1, -1)= -1
88 | (-1, -1)= -1
89 | (-1, -1)= -1

90 | (-1, -1)= -1
91 | (-1, -1)= -1
92 | (-1, -1)= -1
93 | (-1, -1)= -1
94 | (-1, -1)= -1
95 | (-1, -1)= -1
96 | (-1, -1)= -1
97 | (-1, -1)= -1
98 | (-1, -1)= -1
99 | (-1, -1)= -1

feat2.txt
Feel free to place comments here.

!!
!!! Warning: This is a KLT data file. Do not modify below this line !!!

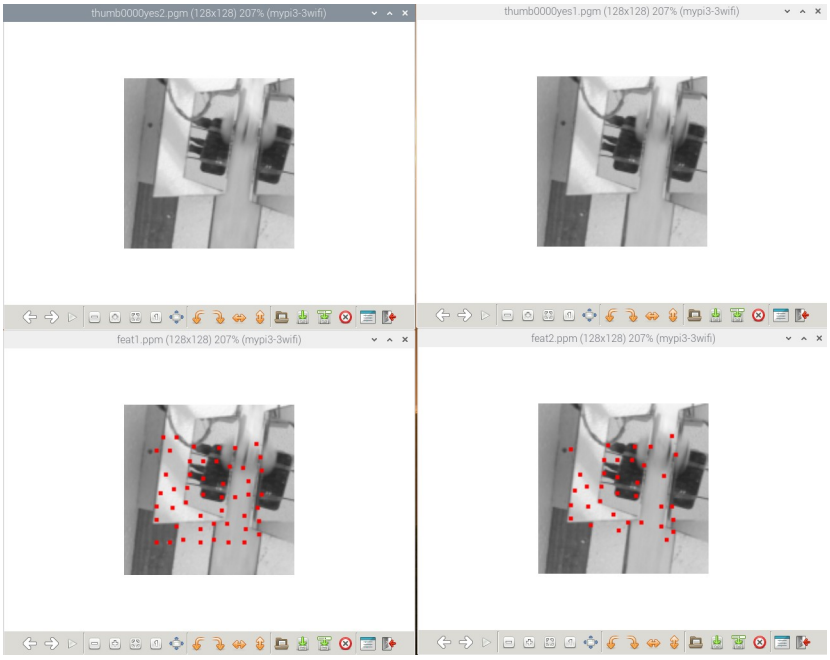
KLT Feature List
---

nFeatures = 100

feature | (x,y)=val
---+---
0 | (59.1, 42.1)= 0
1 | (49.2, 52.0)= 0
2 | (70.3, 33.2)= 0
3 | (38.9, 91.1)= 0
4 | (59.1, 66.9)= 0
5 | (100.0, 76.9)= 0
6 | (73.0, 68.8)= 0
7 | (-1.0, -1.0)= -4
8 | (52.2, 31.1)= 0
9 | (49.1, 42.1)= 0
10 | (66.9, 89.2)= 0
11 | (74.0, 58.9)= 0
12 | (-1.0, -1.0)= -4
13 | (101.0, 87.1)= 0
14 | (59.1, 56.9)= 0
15 | (102.8, 99.5)= 0
16 | (98.0, 29.9)= 0
17 | (46.2, 72.8)= 0
18 | (103.0, 66.9)= 0
19 | (79.3, 45.3)= 0
20 | (83.2, 32.1)= 0
21 | (47.2, 62.8)= 0
22 | (102.1, 47.5)= 0

23 | (39.2, 24.2)= 0
24 | (33.8,102.9)= 0
25 | (68.7, 43.5)= 0
26 | (57.5, 82.9)= 0
27 | (31.0, 52.1)= 0
28 | (-1.0, -1.0)= -4
29 | (-1.0, -1.0)= -4
30 | (95.9, 50.8)= 0
31 | (73.5, 80.0)= 0
32 | (-1.0, -1.0)= -4
33 | (26.9, 66.3)= 0
34 | (28.9, 24.4)= 0
35 | (90.7, 59.8)= 0
36 | (-1.0, -1.0)= -4
37 | (-1.0, -1.0)= -3
38 | (35.3, 77.3)= 0
39 | (77.3, 89.6)= 0
40 | (44.9, 96.9)= 0
41 | (60.9, 95.4)= 0
42 | (33.3, 35.3)= 0
43 | (93.0, 62.8)= 0
44 | (-1.0, -1.0)= -3
45 | (-1.0, -1.0)= -4
46 | (-1.0, -1.0)= -4
47 | (81.6, 81.2)= 0
48 | (37.8, 63.2)= 0
49 | (-1.0, -1.0)= -1
50 | (-1.0, -1.0)= -1
51 | (-1.0, -1.0)= -1
52 | (-1.0, -1.0)= -1
53 | (-1.0, -1.0)= -1
54 | (-1.0, -1.0)= -1
55 | (-1.0, -1.0)= -1
56 | (-1.0, -1.0)= -1
57 | (-1.0, -1.0)= -1
58 | (-1.0, -1.0)= -1
59 | (-1.0, -1.0)= -1
60 | (-1.0, -1.0)= -1
61 | (-1.0, -1.0)= -1
62 | (-1.0, -1.0)= -1
63 | (-1.0, -1.0)= -1
64 | (-1.0, -1.0)= -1
65 | (-1.0, -1.0)= -1
66 | (-1.0, -1.0)= -1
67 | (-1.0, -1.0)= -1
68 | (-1.0, -1.0)= -1
69 | (-1.0, -1.0)= -1
70 | (-1.0, -1.0)= -1
71 | (-1.0, -1.0)= -1

72 | (-1.0, -1.0)= -1
73 | (-1.0, -1.0)= -1
74 | (-1.0, -1.0)= -1
75 | (-1.0, -1.0)= -1
76 | (-1.0, -1.0)= -1
77 | (-1.0, -1.0)= -1
78 | (-1.0, -1.0)= -1
79 | (-1.0, -1.0)= -1
80 | (-1.0, -1.0)= -1
81 | (-1.0, -1.0)= -1
82 | (-1.0, -1.0)= -1
83 | (-1.0, -1.0)= -1
84 | (-1.0, -1.0)= -1
85 | (-1.0, -1.0)= -1
86 | (-1.0, -1.0)= -1
87 | (-1.0, -1.0)= -1
88 | (-1.0, -1.0)= -1
89 | (-1.0, -1.0)= -1
90 | (-1.0, -1.0)= -1
91 | (-1.0, -1.0)= -1
92 | (-1.0, -1.0)= -1
93 | (-1.0, -1.0)= -1
94 | (-1.0, -1.0)= -1
95 | (-1.0, -1.0)= -1
96 | (-1.0, -1.0)= -1
97 | (-1.0, -1.0)= -1
98 | (-1.0, -1.0)= -1
99 | (-1.0, -1.0)= -1
end of feat.txt



Modified example1.c to use thumb0000yes2.pgm and thumb0000yes1.pgm

feat1.txt
Feel free to place comments here.

!!!
!!! Warning: This is a KLT data file. Do not modify below this line !!!

KLT Feature List
---

nFeatures = 100

feature | (x,y)=val
--------+----------------
      0 | (59, 42)=12951
      1 | (71, 32)=11510
      2 | (49, 52)=11472
      3 | (59, 67)=10930
      4 | (39, 91)=10416
      5 | (100, 77)= 9166
      6 | (73, 69)= 8837
      7 | (24, 86)= 8779
      8 | (52, 31)= 7268
      9 | (49, 42)= 5364
     10 | (74, 59)= 3307
     11 | (67, 89)= 2881

12 | (101, 87)= 2445
13 | (83, 32)= 1920
14 | (102, 39)= 1830
15 | (101, 97)= 1785
16 | (103, 49)= 1728
17 | (59, 55)= 1637
18 | (103, 67)= 1183
19 | (46, 73)= 1097
20 | (79, 46)= 1035
21 | (69, 42)= 974
22 | (47, 62)= 929
23 | (89, 47)= 928
24 | (99, 29)= 804
25 | (39, 24)= 781
26 | (34,103)= 731
27 | (57, 83)= 470
28 | (31, 52)= 415
29 | (24, 34)= 256
30 | (73, 79)= 253
31 | (24, 76)= 232
32 | (93, 57)= 121
33 | (27, 66)= 121
34 | (29, 24)=   93
35 | (91, 93)=   60
36 | (24,103)=   57
37 | (36, 77)=   54
38 | (77, 89)=   42
39 | (67,101)=   33
40 | (34, 34)=   24
41 | (44,101)=   23
42 | (90,103)=   23
43 | (78,103)=   19
44 | (93, 67)=   15
45 | (57, 93)=   8
46 | (90, 83)=   7
47 | (57,103)=   7
48 | (37, 63)=   2
49 | (83, 69)=   2
50 | (-1, -1)=   -1
51 | (-1, -1)=   -1
52 | (-1, -1)=   -1
53 | (-1, -1)=   -1
54 | (-1, -1)=   -1
55 | (-1, -1)=   -1
56 | (-1, -1)=   -1
57 | (-1, -1)=   -1
58 | (-1, -1)=   -1
59 | (-1, -1)=   -1
60 | (-1, -1)=   -1

61 | (-1, -1)= -1
62 | (-1, -1)= -1
63 | (-1, -1)= -1
64 | (-1, -1)= -1
65 | (-1, -1)= -1
66 | (-1, -1)= -1
67 | (-1, -1)= -1
68 | (-1, -1)= -1
69 | (-1, -1)= -1
70 | (-1, -1)= -1
71 | (-1, -1)= -1
72 | (-1, -1)= -1
73 | (-1, -1)= -1
74 | (-1, -1)= -1
75 | (-1, -1)= -1
76 | (-1, -1)= -1
77 | (-1, -1)= -1
78 | (-1, -1)= -1
79 | (-1, -1)= -1
80 | (-1, -1)= -1
81 | (-1, -1)= -1
82 | (-1, -1)= -1
83 | (-1, -1)= -1
84 | (-1, -1)= -1
85 | (-1, -1)= -1
86 | (-1, -1)= -1
87 | (-1, -1)= -1
88 | (-1, -1)= -1
89 | (-1, -1)= -1
90 | (-1, -1)= -1
91 | (-1, -1)= -1
92 | (-1, -1)= -1
93 | (-1, -1)= -1
94 | (-1, -1)= -1
95 | (-1, -1)= -1
96 | (-1, -1)= -1
97 | (-1, -1)= -1
98 | (-1, -1)= -1
99 | (-1, -1)= -1

feat2.txt
Feel free to place comments here.

!!!
!!! Warning: This is a KLT data file. Do not modify below this line !!!

```
------------------------------
KLT Feature List
------------------------------

nFeatures = 100

feature | (x,y)=val
--------+---------------------
      0 | ( 58.8, 41.9)=    0
      1 | ( 71.7, 31.9)=    0
      2 | ( 48.8, 52.0)=    0
      3 | ( 58.9, 67.0)=    0
      4 | ( 39.1, 90.9)=    0
      5 | (100.0, 77.1)=    0
      6 | ( 73.0, 69.1)=    0
      7 | ( 24.1, 85.9)=    0
      8 | ( 51.9, 30.9)=    0
      9 | ( 49.0, 41.9)=    0
     10 | ( 74.0, 59.1)=    0
     11 | ( 67.1, 88.8)=    0
     12 | (101.0, 86.9)=    0
     13 | ( 83.7, 31.9)=    0
     14 | (102.8, 38.2)=    0
     15 | (101.3, 96.2)=    0
     16 | ( -1.0, -1.0)=   -4
     17 | ( 58.9, 55.0)=    0
     18 | ( -1.0, -1.0)=   -4
     19 | ( 45.9, 73.2)=    0
     20 | ( 78.7, 45.7)=    0
     21 | ( 69.6, 41.8)=    0
     22 | ( 46.9, 62.3)=    0
     23 | ( -1.0, -1.0)=   -5
     24 | (100.3, 24.0)=    0
     25 | ( -1.0, -1.0)=   -4
     26 | ( -1.0, -1.0)=   -4
     27 | ( 56.4, 83.0)=    0
     28 | ( 31.0, 52.9)=    0
     29 | ( 24.1, 33.9)=    0
     30 | ( -1.0, -1.0)=   -3
     31 | ( 24.1, 75.6)=    0
     32 | ( 93.8, 54.0)=    0
     33 | ( 27.2, 65.4)=    0
     34 | ( -1.0, -1.0)=   -4
     35 | ( 92.4, 92.2)=    0
     36 | ( -1.0, -1.0)=   -4
     37 | ( 36.7, 76.6)=    0
     38 | ( 76.7, 88.6)=    0
     39 | ( -1.0, -1.0)=   -4
     40 | ( -1.0, -1.0)=   -3
```

41 | (-1.0, -1.0)= -4
42 | (96.3,102.3)= 0
43 | (-1.0, -1.0)= -3
44 | (-1.0, -1.0)= -3
45 | (59.7, 94.7)= 0
46 | (91.6, 77.4)= 0
47 | (-1.0, -1.0)= -4
48 | (35.9, 62.4)= 0
49 | (-1.0, -1.0)= -3
50 | (-1.0, -1.0)= -1
51 | (-1.0, -1.0)= -1
52 | (-1.0, -1.0)= -1
53 | (-1.0, -1.0)= -1
54 | (-1.0, -1.0)= -1
55 | (-1.0, -1.0)= -1
56 | (-1.0, -1.0)= -1
57 | (-1.0, -1.0)= -1
58 | (-1.0, -1.0)= -1
59 | (-1.0, -1.0)= -1
60 | (-1.0, -1.0)= -1
61 | (-1.0, -1.0)= -1
62 | (-1.0, -1.0)= -1
63 | (-1.0, -1.0)= -1
64 | (-1.0, -1.0)= -1
65 | (-1.0, -1.0)= -1
66 | (-1.0, -1.0)= -1
67 | (-1.0, -1.0)= -1
68 | (-1.0, -1.0)= -1
69 | (-1.0, -1.0)= -1
70 | (-1.0, -1.0)= -1
71 | (-1.0, -1.0)= -1
72 | (-1.0, -1.0)= -1
73 | (-1.0, -1.0)= -1
74 | (-1.0, -1.0)= -1
75 | (-1.0, -1.0)= -1
76 | (-1.0, -1.0)= -1
77 | (-1.0, -1.0)= -1
78 | (-1.0, -1.0)= -1
79 | (-1.0, -1.0)= -1
80 | (-1.0, -1.0)= -1
81 | (-1.0, -1.0)= -1
82 | (-1.0, -1.0)= -1
83 | (-1.0, -1.0)= -1
84 | (-1.0, -1.0)= -1
85 | (-1.0, -1.0)= -1
86 | (-1.0, -1.0)= -1
87 | (-1.0, -1.0)= -1
88 | (-1.0, -1.0)= -1
89 | (-1.0, -1.0)= -1

90 | (-1.0, -1.0)= -1
91 | (-1.0, -1.0)= -1
92 | (-1.0, -1.0)= -1
93 | (-1.0, -1.0)= -1
94 | (-1.0, -1.0)= -1
95 | (-1.0, -1.0)= -1
96 | (-1.0, -1.0)= -1
97 | (-1.0, -1.0)= -1
98 | (-1.0, -1.0)= -1
99 | (-1.0, -1.0)= -1
end of feat.txt

*************Draft*************

Principal component analysis (PCA)

08/29/19

*************Draft*************

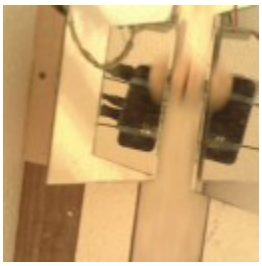
Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables (entities each of which takes on various numerical values) into a set of values of linearly uncorrelated variables called principal components.

Machine Learning — Singular Value Decomposition (SVD) & Principal Component Analysis (PCA)

Analysis of 4 images 2 cracked and 2 not cracked. The (SVD) or (PCA) does appears to track that pistachios that are cracked do have a higher (PCA) than pistachios that are not cracked.
Thumb0000yes1.bmp

thumb0000no1.bmp

Thumb0000yes2.bmp



thumb0000n2.bmp

thumb0000yes1.bmp thumb0000no1.bmp thumb0000yes2.bmp thumb0000n2.bmp
pca1(1:20)
ans =

2.5118e+04	2.4510e+04	2.5212e+04	2.4252e+04
4.1047e+03			
1.7342e+03			
1.3414e+03			
1.3223e+03			
1.0863e+03			
8.6049e+02			
7.6984e+02			
6.8771e+02			
6.0650e+02			
5.2599e+02			
4.5459e+02			
4.4436e+02			
3.8315e+02			

3.7725e+02
3.3203e+02
3.1981e+02
2.7991e+02
2.7412e+02
2.5770e+02

pca2(1:20)
ans =

2.0217e+04 1.9552e+04 2.0434e+04 1.9248e+04
3.8104e+03
1.5775e+03
1.3825e+03
1.1628e+03
1.0376e+03
7.8174e+02
7.4592e+02
6.8873e+02
5.8089e+02
5.1885e+02
4.6897e+02
4.5024e+02
4.0410e+02
3.6088e+02
3.2620e+02
3.0089e+02
2.8690e+02
2.6073e+02
2.4677e+02

pca3(1:20)
ans =

1.3455e+04 1.2802e+04 1.3600e+04 1.2537e+04
2.7543e+03
1.2505e+03
1.0014e+03
8.8897e+02
7.7139e+02
6.2903e+02
5.8134e+02
5.3249e+02
4.6860e+02
4.0902e+02
3.9088e+02
3.6356e+02
3.4791e+02
3.0013e+02

2.6766e+02
2.5222e+02
2.3809e+02
2.1705e+02
2.0159e+02

thumb0000no1.bmp
pca1(1:20)
ans =

2.4510e+04
4.0433e+03
1.9649e+03
1.4272e+03
1.3475e+03
9.9684e+02
8.2375e+02
7.9589e+02
6.8341e+02
5.8102e+02
5.0413e+02
4.6857e+02
4.2710e+02
4.0367e+02
3.7746e+02
3.4601e+02
3.3557e+02
2.9683e+02
2.8394e+02
2.5602e+02

pca2(1:20)
ans =

1.9552e+04
3.6803e+03
1.6822e+03
1.4549e+03
1.1840e+03
9.1180e+02
7.5005e+02
7.1683e+02
6.8642e+02
5.3968e+02
4.8279e+02
4.4007e+02
4.3046e+02
4.0756e+02
3.5801e+02

```
   3.3369e+02
   3.1684e+02
   2.8013e+02
   2.6143e+02
   2.4284e+02

pca3(1:20)
ans =

   1.2802e+04
   2.6358e+03
   1.2603e+03
   1.1070e+03
   8.7383e+02
   7.0593e+02
   5.8519e+02
   5.8225e+02
   5.2708e+02
   4.2259e+02
   3.9897e+02
   3.7471e+02
   3.5758e+02
   3.3290e+02
   3.1216e+02
   2.7739e+02
   2.5960e+02
   2.3723e+02
   2.1209e+02
   2.0476e+02

thumb0000yes2.bmp
pca1(1:20)
ans =

   2.5212e+04
   4.0210e+03
   1.8347e+03
   1.4258e+03
   1.3558e+03
   1.0733e+03
   8.3836e+02
   7.6427e+02
   6.8187e+02
   6.1109e+02
   5.2345e+02
   4.8893e+02
   4.5993e+02
   4.1018e+02
   4.0371e+02
```

```
   3.5510e+02
   3.3618e+02
   2.9982e+02
   2.6943e+02
   2.5862e+02

pca2(1:20)
ans =

   2.0434e+04
   3.7564e+03
   1.6314e+03
   1.4176e+03
   1.2380e+03
   1.0131e+03
   7.6505e+02
   7.4708e+02
   6.7221e+02
   5.7194e+02
   5.2257e+02
   4.7293e+02
   4.6234e+02
   4.2547e+02
   3.7508e+02
   3.3221e+02
   3.3095e+02
   2.8798e+02
   2.6839e+02
   2.5635e+02

pca3(1:20)
ans =

   1.3600e+04
   2.7226e+03
   1.2751e+03
   1.0553e+03
   9.2998e+02
   7.9118e+02
   6.0423e+02
   5.9610e+02
   5.1626e+02
   4.6031e+02
   4.2646e+02
   4.0938e+02
   3.8739e+02
   3.5952e+02
   3.1919e+02
   2.8066e+02
```

2.6825e+02
2.4342e+02
2.2798e+02
2.1238e+02

thumb0000n2.bmp

pca1(1:20)
ans =

2.4252e+04
4.3798e+03
1.6566e+03
1.4539e+03
1.2313e+03
9.4545e+02
8.6362e+02
7.0752e+02
6.3207e+02
5.8339e+02
5.0927e+02
4.6314e+02
4.3968e+02
3.7103e+02
3.2726e+02
3.1503e+02
2.9399e+02
2.7929e+02
2.6932e+02
2.6126e+02

>> pca2(1:20)
ans =

1.9248e+04
3.8751e+03
1.6063e+03
1.3434e+03
1.0795e+03
8.8676e+02
7.6481e+02
6.9949e+02
5.9415e+02
5.6022e+02
4.9497e+02
4.3213e+02
4.0966e+02
3.5401e+02
3.1833e+02

```
   2.9621e+02
   2.8560e+02
   2.7431e+02
   2.5903e+02
   2.4629e+02

>> pca3(1:20)
ans =

   1.2537e+04
   2.7423e+03
   1.2570e+03
   1.0034e+03
   7.9929e+02
   6.7685e+02
   5.8549e+02
   5.6615e+02
   4.7492e+02
   4.3317e+02
   4.0130e+02
   3.5044e+02
   3.3603e+02
   3.0458e+02
   2.7552e+02
   2.5449e+02
   2.4492e+02
   2.2631e+02
   2.1090e+02
   2.0487e+02
```