COEN 166 Artificial Intelligence
Fall 2018

Lab Assignment #4: Face Recognition
Assigned on October 29, 2018, Due on November 27, 2018

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1 Requirements

1.1 Version

This program is designed to run with `Python 3.6`.

1.2 Modules

The following modules must be installed prior to usage:

- `cv2` (opencv-python)
- `numpy`
- `sklearn` (scikit-learn)

2 Usage

This program is designed to work with the `att_faces_10` directory. However, any directory if images should work as long as it is structured like so:

```
training
├── s1
│   ├── 1.pgm
│   ├── 2.pgm
│   ├── 3.pgm
│   └── ...
├── s2
├── s3
├── s4
└── ...
```

```
testing
├── s1
│   ├── 1.pgm
│   ├── 2.pgm
│   ├── 3.pgm
│   └── ...
├── s2
├── s3
├── s4
└── ...
```

To run the face recognition algorithm on the provided images, navigate to the project directory and type the following command into the terminal:

```
$ python3 example_model.py
```

Refer to the terminal output to verify/analyze each step of the program.

3 Face Recognition Algorithm

3.1 Pseudocode

3.1.1 Read Images

```
for every file in directory:
    subject = get subject name
    add subject name to list
    read image
    if image is not empty:
        add image to list
return image list, labels list
```

3.1.2 Convert Images to Vector

```
D = height * width
N = number of images
allocate space for images of size D * N
for every image in image list:
    flatten 2D image to 1D vector
    add flattened vector to matrix
return matrix
```

3.1.3 Perform Principal Component Analysis

```
apply PCA to data matrix with current rank components
fit the model with training data matrix
fit the model with testing data matrix
apply dimensional reduction on both matrices
```

```
return both reduced matrices
```

3.1.4 Apply K-Nearest-Neighbors Algorithm

```
create the kNN classifier
fit classifier to the training data
use subject labels as target values
return classifier
```

3.1.5 Predict Subject Labels

```
use fitted kNN classifier
predict label of current model
display predicted and actual labels
```

3.1.6 Determine Accuracy

```
score mean accuracy on given test data and labels
```

3.2 Explanation

3.2.1 Read Images

Iterate through all files in the given path. Perform a regex search for the subject directory. Add subject to list of subject labels. Read image from file as grayscale. Add image to list if read correctly. Return the image and label lists

3.2.2 Convert Images to Vector

Stack N training images of all 10 subjects to form a matrix of size D X N. Create an all-zero array to allocate space for images. Flatten image to 1D vector. Add flattened image to matrix. Return the matrix.

3.2.3 Perform Principal Component Analysis

Import the scikit PCA function. Perform linear dimensionality reduction using Singular Value Decomposition of the data to project it to a lower dimensional space. Fit the PCA model with the training and testing matrices. Apply dimensional reduction to both matrices. Return both reduced matrices.

3.2.4 Apply K-Nearest-Neighbors Algorithm

Import the sciki KNN function to create the classifier. Fit the classifier using the training matrix as the training data and training labels as target values. Return the classifier.

3.2.5 Predict Subject Labels

Use the scikit `predict()` function to predict the class labels for the provided KNN classifier. Iterate through all data models. Display the predicted and actual subjects of each model. Write the results to a text file.

3.2.6 Determine Accuracy

Use the scikit `score()` function to calculate the mean accuracy for each rank. Return the accuracy as both a decimal and percentage.

4 Recognition Accuracy

To determine the algorithm's accuracy, I recorded both the predicted and actual subject labels for each rank. Accuracy for each rank was calculated by finding the percentage of correctly identified subjects.

4.1 Rank 1

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
```

```
Predicted: s5 Actual: s2
Predicted: s5 Actual: s2
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s3
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s3
Predicted: s5 Actual: s4
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s9 Actual: s10
Predicted: s3 Actual: s8
Predicted: s9 Actual: s8
Predicted: s4 Actual: s8
Predicted: s8 Actual: s8 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s4 Actual: s6
Predicted: s3 Actual: s6
Predicted: s4 Actual: s6
Predicted: s4 Actual: s6
Predicted: s9 Actual: s7
Predicted: s9 Actual: s7
Predicted: s9 Actual: s7
Predicted: s4 Actual: s7
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s8 Actual: s9
```

With $rank = 1$, the algorithm correctly identified 22/40 or 55% of subjects.

4.2 Rank 2

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s3
Predicted: s4 Actual: s3
Predicted: s4 Actual: s3
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s8 Actual: s10
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s4 Actual: s8
Predicted: s8 Actual: s8 MATCHED
Predicted: s5 Actual: s1
Predicted: s5 Actual: s1
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s8 Actual: s7
Predicted: s7 Actual: s7 MATCHED
Predicted: s4 Actual: s7
```

```
Predicted: s9 Actual: s9 MATCHED
Predicted: s7 Actual: s9
Predicted: s9 Actual: s9 MATCHED
Predicted: s7 Actual: s9
```

With $rank = 2$, the algorithm correctly identified 29/40 or 72.5% of subjects.

4.3 Rank 3

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s7 Actual: s3
Predicted: s4 Actual: s3
Predicted: s4 Actual: s3
Predicted: s4 Actual: s3
Predicted: s5 Actual: s4
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s5 Actual: s1
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s6 Actual: s6 MATCHED
```

```
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s10 Actual: s7
Predicted: s4 Actual: s7
Predicted: s7 Actual: s9
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
```

With $rank = 3$, the algorithm correctly identified 31/40 or 77.5% of subjects.

4.4 Rank 6

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s4 Actual: s3
Predicted: s4 Actual: s3
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s3 Actual: s4
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s4 Actual: s10
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
```

```
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
```

With $rank = 6$, the algorithm correctly identified 36/40 or 90% of subjects.

4.5 Rank 10

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
```

```
Predicted: s3 Actual: s4
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s8 Actual: s10
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s5 Actual: s1
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
```

With $rank = 10$, the algorithm correctly identified 37/40 or 92.5% of subjects.

4.6 Rank 20

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
```

```
Predicted: s2 Actual: s2 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s4 Actual: s10
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s5 Actual: s1
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
```

With $rank = 20$, the algorithm correctly identified 38/40 or 95% of subjects.

4.7 Rank 30

```
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s5 Actual: s5 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s2 Actual: s2 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s3 Actual: s3 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s4 Actual: s4 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s10 Actual: s10 MATCHED
Predicted: s4 Actual: s10
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s8 Actual: s8 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s5 Actual: s1
Predicted: s1 Actual: s1 MATCHED
Predicted: s1 Actual: s1 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s6 Actual: s6 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
Predicted: s7 Actual: s7 MATCHED
```

```
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
Predicted: s9 Actual: s9 MATCHED
```

With $rank = 30$, the algorithm correctly identified 38/40 or 95% of subjects.

4.8 Comments

From the output files generated from the predictions, it appears that the accuracy increases with rank. However, this increase is less substantial with higher order ranks. Figure 1 visualizes this relationship, depicting a logarithmic function.

Figure 1: Accuracy vs. Rank