Assignmnet 5: Principal Components Analysis

Benchmark testing of alternative modeling approaches using MNIST data set from chapter 3, page 79

Based on the F1 scores of the different models and subsets of data, I would recommend using the forest classifier before the PCA transformation since the F1 score was 94%

The predictive accuracy must be weighed against the costs of the model development and implementation. Therefore, I would recommend the random forest model since it is faster. The difference in speed is not large enough to use a model with lower accuracy.

In [65]:

```
import scipy.io
mnist = scipy.io.loadmat('mnist-original.mat')
X, y = mnist['data'].T, mnist['label'].T
```

Observe mnist data

In [66]:

```
mnist
```

Out[66]:

```
{'__globals__': [],
 '__header__': b'MATLAB 5.0 MAT-file Platform: posix, Created on: Sun Mar 30
03:19:02 2014',
 '__version__': '1.0',
 'data': array([[0, 0, 0, ..., 0, 0, 0],
        [0, 0, 0, ..., 0, 0, 0],
        [0, 0, 0, ..., 0, 0, 0],
        ...,
        [0, 0, 0, ..., 0, 0, 0],
        [0, 0, 0, ..., 0, 0, 0],
        [0, 0, 0, ..., 0, 0, 0]], dtype=uint8),
 'label': array([[0., 0., 0., ..., 9., 9., 9.]]),
 'mldata_descr_ordering': array([[array(['label'], dtype='<U5'), array(['dat
a'], dtype='<U4')]],
       dtype=object)}
```

Review the shape of the predictor variables and the response varaiable

In [67]:

```
X.shape
```

Out[67]:

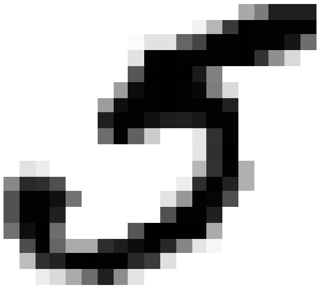
```
(70000, 784)
```

```
In [68]: y.shape
```

```
Out[68]: (70000, 1)
```

Observe a sample digit

```
In [69]: import matplotlib
         import matplotlib.pyplot as plt
         some_digit = X[36000]
         some_digit_image = some_digit.reshape(28, 28)
         plt.imshow(some_digit_image,cmap = matplotlib.cm.binary, interpolation="nearest")
         plt.axis("off")
         plt.show()
```



```
In [70]: # see if y can predict the correct value
         y[36000]
```

```
Out[70]: array([5.])
```

Utilize the first 60,000 as a model development set and the final 10,000 as a holdout test set. Next, we develop a multiclass classifier

```
In [71]: X_train, X_test, y_train, y_test = X[: 60000], X[ 60000:], y[: 60000], y[ 60000:]
```

Begin by fitting a random forest classifier using the full set of 784 explanatory variables and the model development set of 60,000 observation. Below I walk through a stochastic Grandient Descent classifier model as an example.

In [72]:

```
import time
start = time.time()
import numpy as np
shuffle_index = np.random.permutation(60000)
X_train, y_train = X_train[shuffle_index],y_train[shuffle_index]

# will use the multiclass classification method
from sklearn.linear_model import SGDClassifier
sgd_clf = SGDClassifier(random_state=42)
sgd_clf.fit(X_train, y_train)
end = time.time()
print(end-start)
```

```
C:\Users\lcamero\AppData\Local\Continuum\Anaconda3\lib\site-packages\sklearn
\utils\validation.py:526: DataConversionWarning: A column-vector y was passed
when a 1d array was expected. Please change the shape of y to (n_samples, ),
for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
9.818561792373657
```

This model took 9 seconds to run. Next, I predict the response variable and score the model using the F1 score.

In [74]:

```
# reshape the y train array
c,r = y_test.shape
y_test = y_test.reshape(c,)
```

In [115]:

```
start = time.time()
y_train_predict = cross_val_predict(sgd_clf, X_train, y_train, cv=3)
end = time.time()
print(end-start)
```

```
24.580405950546265
```

In [116]:

```
from sklearn.metrics import f1_score
```

In [117]:

```
f1_score(y_train, y_train_predict, average="macro")
```

Out[117]:

```
0.8669597087235005
```

Next I fit a random forest classifer

In [118]:

```
start = time.time()
from sklearn.ensemble import RandomForestClassifier
forest_clf = RandomForestClassifier(random_state=42)
forest_clf.fit(X_train, y_train)
end = time.time()
print(end-start)
```

```
10.599606275558472
```

This model took 18 seconds to complete. Next, we set up the y train predictor and use the F1 score to find the harmonic mean of precision and recall

In [119]:

```
start = time.time()
y_train_predict = cross_val_predict(forest_clf, X_train, y_train, cv=3)
end = time.time()
print(end-start)
```

```
26.368508338928223
```

In [120]:

```
f1_score(y_train, y_train_predict, average="macro")
```

```
Out[120]: 0.9397497464092263
```

Next use a Multiclass classifier using the K Neighbor

In [121]:

```
from sklearn.neighbors import KNeighborsClassifier
knn_clf = KNeighborsClassifier()
```

In [122]:

```
# create the response prediction array
from sklearn.model_selection import cross_val_predict
```

In [123]:

```
start = time.time()
y_test_predict = cross_val_predict(knn_clf, X_test, y_test, cv=3)
end = time.time()
print(end-start)
```

```
217.35143160820007
```

In [124]:

```
f1_score(y_test, y_test_predict, average="macro")
```

```
Out[124]: 0.9357079587489915
```

Compare test set performance across the two modeling approaches: 784 variable model versus the 95% PCA model.

Execute PCA on the full set of 70,000, generating PCA that represent 95 percent of the variability. It took 5 seconds.

In [86]:

```
from sklearn.decomposition import PCA
pca = PCA(X)
```

In [87]:

```
start = time.time()
pca = PCA(n_components=0.95)
X_reduced = pca.fit_transform(X)
end = time.time()
print(end-start)
```

```
17.362993240356445
```

In [88]:

```
start = time.time()
forest_clf.fit(X_reduced, y)
end = time.time()
print(end-start)
```

```
C:\Users\lcamero\AppData\Local\Continuum\Anaconda3\lib\site-packages\ipykerne
l\__main__.py:2: DataConversionWarning: A column-vector y was passed when a 1
d array was expected. Please change the shape of y to (n_samples,), for examp
le using ravel().
  from ipykernel import kernelapp as app
```

```
40.56231999397278
```

In [89]:

```
# reshape the y train array
c,r = y.shape
y = y.reshape(c,)
```

In [90]:

```
start = time.time()
y_predict = cross_val_predict(forest_clf, X_reduced, y, cv=3)
end = time.time()
print(end-start)
```

```
66.93882846832275
```

In [91]:

```
f1_score(y, y_predict, average="macro")
```

Out[91]:

```
0.881805729042257
```

Execute PCA on the set of 60,000 to build another random forest classifier.

In [92]:

```
pca = PCA()
pca.fit(X_train)
```

Out[92]:

```
PCA(copy=True, iterated_power='auto', n_components=None, random_state=None,
  svd_solver='auto', tol=0.0, whiten=False)
```

In [93]:

```
start = time.time()
pca = PCA(n_components=0.95)
X_reduced_train = pca.fit_transform(X_train)
end = time.time()
print(end-start)
```

```
12.896737575531006
```

In [94]:

```
start = time.time()
forest_clf.fit(X_reduced_train, y_train)
end = time.time()
print(end-start)
```

```
C:\Users\lcamero\AppData\Local\Continuum\Anaconda3\lib\site-packages\ipykerne
l\__main__.py:2: DataConversionWarning: A column-vector y was passed when a 1
d array was expected. Please change the shape of y to (n_samples,), for examp
le using ravel().
  from ipykernel import kernelapp as app

36.78110384941101
```

In [105]:

```
start = time.time()
y_train_predict = cross_val_predict(forest_clf, X_reduced_train, y_train, cv=3
)
end = time.time()
print(end-start)
```

```
62.59558033943176
```

In [106]:

```
y_train.shape
```

Out[106]:

```
(60000,)
```

In [107]:

```
y_train_predict.shape
```

Out[107]:

```
(60000,)
```

In [112]:

```
# reshape the y train array
# c,r = y_train.shape
# y_train = y_train.reshape(c,)
```

In [114]:

```
f1_score(y_train, y_train_predict, average="macro")
```

Out[114]:

```
0.8791328511686146
```

The flaw is that we did not use the test dataset. We refit the models using the test datasets and rescore. First we set up the random forest o the test dataset.

In [125]:

```
start = time.time()
from sklearn.ensemble import RandomForestClassifier
forest_clf = RandomForestClassifier(random_state=42)
forest_clf.fit(X_test, y_test)
end = time.time()
print(end-start)
```

```
1.9611120223999023
```

In [126]:

```
start = time.time()
y_test_predict = cross_val_predict(forest_clf, X_test, y_test, cv=3)
end = time.time()
print(end-start)
```

```
4.1352362632751465
```

In [127]:

```
f1_score(y_test, y_test_predict, average="macro")
```

Out[127]:

```
0.8906431987279889
```

Set up the PCA model on the test dataset.

In [130]:

```
pca = PCA()
pca.fit(X_test)
```

Out[130]:

```
PCA(copy=True, iterated_power='auto', n_components=None, random_state=None,
  svd_solver='auto', tol=0.0, whiten=False)
```

In [128]:

```
start = time.time()
pca = PCA(n_components=0.95)
X_reduced_test = pca.fit_transform(X_test)
end = time.time()
print(end-start)
```

```
3.0351736545562744
```

In [129]:

```
start = time.time()
forest_clf.fit(X_reduced_test, y_test)
end = time.time()
print(end-start)
```

```
3.583204746246338
```

In [131]:

```
start = time.time()
y_test_predict = cross_val_predict(forest_clf, X_reduced_test, y_test, cv=3)
end = time.time()
print(end-start)
```

```
7.81244683265686
```

In [132]:

```
f1_score(y_test, y_test_predict, average="macro")
```

Out[132]:

```
0.7674240306924224
```