jean-hw-2

September 3, 2024

KNN Classifier

[2]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.stats import multivariate_normal as mvn
```

[9]:
```
# Load the MNIST dataset
mnist_train = pd.read_csv('MNIST_train.csv')
mnist_test = pd.read_csv('MNIST_test.csv')
mnist_train.shape
```

[9]:
```
(60000, 787)
```

[13]:
```
mnist_train.describe ()
```

[13]:
```
        Unnamed: 0         index        labels        0        1        2  \
count  60000.000000  60000.000000  60000.000000  60000.0  60000.0  60000.0
mean   29999.500000  29999.500000      4.453933      0.0      0.0      0.0
std    17320.652413  17320.652413      2.889270      0.0      0.0      0.0
min        0.000000      0.000000      0.000000      0.0      0.0      0.0
25%    14999.750000  14999.750000      2.000000      0.0      0.0      0.0
50%    29999.500000  29999.500000      4.000000      0.0      0.0      0.0
75%    44999.250000  44999.250000      7.000000      0.0      0.0      0.0
max    59999.000000  59999.000000      9.000000      0.0      0.0      0.0

             3        4        5        6  …           774           775  \
count  60000.0  60000.0  60000.0  60000.0  …  60000.000000  60000.000000
mean       0.0      0.0      0.0      0.0  …      0.200433      0.088867
std        0.0      0.0      0.0      0.0  …      6.042472      3.956189
min        0.0      0.0      0.0      0.0  …      0.000000      0.000000
25%        0.0      0.0      0.0      0.0  …      0.000000      0.000000
50%        0.0      0.0      0.0      0.0  …      0.000000      0.000000
75%        0.0      0.0      0.0      0.0  …      0.000000      0.000000
max        0.0      0.0      0.0      0.0  …    254.000000    254.000000

                776           777           778         779      780      781  \
count  60000.000000  60000.000000  60000.000000  60000.0000  60000.0  60000.0
```

```
mean       0.045633      0.019283      0.015117      0.0020      0.0      0.0
std        2.839845      1.686770      1.678283      0.3466      0.0      0.0
min        0.000000      0.000000      0.000000      0.0000      0.0      0.0
25%        0.000000      0.000000      0.000000      0.0000      0.0      0.0
50%        0.000000      0.000000      0.000000      0.0000      0.0      0.0
75%        0.000000      0.000000      0.000000      0.0000      0.0      0.0
max      253.000000    253.000000    254.000000     62.0000      0.0      0.0

           782      783
count  60000.0  60000.0
mean       0.0      0.0
std        0.0      0.0
min        0.0      0.0
25%        0.0      0.0
50%        0.0      0.0
75%        0.0      0.0
max        0.0      0.0

[8 rows x 787 columns]
```

[3]:
```
mnist_test.head()
```

[3]:
```
   Unnamed: 0  index  labels  0  1  2  3  4  5  6  …  774  775  776  777  \
0           0      0       7  0  0  0  0  0  0  0  …    0    0    0    0
1           1      1       2  0  0  0  0  0  0  0  …    0    0    0    0
2           2      2       1  0  0  0  0  0  0  0  …    0    0    0    0
3           3      3       0  0  0  0  0  0  0  0  …    0    0    0    0
4           4      4       4  0  0  0  0  0  0  0  …    0    0    0    0

   778  779  780  781  782  783
0    0    0    0    0    0    0
1    0    0    0    0    0    0
2    0    0    0    0    0    0
3    0    0    0    0    0    0
4    0    0    0    0    0    0

[5 rows x 787 columns]
```

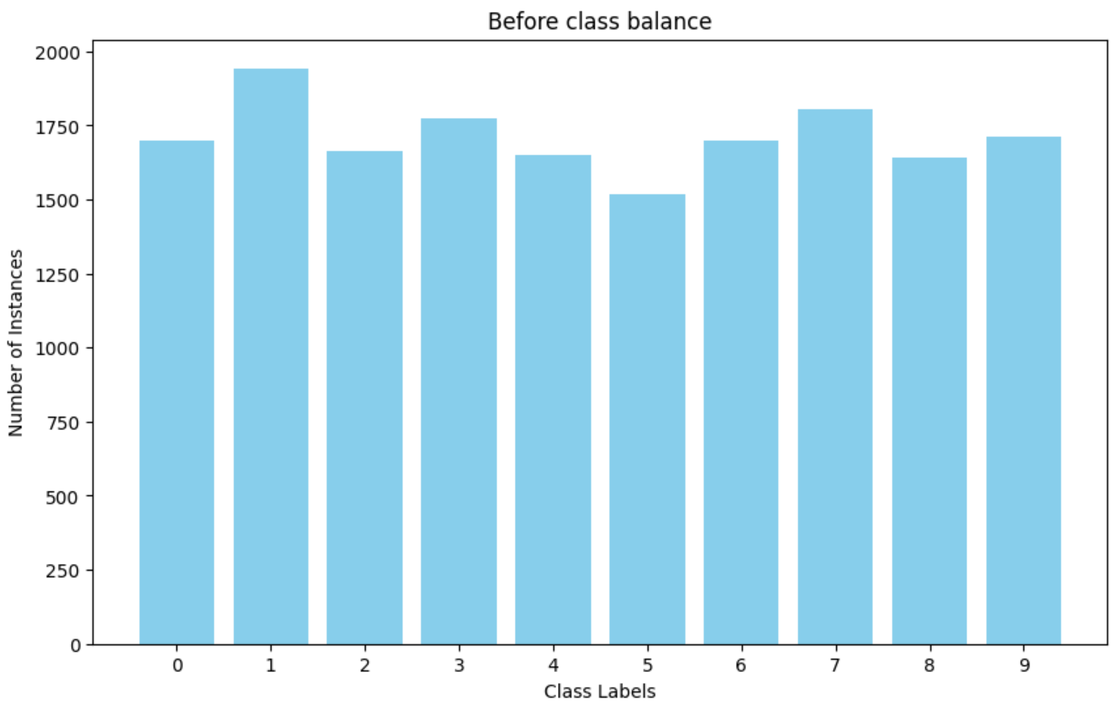
[4]:
```
# Separate features and labels and Normalize pixel values to [0, 1]
X_train = mnist_train.iloc[:, 3:].to_numpy() / 255.0
y_train = mnist_train['labels'].to_numpy()
X_test = mnist_test.iloc[:, 3:].to_numpy() / 255.0
y_test = mnist_test['labels'].to_numpy()
```

[10]:
```
import numpy as np
import matplotlib.pyplot as plt
```

```
unique, counts = np.unique(y_train, return_counts=True)
plt.figure(figsize=(10, 6))
plt.bar(unique, counts, color='skyblue')

plt.xlabel('Class Labels')
plt.ylabel('Number of Instances')
plt.title('Before class balance')
plt.xticks(unique)

plt.show()
```



[8]:
```
#Class balance
balanced_X_train = []
balanced_y_train = []

# Find the minimum class count (minority class)
min_count = min(counts)

# Loop through each class and undersample
for label in unique:
    class_indices = np.where(y_train == label)[0]
    class_X = X_train[class_indices]
    class_y = y_train[class_indices]
```

```
    # Randomly select min_count samples
    selected_indices = np.random.choice(len(class_y), min_count, replace=False)

    # Append the selected data
    balanced_X_train.append(class_X[selected_indices])
    balanced_y_train.append(class_y[selected_indices])

# Combine all balanced classes
balanced_X_train = np.vstack(balanced_X_train)
balanced_y_train = np.hstack(balanced_y_train)
```

[11]:
```
new_unique, new_counts = np.unique(balanced_y_train, return_counts=True)
print(dict(zip(new_unique, new_counts)))

# Plot the new class distribution
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 6))
plt.bar(new_unique, new_counts, color='lightgreen')
plt.xlabel('Class Labels')
plt.ylabel('Number of Instances')
plt.title('After Class balance')
plt.xticks(new_unique)
plt.show()
```

```
{0: 1516, 1: 1516, 2: 1516, 3: 1516, 4: 1516, 5: 1516, 6: 1516, 7: 1516, 8:
1516, 9: 1516}
```

##KNN Classifier

[18]:
```
# Implementing KNN Classifier
class KNNClassifier:
    def fit(self, X, y):
        self.X = X
        self.y = y

    def predict(self, X, K, epsilon=1e-3):
        N = len(X)
        y_hat = np.zeros(N)
        for i in range(N):
            dist2 = np.sum((self.X - X[i]) ** 2, axis=1)
            idxt = np.argsort(dist2)[:K]
            gamma_k = 1 / (np.sqrt(dist2[idxt] + epsilon))
            y_hat[i] = np.bincount(self.y[idxt], weights=gamma_k).argmax()
        return y_hat
```

[19]:
```
# Train and predict with KNN
knn = KNNClassifier()
knn.fit(X_train, y_train)

knn_predictions = knn.predict(X_test, K=5)
```

[20]:
```
def accuracy(y, y_hat):
    return np.mean(y == y_hat)

knn_accuracy = accuracy(y_test, knn_predictions)
print(f'KNN Accuracy: {knn_accuracy:.4f}')
```

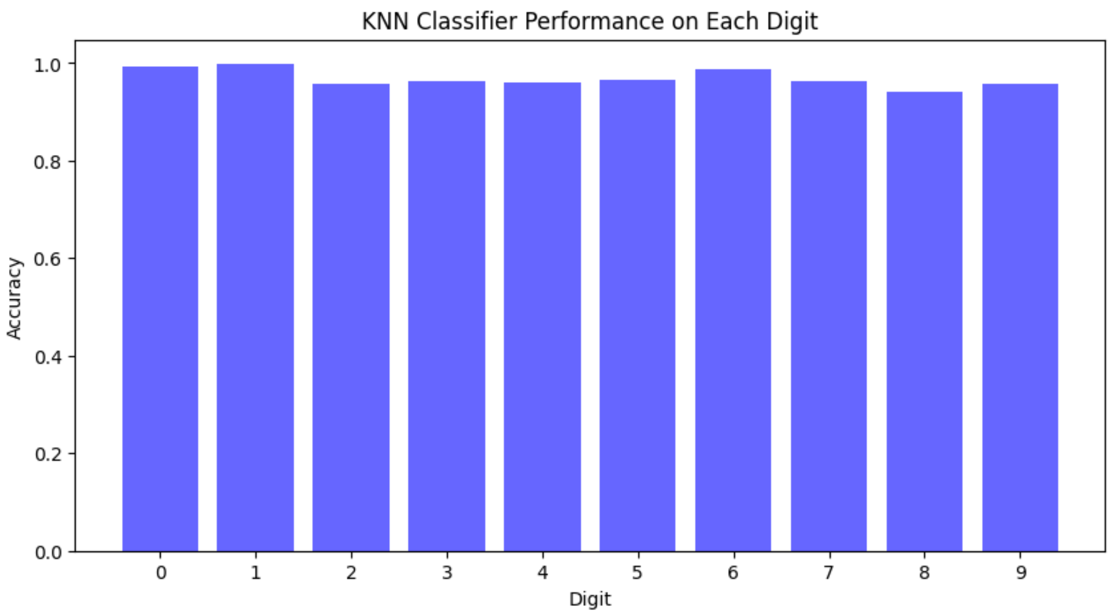
```
KNN Accuracy: 0.9691
```

[23]:
```
# Evaluate performance by digit
digit_performance = {}
for digit in range(10):
    digit_indices = y_test == digit
    digit_accuracy = accuracy(y_test[digit_indices],␣
 ↪knn_predictions[digit_indices])
    digit_performance[digit] = digit_accuracy
    print(f'Accuracy for digit {digit}: {digit_accuracy:.4f}')
```

```
Accuracy for digit 0: 0.9939
Accuracy for digit 1: 0.9982
Accuracy for digit 2: 0.9583
Accuracy for digit 3: 0.9634
```

```
Accuracy for digit 4: 0.9603
Accuracy for digit 5: 0.9652
Accuracy for digit 6: 0.9864
Accuracy for digit 7: 0.9630
Accuracy for digit 8: 0.9405
Accuracy for digit 9: 0.9584
```

[24]:
```
# Visualize predictions
plt.figure(figsize=(10, 5))
plt.bar(digit_performance.keys(), digit_performance.values(), color='blue',␣
  ↪alpha=0.6)
plt.xlabel('Digit')
plt.ylabel('Accuracy')
plt.title('KNN Classifier Performance on Each Digit')
plt.xticks(range(10))
plt.show()
```



Naive Bayes Classifier

[25]:
```
from scipy.stats import multivariate_normal as mvn

class GaussNB:
    def fit(self, X, y, epsilon=1e-3):
        self.likelihoods = {}
        self.priors = {}
        self.k = set(y.astype(int))
        for k in self.k:
```

```
            X_k = X[y == k]
            self.likelihoods[k] = {'mean': X_k.mean(axis=0), 'cov': X_k.
↪var(axis=0) + epsilon}
            self.priors[k] = len(X_k) / len(X)

    def predict(self, X):
        N, D = X.shape
        P_hat = np.zeros((N, len(self.k)))
        for k, l in self.likelihoods.items():
            P_hat[:, k] = mvn.logpdf(X, l['mean'], l['cov']) + np.log(self.
↪priors[k])
        return P_hat.argmax(axis=1)
```

[26]:
```
# Train and predict with Naive Bayes
gnb = GaussNB()
gnb.fit(X_train, y_train)

nb_predictions = gnb.predict(X_test)
```

[27]:
```
# Calculate accuracy for Naive Bayes
nb_accuracy = accuracy(y_test, nb_predictions)
print(f'Naive Bayes Accuracy: {nb_accuracy:.4f}')
```

```
Naive Bayes Accuracy: 0.7746
```

[30]:
```
# Evaluate performance by digit for Naive Bayes
digit_performance_nb = {}
for digit in range(10):
    digit_indices = y_test == digit
    digit_accuracy = accuracy(y_test[digit_indices],␣
↪nb_predictions[digit_indices])
    digit_performance_nb[digit] = digit_accuracy
    print(f'Naive Bayes Accuracy for digit {digit}: {digit_accuracy:.4f}')
```

```
Naive Bayes Accuracy for digit 0: 0.9051
Naive Bayes Accuracy for digit 1: 0.9577
Naive Bayes Accuracy for digit 2: 0.6686
Naive Bayes Accuracy for digit 3: 0.7584
Naive Bayes Accuracy for digit 4: 0.5692
Naive Bayes Accuracy for digit 5: 0.5235
Naive Bayes Accuracy for digit 6: 0.9175
Naive Bayes Accuracy for digit 7: 0.7578
Naive Bayes Accuracy for digit 8: 0.7402
Naive Bayes Accuracy for digit 9: 0.9029
```

[31]:
```
# Visualize Naive Bayes performance by digit
plt.figure(figsize=(10, 5))
```

```
plt.bar(digit_performance_nb.keys(), digit_performance_nb.values(),␣
 ↪color='green', alpha=0.6)
plt.xlabel('Digit')
plt.ylabel('Accuracy')
plt.title('Naive Bayes Classifier Performance on Each Digit')
plt.xticks(range(10))
plt.show()
```