mnist-cnn

May 12, 2023

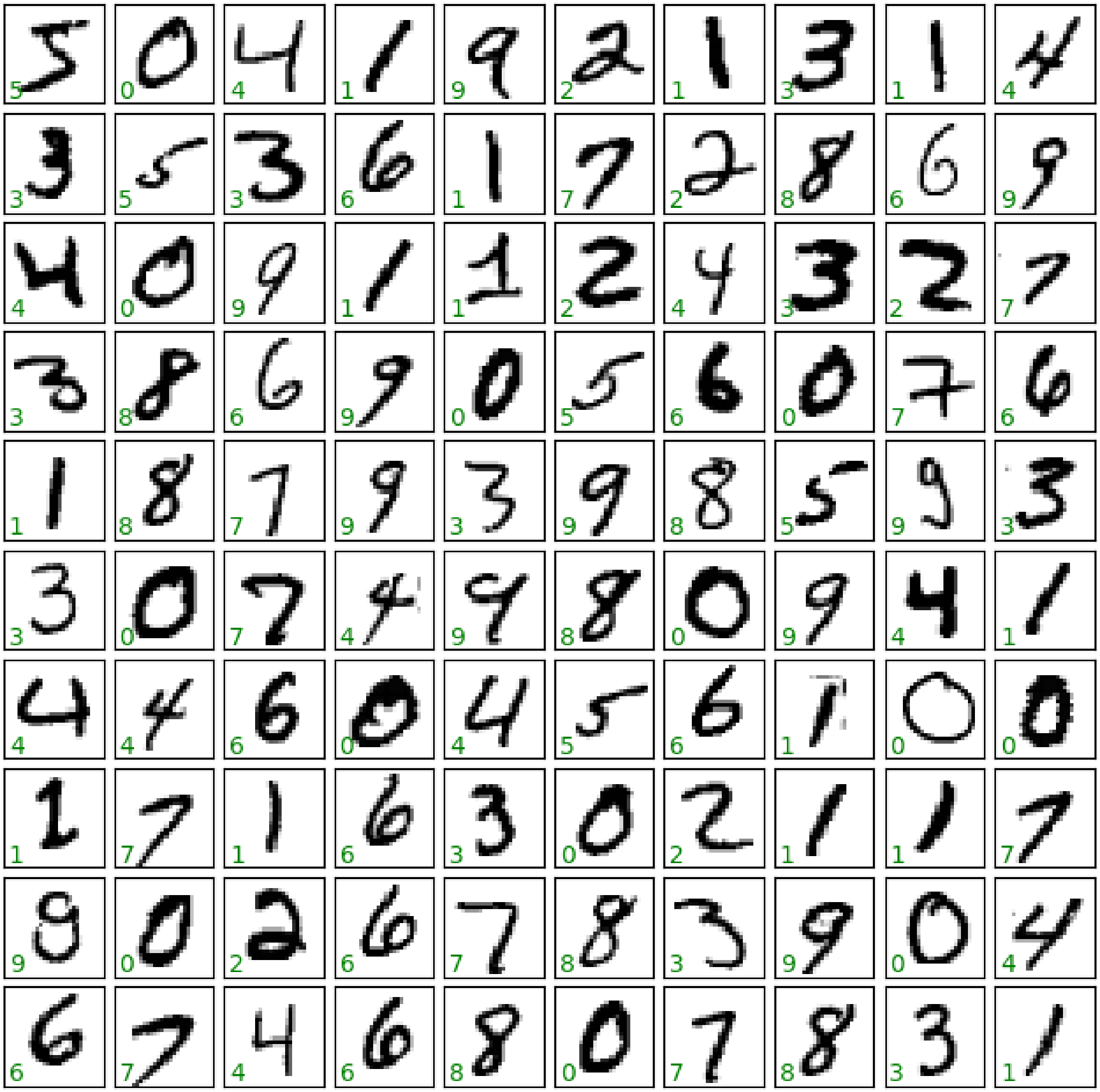
0.1 Getting the MNIST Dataset

[ ]:
```
from tensorflow.keras.datasets import mnist
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.optimizers import SGD
from sklearn.preprocessing import LabelBinarizer
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report
from imutils import build_montages
import matplotlib.pyplot as plt
import numpy as np
import argparse
import cv2

((trainData, trainLabels), (testData, testLabels)) = mnist.load_data()
data = np.vstack([trainData, testData])
labels = np.hstack([trainLabels, testLabels])
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/mnist.npz
11490434/11490434 [==============================] - 0s 0us/step
```

0.2 The MNIST Digits

[ ]:
```
fig, axes = plt.subplots(10, 10, figsize = (8, 8), gridspec_kw = dict(hspace =␣
↪0.1, wspace = 0.1), subplot_kw = {"xticks" : [], "yticks" : []})

for i, ax in enumerate(axes.flat):
    ax.imshow(data[i], cmap = "binary", interpolation = "nearest")
    ax.text(0.05, 0.05, str(labels[i]), transform = ax.transAxes, color =␣
↪"green")
```



```
[ ]: dataFlat = data.reshape(data.shape[0], -1)
     dataFlat.shape
```

```
[ ]: (70000, 784)
```

0.3 KMeans Clustering on the Digits

```
[ ]: from sklearn.cluster import KMeans
     from sklearn.metrics import accuracy_score
     from scipy.stats import mode
     from warnings import simplefilter
     simplefilter(action = "ignore", category = FutureWarning)
```

```
km = KMeans(n_clusters = 10, n_init = "auto")
km.fit(dataFlat)
pred_labels = km.predict(dataFlat)

lab = np.zeros_like(pred_labels)
for i in range(10):
  mask = (pred_labels == i)
  lab[mask] = mode(labels[mask])[0]

print(lab)
print(labels)
print(accuracy_score(lab, labels))
```

```
[8 0 4 … 7 8 6]
[5 0 4 … 4 5 6]
0.5807
```

0.4 Naive Bayes Classifier on the Digits

[ ]:
```
from sklearn.naive_bayes import GaussianNB
GNB = GaussianNB()
Xtrain, Xtest, Ytrain, Ytest = train_test_split(dataFlat, labels, train_size =␣
 ↪0.7)
GNB.fit(Xtrain, Ytrain)
y_predict = GNB.predict(Xtest)

print(y_predict)
print(Ytest)
print(accuracy_score(y_predict, Ytest))
```

```
[1 0 6 … 9 6 8]
[1 4 6 … 7 8 4]
0.5615238095238095
```

0.5 Preparing the Data for the CNN

[ ]:
```
print(trainData.shape)
print(trainLabels.shape)
print(testData.shape)
print(testLabels.shape)
```

```
(60000, 28, 28)
(60000,)
(10000, 28, 28)
(10000,)
```

[ ]:
```
Xtrain = trainData.reshape(trainData.shape[0], trainData.shape[1], trainData.
    ↪shape[2], 1)
Xtest = testData.reshape(testData.shape[0], testData.shape[1], testData.
    ↪shape[2], 1)
print(Xtrain.shape)
```

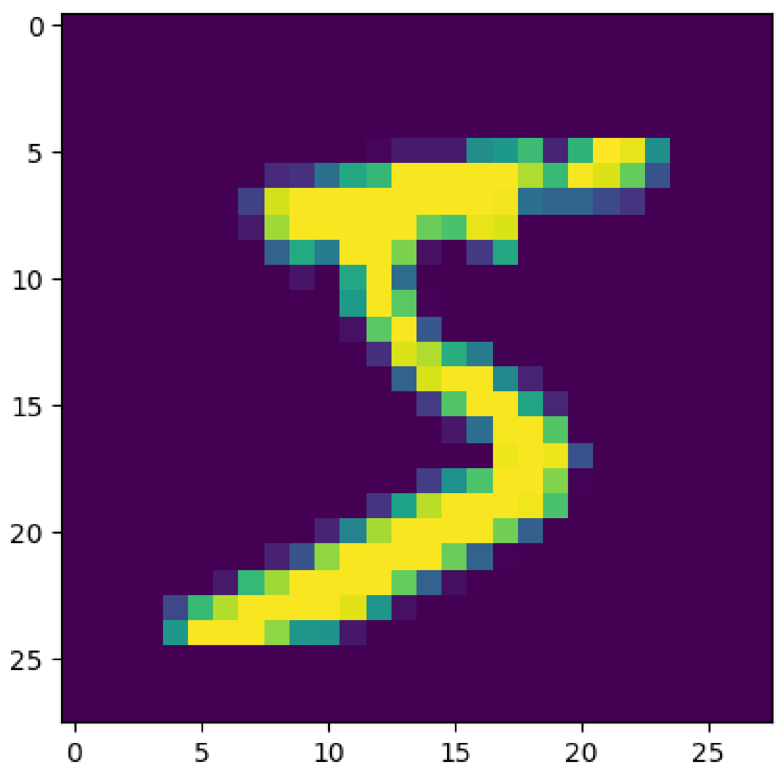
```
(60000, 28, 28, 1)
```

[ ]:
```
print(trainData[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   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   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   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   0   0   0   0   0   0   0   0   0   3  18  18  18 126 136
  175  26 166 255 247 127   0   0   0   0]
 [  0   0   0   0   0   0   0   0  30  36  94 154 170 253 253 253 253 253
  225 172 253 242 195  64   0   0   0   0]
 [  0   0   0   0   0   0   0  49 238 253 253 253 253 253 253 253 253 251
   93  82  82  56  39   0   0   0   0   0]
 [  0   0   0   0   0   0   0  18 219 253 253 253 253 253 198 182 247 241
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0  80 156 107 253 253 205  11   0  43 154
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0  14   1 154 253  90   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0 139 253 190   2   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0  11 190 253  70   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  35 241 225 160 108   1
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0  81 240 253 253 119
   25   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0  45 186 253 253
  150  27   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  16  93 252
  253 187   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 249
  253 249  64   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0  46 130 183 253
```

```
 253 207   2   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0  39 148 229 253 253 253
 250 182   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0  24 114 221 253 253 253 253 201
   78   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0  23  66 213 253 253 253 253 198  81   2
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0  18 171 219 253 253 253 253 195  80   9   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0  55 172 226 253 253 253 253 244 133  11   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0 136 253 253 253 212 135 132  16   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   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]
 [  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]]
```

[ ]:
```
plt.imshow(Xtrain[0])
plt.show()
```



0.6 Categorization of Labels

For each element in the trainLabels, an array would be created in the Ytrain with size that of the number of distinct labels and only the entry corresponding to the current label will be 1 rest all 0.

[ ]:
```
from keras.utils import to_categorical

Ytrain = to_categorical(trainLabels)
Ytest = to_categorical(testLabels)
print(trainLabels)
print(Ytrain)
```

```
[5 0 4 … 5 6 8]
[[0. 0. 0. … 0. 0. 0.]
 [1. 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. 1. 0.]]
```

0.7 Building the CNN

- **Conv2D(N, kernel_size = p)** N represents the number of nodes in this layer and p x p is the dimension of the kernel matrix
- relu –> **ReLU : Rectified Linear Activation**
- Activation functions like the **sigmoid, tanh, ReLU(max(x, 0)), step** map the input to a value between some range (usually -1 to 1)
- input_shape –> Shape of each input image
- The **"Flatten()"** connects the Convolutional layers to the Dense layers of the Neural Network
- **Dense(x, activation)** –> x represents the number of possible outputs (0 - 9 in our case)
- **Softmax** function outputs the values with all summing upto 1 like they are probabilities

[ ]:
```
from keras.models import Sequential
from keras.layers import Dense, Conv2D, Flatten

model = Sequential()

model.add(Conv2D(64, kernel_size = 3, activation = "relu", input_shape = Xtrain.
 ↪shape[1:]))
model.add(Conv2D(32, kernel_size = 3, activation = "relu"))
model.add(Flatten())
model.add(Dense(10, activation = "softmax"))
```

0.8 Compiling the CNN

- We require three parameters for compiling : **optimizer, loss, metrics**.
- **Optimizer** decides the **Learning Rate**, LR determines the Weights in each layer
- We have chose **"adam"** as our optimizer

- **Loss** and **metrics** tell our model on which factor's value should it decide/change the weight in each step

[ ]:
```
model.compile(optimizer = "adam", loss = "categorical_crossentropy", metrics =␣
↪["accuracy"])
```

0.9 Training the Model

[ ]:
```
model.fit(Xtrain, Ytrain, validation_data = (Xtest, Ytest), epochs = 3)
```

```
Epoch 1/3
1875/1875 [==============================] - 212s 112ms/step - loss: 0.1965 -
accuracy: 0.9536 - val_loss: 0.0878 - val_accuracy: 0.9727
Epoch 2/3
1875/1875 [==============================] - 229s 122ms/step - loss: 0.0640 -
accuracy: 0.9800 - val_loss: 0.0749 - val_accuracy: 0.9767
Epoch 3/3
1875/1875 [==============================] - 259s 138ms/step - loss: 0.0483 -
accuracy: 0.9843 - val_loss: 0.0773 - val_accuracy: 0.9768
```

[ ]:
```
<keras.callbacks.History at 0x7f391ab1cb50>
```

0.10 Predictions

[ ]:
```
from sklearn.metrics import accuracy_score
y_model = model.predict(Xtest[:100])
pred = np.argmax(y_model, axis = 1)
actual = np.argmax(Ytest[:100], axis = 1)
print(pred)
print(actual)
print(accuracy_score(pred, actual))
```

```
4/4 [==============================] - 0s 31ms/step
[7 2 1 0 4 1 4 9 6 9 0 6 9 0 1 5 9 7 8 4 9 6 6 5 4 0 7 4 0 1 3 1 3 4 7 2 7
 1 2 1 1 7 4 2 3 5 1 2 4 4 6 3 5 5 6 0 4 1 9 5 7 8 9 3 7 4 6 4 3 0 7 0 2 9
 1 7 3 2 9 7 7 6 2 7 8 4 7 3 6 1 3 6 9 3 1 6 1 7 6 9]
[7 2 1 0 4 1 4 9 5 9 0 6 9 0 1 5 9 7 3 4 9 6 6 5 4 0 7 4 0 1 3 1 3 4 7 2 7
 1 2 1 1 7 4 2 3 5 1 2 4 4 6 3 5 5 6 0 4 1 9 5 7 8 9 3 7 4 6 4 3 0 7 0 2 9
 1 7 3 2 9 7 7 6 2 7 8 4 7 3 6 1 3 6 9 3 1 4 1 7 6 9]
0.97
```