

MODEL BUILDING (SPRINT 2)

Team ID	PNT2022TMID26205
Project Name	A Novel Method for Handwritten Digit Recognition System

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import mnist

(x_train, y_train), (x_test, y_test) = mnist.load_data()

Downloading data from https://storage.googleapis.com/tensorflow/tf-
keras-datasets/mnist.npz
11490434/11490434 [=====] - 2s 0us/step

x_train
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]],

       [[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],											
170,	[0,	0,	0,	0,	0,	0,	0,	0,	30,	36,	94,	154,	
0,		253,	253,	253,	253,	253,	225,	172,	253,	242,	195,	64,	0,
	0,	0],											
253,	[0,	0,	0,	0,	0,	0,	0,	49,	238,	253,	253,	253,	
0,		253,	253,	253,	253,	251,	93,	82,	82,	56,	39,	0,	0,
	0,	0],											
253,	[0,	0,	0,	0,	0,	0,	0,	18,	219,	253,	253,	253,	
0,		253,	198,	182,	247,	241,	0,	0,	0,	0,	0,	0,	0,
	0,	0],											
253,	[0,	0,	0,	0,	0,	0,	0,	0,	80,	156,	107,	253,	
0,		205,	11,	0,	43,	154,	0,	0,	0,	0,	0,	0,	0,
	0,	0],											
253,	[0,	0,	0,	0,	0,	0,	0,	0,	0,	14,	1,	154,	
0,		90,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,
	0,	0],											
253,	[0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	139,	
0,		190,	2,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,
	0,	0],											
190,	[0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	11,	
0,		253,	70,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,
	0,	0],											
35,	[0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,
0,		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,
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,

[illegible]

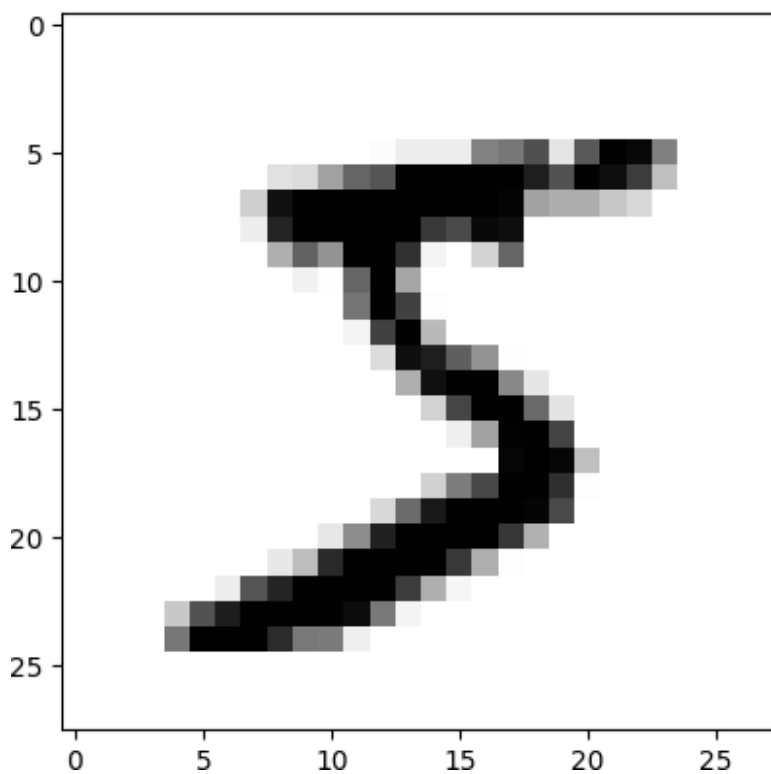
```

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]], dtype=uint8)

```

```
plt.imshow(one_img, cmap='binary')
```

```
<matplotlib.image.AxesImage at 0x1c0f14903a0>
```



```
y_train
```

```
array([5, 0, 4, ..., 5, 6, 8], dtype=uint8)
```

```
from tensorflow.keras.utils import to_categorical
```

```
y_train.shape
```

```
(60000,)
```

```
y_example = to_categorical(y_train)
print(y_example, y_example.shape)
```

```
[ [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.]] (60000, 10)
```

```
y_cat_test = to_categorical(y_test,num_classes=10)
```

```
y_cat_train = to_categorical(y_train,10)
```

```
one_img.max(), one_img.min()
```

(255, 0)

```
x_train = x_train/255
```

$$\bar{x}_{\text{test}} = \bar{x}_{\text{test}}/255$$

```
scaled_img = x_train[0]
```

```
scaled_img
```

[illegible]

0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0.],
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0.65098039, 1. , 0.96862745, 0.49803922, 0. ,
0. , 0. , 0.],
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0.36862745, 0.60392157, 0.66666667, 0.99215686, 0.99215686,
0.99215686, 0.99215686, 0.99215686, 0.88235294, 0.6745098 ,
0.99215686, 0.94901961, 0.76470588, 0.25098039, 0. ,
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0.99215686, 0.99215686, 0.98431373, 0.36470588, 0.32156863,
0.32156863, 0.21960784, 0.15294118, 0. , 0. ,
0. , 0. , 0.],
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0. , 0. , 0.07058824, 0.85882353, 0.99215686,
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0.71372549, 0.96862745, 0.94509804, 0. , 0. ,
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0. , 0. , 0.],
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0. , 0. , 0.],
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0. , 0.54509804, 0.99215686, 0.74509804, 0.00784314,
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0. , 0.04313725, 0.74509804, 0.99215686, 0.2745098 ,
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[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
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0.62745098 , 0.42352941 , 0.00392157 , 0. , 0. ,
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0. , 0. , 0. ,],
[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0.31764706 , 0.94117647 ,
0.99215686 , 0.99215686 , 0.46666667 , 0.09803922 , 0. ,
0. , 0. , 0. , 0. , 0. ,
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[0. , 0. , 0. , 0. , 0. ,
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0. , 0. , 0. , 0. , 0.17647059 ,
0.72941176 , 0.99215686 , 0.99215686 , 0.58823529 , 0.10588235 ,
0. , 0. , 0. , 0. , 0. ,
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[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0.0627451 , 0.36470588 , 0.98823529 , 0.99215686 , 0.73333333 ,
0. , 0. , 0. , 0. , 0. ,
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[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0.97647059 , 0.99215686 , 0.97647059 ,
0.25098039 , 0. , 0. , 0. , 0. ,
0. , 0. , 0. ,],
[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0.18039216 ,
0.50980392 , 0.71764706 , 0.99215686 , 0.99215686 , 0.81176471 ,
0.00784314 , 0. , 0. , 0. , 0. ,
0. , 0. , 0. ,],
[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0.15294118 , 0.58039216 , 0.89803922 ,
0.99215686 , 0.99215686 , 0.99215686 , 0.98039216 , 0.71372549 ,
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0. , 0. , 0. ,],
[0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. , 0. , 0. ,
0.09411765 , 0.44705882 , 0.86666667 , 0.99215686 , 0.99215686 ,
0.99215686 , 0.99215686 , 0.78823529 , 0.30588235 , 0. ,
0. , 0. , 0. , 0. , 0. ,
0. , 0. , 0. ,],
[0. , 0. , 0. , 0. , 0. ,

```
x_train = x_train.reshape(60000,28,28,1)
x_test = x_test.reshape(10000,28,28,1)

x_train.shape,x_test.shape

((60000, 28, 28, 1), (10000, 28, 28, 1))
```

```

from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPool2D

model = Sequential()
model.add(Conv2D(filters=32,
kernel_size=(4,4),activation='relu',input_shape=(28,28,1)))
model.add(MaxPool2D(pool_size=(2,2)))
model.add(Flatten())
model.add(Dense(128,activation='relu'))
model.add(Dense(10,activation='softmax'))

model.compile(loss='categorical_crossentropy',optimizer='Adadelta',metrics=['accuracy'])

from tensorflow.keras.callbacks import EarlyStopping

early_stop = EarlyStopping(monitor='val-loss', patience=1)

model.fit(x_train,y_cat_train,
          epochs=15,
          validation_data=(x_test,y_cat_test),
          callbacks=[early_stop])

Epoch 1/15
1872/1875 [=====>.] - ETA: 0s - loss: 2.2094 -
accuracy: 0.3759WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 28s 15ms/step - loss:
2.2092 - accuracy: 0.3763 - val_loss: 2.1020 - val_accuracy: 0.6113
Epoch 2/15
1873/1875 [=====>.] - ETA: 0s - loss: 1.9765 -
accuracy: 0.6747WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 30s 16ms/step - loss:
1.9764 - accuracy: 0.6747 - val_loss: 1.8295 - val_accuracy: 0.7500
Epoch 3/15
1874/1875 [=====>.] - ETA: 0s - loss: 1.6821 -
accuracy: 0.7542WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 29s 16ms/step - loss:
1.6820 - accuracy: 0.7542 - val_loss: 1.5128 - val_accuracy: 0.7897
Epoch 4/15
1875/1875 [=====] - ETA: 0s - loss: 1.3724 -
accuracy: 0.7861WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 28s 15ms/step - loss:

```

1.3724 - accuracy: 0.7861 - val_loss: 1.2101 - val_accuracy: 0.8131
Epoch 5/15
1872/1875 [=====>.] - ETA: 0s - loss: 1.1030 -
accuracy: 0.8060WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 28s 15ms/step - loss:
1.1027 - accuracy: 0.8061 - val_loss: 0.9695 - val_accuracy: 0.8330
Epoch 6/15
1872/1875 [=====>.] - ETA: 0s - loss: 0.9026 -
accuracy: 0.8225WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 30s 16ms/step - loss:
0.9024 - accuracy: 0.8225 - val_loss: 0.8019 - val_accuracy: 0.8455
Epoch 7/15
1872/1875 [=====>.] - ETA: 0s - loss: 0.7650 -
accuracy: 0.8364WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 28s 15ms/step - loss:
0.7649 - accuracy: 0.8365 - val_loss: 0.6880 - val_accuracy: 0.8577
Epoch 8/15
1871/1875 [=====>.] - ETA: 0s - loss: 0.6699 -
accuracy: 0.8478WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 26s 14ms/step - loss:
0.6697 - accuracy: 0.8478 - val_loss: 0.6082 - val_accuracy: 0.8668
Epoch 9/15
1871/1875 [=====>.] - ETA: 0s - loss: 0.6020 -
accuracy: 0.8572WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 25s 14ms/step - loss:
0.6019 - accuracy: 0.8573 - val_loss: 0.5509 - val_accuracy: 0.8738
Epoch 10/15
1874/1875 [=====>.] - ETA: 0s - loss: 0.5520 -
accuracy: 0.8641WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 31s 17ms/step - loss:
0.5519 - accuracy: 0.8641 - val_loss: 0.5084 - val_accuracy: 0.8782
Epoch 11/15
1874/1875 [=====>.] - ETA: 0s - loss: 0.5141 -
accuracy: 0.8697WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 27s 14ms/step - loss:
0.5141 - accuracy: 0.8697 - val_loss: 0.4754 - val_accuracy: 0.8839

```
Epoch 12/15
1871/1875 [=====>.] - ETA: 0s - loss: 0.4841 -
accuracy: 0.8748WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 24s 13ms/step - loss:
0.4842 - accuracy: 0.8747 - val_loss: 0.4494 - val_accuracy: 0.8870
Epoch 13/15
1874/1875 [=====>.] - ETA: 0s - loss: 0.4603 -
accuracy: 0.8790WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 23s 12ms/step - loss:
0.4603 - accuracy: 0.8791 - val_loss: 0.4283 - val_accuracy: 0.8908
Epoch 14/15
1873/1875 [=====>.] - ETA: 0s - loss: 0.4408 -
accuracy: 0.8829WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 26s 14ms/step - loss:
0.4406 - accuracy: 0.8830 - val_loss: 0.4107 - val_accuracy: 0.8924
Epoch 15/15
1875/1875 [=====] - ETA: 0s - loss: 0.4240 -
accuracy: 0.8863WARNING:tensorflow:Early stopping conditioned on
metric `val-loss` which is not available. Available metrics are:
loss,accuracy,val_loss,val_accuracy
1875/1875 [=====] - 29s 15ms/step - loss:
0.4240 - accuracy: 0.8863 - val_loss: 0.3960 - val_accuracy: 0.8954

<keras.callbacks.History at 0x1c0f16fde10>
```