2_notebook

February 6, 2019

1 Problem 2

2 Philip Carr

Use this notebook to write your code for problem 2.

```
In [370]: import numpy as np
          import matplotlib.pyplot as plt
          %matplotlib inline
```

2.1 Dense network

Load, preprocess, and deal with the MNIST data.

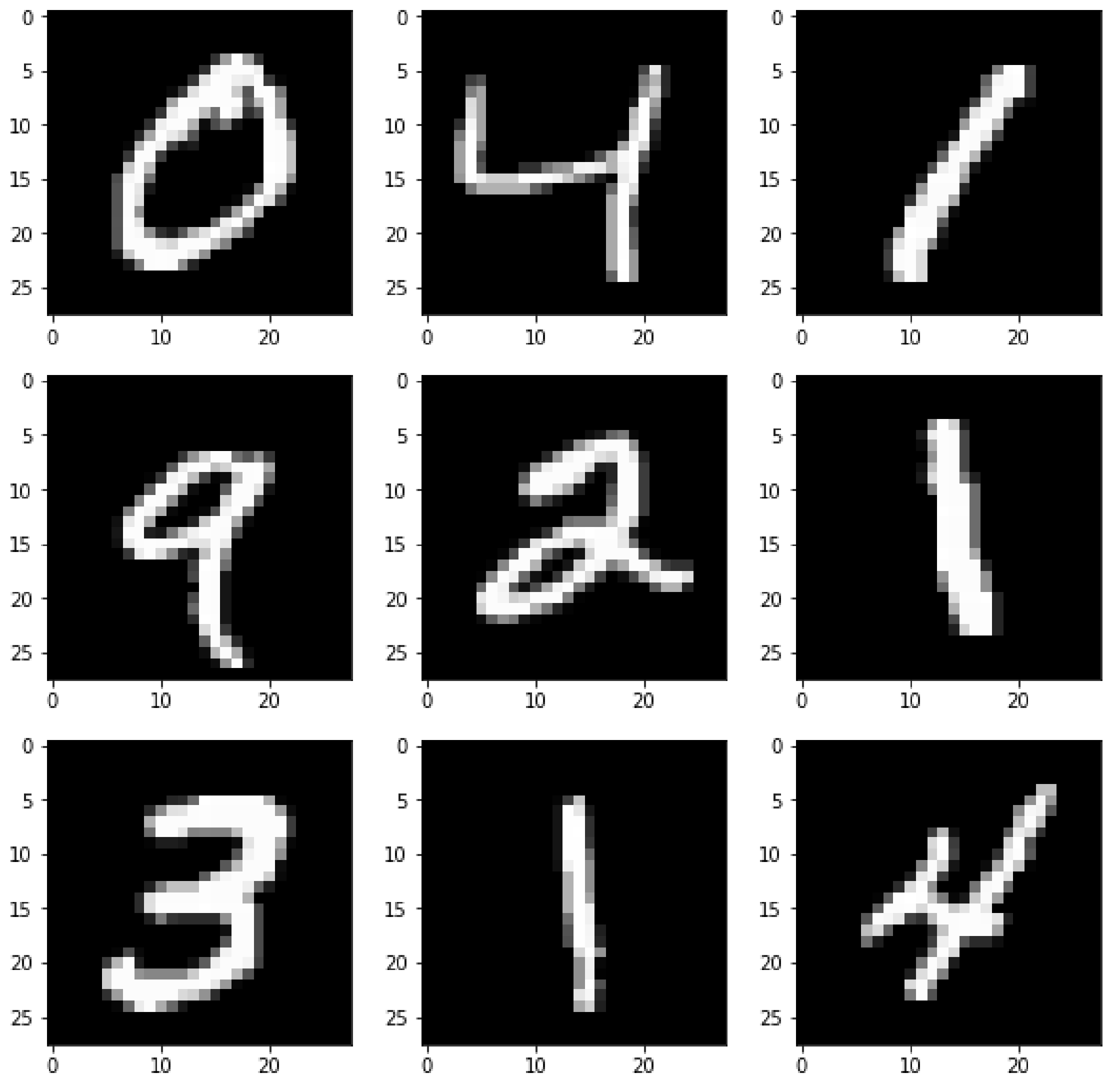
```
In [371]: # load MNIST data into Keras format
          import keras
          from keras.datasets import mnist

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

```
In [372]: # look at the shapes
          print(x_train.shape)
          print(x_test.shape)
```

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

```
In [373]: fig = plt.figure(figsize=(10,10))
          size = 3
          for i in range(1, size*size+1):
              fig.add_subplot(size, size, i)
              plt.imshow(x_train[i], cmap=plt.get_cmap('gray'))
```



2.2 Problem C

In [374]:
```
# One-hot encode the labels.
y_train = keras.utils.np_utils.to_categorical(y_train)
y_test = keras.utils.np_utils.to_categorical(y_test)
```

In [375]:
```
# Normalize the input data.
x_train = np.divide(x_train, 255)
x_test = np.divide(x_test, 255)
```

In [376]:
```
# we must reshape the X data (add a channel dimension)
x_train = np.reshape(x_train, (len(x_train), len(x_train[0])
                                * len(x_train[0][0])))
x_test = np.reshape(x_test, (len(x_test), len(x_test[0])
                              * len(x_test[0][0])))
```

In [377]:
```
# Shape of the training input.
print(x_train.shape)
print(x_test.shape)
```

```
(60000, 784)
(10000, 784)
```

2.3 Problem D

In [378]:
```
from keras.models import Sequential
from keras.layers.core import Dense, Activation, Flatten, Dropout
```

In [379]:
```
## Create the model here.
modelD = Sequential()
modelD.add(Dense(100))
modelD.add(Activation('relu'))
modelD.add(Dense(10))
modelD.add(Activation('softmax'))
```

In [380]:
```
modelD.compile(loss='categorical_crossentropy',
               optimizer='adadelta', metrics=['accuracy'])
```

In [381]:
```
fit = modelD.fit(x_train, y_train, batch_size=64, epochs=10,
    verbose=1)
```

```
Epoch 1/10
60000/60000 [==============================] - 8s 128us/step - loss: 0.3205 - acc: 0.9103
Epoch 2/10
60000/60000 [==============================] - 5s 91us/step - loss: 0.1578 - acc: 0.9553
Epoch 3/10
60000/60000 [==============================] - 5s 90us/step - loss: 0.1155 - acc: 0.9671
Epoch 4/10
60000/60000 [==============================] - 5s 90us/step - loss: 0.0931 - acc: 0.9733
Epoch 5/10
60000/60000 [==============================] - 5s 91us/step - loss: 0.0779 - acc: 0.9782
Epoch 6/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0676 - acc: 0.9806
Epoch 7/10
60000/60000 [==============================] - 6s 94us/step - loss: 0.0583 - acc: 0.9833
Epoch 8/10
60000/60000 [==============================] - 5s 90us/step - loss: 0.0514 - acc: 0.9857
Epoch 9/10
60000/60000 [==============================] - 5s 90us/step - loss: 0.0455 - acc: 0.9871
Epoch 10/10
60000/60000 [==============================] - 5s 90us/step - loss: 0.0406 - acc: 0.9888
```

In [382]:
```
# Printing a summary of the layers and weights in the model.
modelD.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_235 (Dense)            (None, 100)               78500
_________________________________________________________________
activation_234 (Activation)  (None, 100)               0
_________________________________________________________________
dense_236 (Dense)            (None, 10)                1010
_________________________________________________________________
activation_235 (Activation)  (None, 10)                0
=================================================================
Total params: 79,510
Trainable params: 79,510
Non-trainable params: 0
_________________________________________________________________
```

```
In [383]: # Printing the accuracy of the model, according to the loss function specified in mode
          score = modelD.evaluate(x_test, y_test, verbose=0)
          print('Test score:', score[0])
          print('Test accuracy:', score[1])
```

```
Test score: 0.07948249847483821
Test accuracy: 0.9771
```

2.4 Problem E

```
In [561]: ## Create the model here given the constraints in the problem
          modelE = Sequential()

          modelE.add(Dense(100))
          modelE.add(Activation('relu'))
          modelE.add(Dense(100))
          modelE.add(Activation('relu'))
          modelE.add(Dense(10))
          modelE.add(Activation('softmax'))
```

```
In [562]: modelE.compile(loss='categorical_crossentropy',
                         optimizer='rmsprop', metrics=['accuracy'])
```

```
In [563]: fit = modelE.fit(x_train, y_train, batch_size=64, epochs=20,
              verbose=1)
```

```
Epoch 1/20
60000/60000 [==============================] - 10s 166us/step - loss: 0.2702 - acc: 0.9215
Epoch 2/20
60000/60000 [==============================] - 6s 106us/step - loss: 0.1182 - acc: 0.9646
Epoch 3/20
```

```
60000/60000 [==============================] - 6s 106us/step - loss: 0.0850 - acc: 0.9743
Epoch 4/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0663 - acc: 0.9802
Epoch 5/20
60000/60000 [==============================] - 6s 106us/step - loss: 0.0537 - acc: 0.9833
Epoch 6/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0454 - acc: 0.9860
Epoch 7/20
60000/60000 [==============================] - 7s 110us/step - loss: 0.0394 - acc: 0.9883
Epoch 8/20
60000/60000 [==============================] - 6s 107us/step - loss: 0.0335 - acc: 0.9899
Epoch 9/20
60000/60000 [==============================] - 6s 108us/step - loss: 0.0296 - acc: 0.9909
Epoch 10/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0243 - acc: 0.9926
Epoch 11/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0211 - acc: 0.9934
Epoch 12/20
60000/60000 [==============================] - 6s 106us/step - loss: 0.0191 - acc: 0.9945
Epoch 13/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0172 - acc: 0.9949
Epoch 14/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0151 - acc: 0.9954
Epoch 15/20
60000/60000 [==============================] - 6s 106us/step - loss: 0.0129 - acc: 0.9959
Epoch 16/20
60000/60000 [==============================] - 6s 106us/step - loss: 0.0109 - acc: 0.9967
Epoch 17/20
60000/60000 [==============================] - 6s 107us/step - loss: 0.0102 - acc: 0.9967
Epoch 18/20
60000/60000 [==============================] - 7s 112us/step - loss: 0.0094 - acc: 0.9970
Epoch 19/20
60000/60000 [==============================] - 6s 105us/step - loss: 0.0088 - acc: 0.9975
Epoch 20/20
60000/60000 [==============================] - 6s 106us/step - loss: 0.0081 - acc: 0.9977
```

In [564]:
```
## Printing a summary of the layers and weights in the model.
modelE.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_359 (Dense)            (None, 100)               78500
_________________________________________________________________
activation_351 (Activation)  (None, 100)               0
_________________________________________________________________
dense_360 (Dense)            (None, 100)               10100
```

```
_________________________________________________________________
activation_352 (Activation)  (None, 100)               0
_________________________________________________________________
dense_361 (Dense)            (None, 10)                1010
_________________________________________________________________
activation_353 (Activation)  (None, 10)                0
=================================================================
Total params: 89,610
Trainable params: 89,610
Non-trainable params: 0
_________________________________________________________________
```

```
In [565]: ## Printing the accuracy of the model, according to the loss function specified in mod
          score = modelE.evaluate(x_test, y_test, verbose=0)
          print('Test score:', score[0])
          print('Test accuracy:', score[1])
```

```
Test score: 0.125881357786508
Test accuracy: 0.9801
```

2.5 Problem F

```
In [632]: ## Create the model here given the constraints in the problem.
          modelF = Sequential()
          modelF.add(Dense(400))
          modelF.add(Activation('relu'))
          modelF.add(Dropout(0.1))
          modelF.add(Dense(200))
          modelF.add(Activation('relu'))
          modelF.add(Dropout(0.1))
          modelF.add(Dense(400))
          modelF.add(Activation('relu'))
          modelF.add(Dense(10))
          modelF.add(Activation('softmax'))
```

```
In [633]: modelF.compile(loss='categorical_crossentropy',
                         optimizer='rmsprop', metrics=['accuracy'])
```

```
In [634]: fit = modelF.fit(x_train, y_train, batch_size=64, epochs=20,
              verbose=1)
```

```
Epoch 1/20
60000/60000 [==============================] - 12s 207us/step - loss: 0.2322 - acc: 0.9296
Epoch 2/20
60000/60000 [==============================] - 8s 141us/step - loss: 0.1086 - acc: 0.9684
Epoch 3/20
60000/60000 [==============================] - 8s 132us/step - loss: 0.0872 - acc: 0.9758
```

```
Epoch 4/20
60000/60000 [==============================] - 8s 128us/step - loss: 0.0727 - acc: 0.9805
Epoch 5/20
60000/60000 [==============================] - 8s 131us/step - loss: 0.0678 - acc: 0.9834
Epoch 6/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0631 - acc: 0.9848
Epoch 7/20
60000/60000 [==============================] - 8s 128us/step - loss: 0.0655 - acc: 0.9848
Epoch 8/20
60000/60000 [==============================] - 8s 126us/step - loss: 0.0623 - acc: 0.9858
Epoch 9/20
60000/60000 [==============================] - 8s 131us/step - loss: 0.0585 - acc: 0.9866
Epoch 10/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0596 - acc: 0.9874
Epoch 11/20
60000/60000 [==============================] - 8s 129us/step - loss: 0.0597 - acc: 0.9880
Epoch 12/20
60000/60000 [==============================] - ETA: 0s - loss: 0.0606 - acc: 0.988 - 8s 126us/st
Epoch 13/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0600 - acc: 0.9886
Epoch 14/20
60000/60000 [==============================] - 8s 129us/step - loss: 0.0572 - acc: 0.9889
Epoch 15/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0569 - acc: 0.9897
Epoch 16/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0571 - acc: 0.9896
Epoch 17/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0570 - acc: 0.9903
Epoch 18/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0563 - acc: 0.9908
Epoch 19/20
60000/60000 [==============================] - 8s 127us/step - loss: 0.0647 - acc: 0.9902
Epoch 20/20
60000/60000 [==============================] - 8s 126us/step - loss: 0.0541 - acc: 0.9915
```

In [635]:
```python
## Printing a summary of the layers and weights in the model.
modelF.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_446 (Dense)            (None, 400)               314000
_________________________________________________________________
activation_429 (Activation)  (None, 400)               0
_________________________________________________________________
dropout_120 (Dropout)        (None, 400)               0
_________________________________________________________________
```

```
dense_447 (Dense)            (None, 200)               80200
_________________________________________________________________
activation_430 (Activation)  (None, 200)               0
_________________________________________________________________
dropout_121 (Dropout)        (None, 200)               0
_________________________________________________________________
dense_448 (Dense)            (None, 400)               80400
_________________________________________________________________
activation_431 (Activation)  (None, 400)               0
_________________________________________________________________
dense_449 (Dense)            (None, 10)                4010
_________________________________________________________________
activation_432 (Activation)  (None, 10)                0
=================================================================
Total params: 478,610
Trainable params: 478,610
Non-trainable params: 0
_________________________________________________________________
```

In [636]:
```
## Printing the accuracy of the model, according to the loss function specified in mod
score = modelF.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
```

```
Test score: 0.13775982027360675
Test accuracy: 0.9836
```