Q4 - Aritificial Neural Networks

Train, validate, and test a neural network model using the dataset in hw3q4.zip, which contains training data (75%), validation data (12.5%), and test data (12.5%). There are two output classes in this data set. You can either choose matlab or a python neural networks package, Keras for this problem.

Import Libraries

```
import matplotlib.pyplot as plt
import numpy as np
import zipfile
import math
import sys
import os
np.random.seed(7)
from tensorflow.keras.layers import Activation
from tensorflow.keras.layers import Input
from tensorflow.keras.layers import Dense
from tensorflow.keras import Model
import tensorflow as tf
tf.set_random_seed(7)
%matplotlib inline
```

(a) Please briefly describe how to construct your working environments (e.g. language, package version, backend for neural networks, installation, etc.) in your report, and write how to execute your codes on 'readme' file.

Language

- python 3.7

Prerequisites

- tensorflow 1.8+ (CPU only)

- matplotlib
- numpy

Installation

Install the above packages using the following commands -

- tensorflow 1.8+ (CPU only) - `pip install tensorflow`
- matplotlib - `pip install matplotlib`
- numpy - `pip install numpy`

Data

hw3q4.zip should be in the same directory level as this notebook.

(b) Keras Model

Helper Functions

```
def get_data(zipname,filename):
    zf = zipfile.ZipFile(zipname)
    data = None
    with zf.open(filename, 'r') as fp:
        data = np.asarray([[float(v.strip()) for v in
x.decode().strip().split(',')] for x in fp.readlines()])
    return data
```

```
def ANN(n_neurons, output_dims):
    input_layer = Input(batch_shape = (None, 61), name='input_layer')
    layer = Dense(n_neurons, name='hidden_layer')(input_layer)
    layer = Activation(activation='relu', name='relu')(layer)
    layer = Dense(output_dims, name='output_layer')(layer)
    output_layer = Activation(activation='sigmoid', name='sigmoid')(layer)
    model = Model(inputs=input_layer, outputs=output_layer, name='ann')
    model.compile('adam', 'mse', ['accuracy'])
    return model
```

Read Data

```
train_x = get_data('Data' + os.sep + 'hw3q4.zip','hw3q4' + os.sep +
'X_train.csv')
train_y = get_data('Data' + os.sep + 'hw3q4.zip','hw3q4' + os.sep +
'Y_train.csv')
val_x = get_data('Data' + os.sep + 'hw3q4.zip', 'hw3q4' + os.sep +
'X_val.csv')
val_y = get_data('Data' + os.sep + 'hw3q4.zip', 'hw3q4' + os.sep +
'Y_val.csv')
test_x = get_data('Data' + os.sep + 'hw3q4.zip', 'hw3q4' + os.sep +
'X_test.csv')
test_y = get_data('Data' + os.sep + 'hw3q4.zip', 'hw3q4' + os.sep +
'Y_test.csv')
```

(1) Construct neural networks using the given training dataset (X train, Y train) using different number of hidden neurons. Set the parameters as follows: activation function for hidden layer='relu', activation for output layer ='sigmoid', loss function ='mse', metrics= 'accuracy', epochs=10, batch size=50. For each model, change the number of hidden neurons in the order of 2, 4, 6, 8, 10.

```
hidden_neurons = [2,4,6,8,10]
models = [ANN(hidden_neurons[i], train_y.shape[1]) for i in
range(len(hidden_neurons))]
histories = []
for i in range(len(models)):
    print('Training Model with {} neurons in hidden
layer'.format(hidden_neurons[i]))
    history = models[i].fit(x=train_x,
                  y=train_y,
                  batch_size=50,
                  epochs=10,
                  shuffle=True)
    histories.append(history)
    print()
```

```
Training Model with 2 neurons in hidden layer
Epoch 1/10
1500/1500 [==============================] - 0s 273us/step - loss: 0.2538
- acc: 0.5333
Epoch 2/10
```

```
1500/1500 [==============================] - 0s 25us/step - loss: 0.2481
- acc: 0.5533
Epoch 3/10
1500/1500 [==============================] - 0s 24us/step - loss: 0.2432
- acc: 0.5727
Epoch 4/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2387
- acc: 0.5907
Epoch 5/10
1500/1500 [==============================] - 0s 24us/step - loss: 0.2338
- acc: 0.6087
Epoch 6/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2285
- acc: 0.6193
Epoch 7/10
1500/1500 [==============================] - 0s 22us/step - loss: 0.2229
- acc: 0.6307
Epoch 8/10
1500/1500 [==============================] - 0s 22us/step - loss: 0.2164
- acc: 0.6347
Epoch 9/10
1500/1500 [==============================] - 0s 22us/step - loss: 0.2095
- acc: 0.6480
Epoch 10/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2022
- acc: 0.6733

Training Model with 4 neurons in hidden layer
Epoch 1/10
1500/1500 [==============================] - 0s 195us/step - loss: 0.3337
- acc: 0.4927
Epoch 2/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.3077
- acc: 0.5280
Epoch 3/10
1500/1500 [==============================] - 0s 24us/step - loss: 0.2827
- acc: 0.5680
Epoch 4/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2596
- acc: 0.5967
Epoch 5/10
1500/1500 [==============================] - 0s 37us/step - loss: 0.2387
- acc: 0.6307
Epoch 6/10
1500/1500 [==============================] - 0s 27us/step - loss: 0.2213
- acc: 0.6547
```

```
Epoch 7/10
1500/1500 [==============================] - 0s 24us/step - loss: 0.2066
- acc: 0.6827
Epoch 8/10
1500/1500 [==============================] - 0s 23us/step - loss: 0.1944
- acc: 0.7133
Epoch 9/10
1500/1500 [==============================] - 0s 26us/step - loss: 0.1840
- acc: 0.7360
Epoch 10/10
1500/1500 [==============================] - 0s 24us/step - loss: 0.1753
- acc: 0.7580

Training Model with 6 neurons in hidden layer
Epoch 1/10
1500/1500 [==============================] - 0s 209us/step - loss: 0.2943
- acc: 0.4933
Epoch 2/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2667
- acc: 0.5333
Epoch 3/10
1500/1500 [==============================] - 0s 26us/step - loss: 0.2441
- acc: 0.5673
Epoch 4/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2260
- acc: 0.6000
Epoch 5/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2110
- acc: 0.6453
Epoch 6/10
1500/1500 [==============================] - 0s 27us/step - loss: 0.1988
- acc: 0.6727
Epoch 7/10
1500/1500 [==============================] - 0s 26us/step - loss: 0.1883
- acc: 0.7087
Epoch 8/10
1500/1500 [==============================] - 0s 27us/step - loss: 0.1791
- acc: 0.7387
Epoch 9/10
1500/1500 [==============================] - 0s 31us/step - loss: 0.1711
- acc: 0.7573
Epoch 10/10
1500/1500 [==============================] - 0s 23us/step - loss: 0.1643
- acc: 0.7760

Training Model with 8 neurons in hidden layer
```

```
Epoch 1/10
1500/1500 [==============================] - 0s 214us/step - loss: 0.2895 - acc: 0.5273
Epoch 2/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.2614 - acc: 0.5653
Epoch 3/10
1500/1500 [==============================] - 0s 26us/step - loss: 0.2389 - acc: 0.6087
Epoch 4/10
1500/1500 [==============================] - 0s 27us/step - loss: 0.2202 - acc: 0.6460
Epoch 5/10
1500/1500 [==============================] - 0s 27us/step - loss: 0.2051 - acc: 0.6740
Epoch 6/10
1500/1500 [==============================] - 0s 29us/step - loss: 0.1924 - acc: 0.7073
Epoch 7/10
1500/1500 [==============================] - 0s 28us/step - loss: 0.1815 - acc: 0.7347
Epoch 8/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.1725 - acc: 0.7533
Epoch 9/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.1647 - acc: 0.7680
Epoch 10/10
1500/1500 [==============================] - 0s 23us/step - loss: 0.1580 - acc: 0.7747

Training Model with 10 neurons in hidden layer
Epoch 1/10
1500/1500 [==============================] - 0s 268us/step - loss: 0.2728 - acc: 0.5547
Epoch 2/10
1500/1500 [==============================] - 0s 28us/step - loss: 0.2387 - acc: 0.6080
Epoch 3/10
1500/1500 [==============================] - 0s 26us/step - loss: 0.2110 - acc: 0.6700
Epoch 4/10
1500/1500 [==============================] - 0s 25us/step - loss: 0.1890 - acc: 0.7140
Epoch 5/10
```

```
1500/1500 [==============================] - 0s 29us/step - loss: 0.1722
- acc: 0.7473
Epoch 6/10
1500/1500 [==============================] - 0s 22us/step - loss: 0.1596
- acc: 0.7687
Epoch 7/10
1500/1500 [==============================] - 0s 29us/step - loss: 0.1499
- acc: 0.7880
Epoch 8/10
1500/1500 [==============================] - 0s 22us/step - loss: 0.1425
- acc: 0.8053
Epoch 9/10
1500/1500 [==============================] - 0s 28us/step - loss: 0.1364
- acc: 0.8220
Epoch 10/10
1500/1500 [==============================] - 0s 26us/step - loss: 0.1315
- acc: 0.8240
```

(2) Validate each neural network using the given validation dataset (X val, Y val). The validation accuracy is used to determine how many number of hidden neurons are optimal for this problem.

```
eval_results = []
for i in range(len(models)):
    print('Evaluating Model with {} neurons in hidden
layer'.format(hidden_neurons[i]))
    eval_result = models[i].evaluate(x=val_x, y=val_y, batch_size=50)
    print('Mean Squared Error - {:.4f}'.format(eval_result[0]))
    print('Accuracy - {:.4f}'.format(eval_result[1]))
    eval_results.append(eval_result)
    print()
```

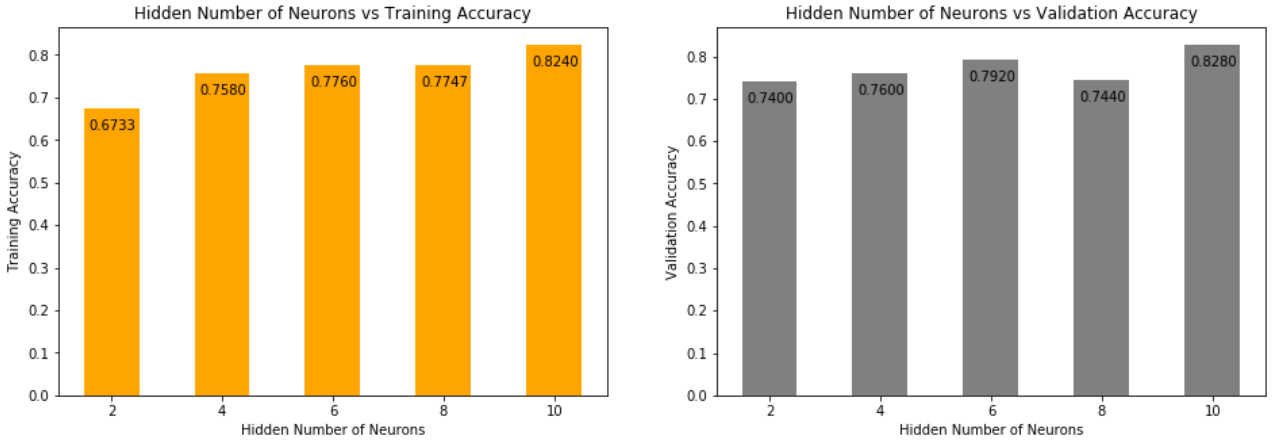
```
Evaluating Model with 2 neurons in hidden layer
250/250 [==============================] - 0s 360us/step
Mean Squared Error - 0.1976
Accuracy - 0.7400

Evaluating Model with 4 neurons in hidden layer
250/250 [==============================] - 0s 346us/step
Mean Squared Error - 0.1650
```

```
Accuracy - 0.7600

Evaluating Model with 6 neurons in hidden layer
250/250 [==============================] - 0s 372us/step
Mean Squared Error - 0.1585
Accuracy - 0.7920

Evaluating Model with 8 neurons in hidden layer
250/250 [==============================] - 0s 341us/step
Mean Squared Error - 0.1595
Accuracy - 0.7440

Evaluating Model with 10 neurons in hidden layer
250/250 [==============================] - 0s 318us/step
Mean Squared Error - 0.1238
Accuracy - 0.8280
```

(c) Plot a figure, where the horizontal x-axis is the number of hidden neurons, and the vertical y-axis is the accuracy. Please plot both training and validation accuracy in your figure. (Note that the exact accuracy could be slightly different according to your working environments, however you can analyze the trend.

```
fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(16,5))
ax[0].set_title('Hidden Number of Neurons vs Training Accuracy')
ax[0].set_ylabel('Training Accuracy')
ax[0].set_xlabel('Hidden Number of Neurons')
ax[0].bar(hidden_neurons,
          [histories[i].history['acc'][-1] for i in
range(len(hidden_neurons))],
          width=1,
          color='orange')
for i in range(len(hidden_neurons)):
    ax[0].annotate('{:.4f}'.format(histories[i].history['acc'][-1]),
                   (hidden_neurons[i]-0.4, histories[i].history['acc']
[-1]-0.05))

ax[1].set_title('Hidden Number of Neurons vs Validation Accuracy')
```

```
ax[1].set_ylabel('Validation Accuracy')
ax[1].set_xlabel('Hidden Number of Neurons')
ax[1].bar(hidden_neurons,
          [eval_results[i][1] for i in range(len(hidden_neurons))],
          width=1,
          color='gray')
for i in range(len(hidden_neurons)):
    ax[1].annotate('{:.4f}'.format(eval_results[i][1]),
                   (hidden_neurons[i]-0.4, eval_results[i][1]-0.05))
```



(d) Provide a simple analysis about your results and choose the optimal number of hidden neuron from the analysis.

```
model = models[4]
```

Based on the above plots, we can clearly see that we get the best validation accuracy when number of neurons in hidden layer is 10. Thus we select the model with 10 neurons in hidden layers.

(e) Report the test accuracy using the given test dataset (X test, Y test) on the neural network with the optimal number of hidden neurons.

```
print('Testing Model with 10 neurons in hidden layer')
eval_result = model.evaluate(x=test_x, y=test_y, batch_size=50)
print('Mean Squared Error - {:.4f}'.format(eval_result[0]))
print('Accuracy - {:.4f}'.format(eval_result[1]))
print()
```

```
Testing Model with 10 neurons in hidden layer
250/250 [==============================] - 0s 19us/step
Mean Squared Error - 0.1594
Accuracy - 0.7880
```

Test Accuracy is 0.7880 with 10 neurons in Hidden Layer.