

```
In [2]: # Classification using neural networks
        # (a)
        import pandas as pd
        from tensorflow.examples.tutorials.mnist import input_data
        from sklearn.model_selection import train_test_split

        mnist = input_data.read_data_sets("MNIST_data/", one_hot=True)
        X = mnist.train.images
        y = mnist.train.labels.astype("int")
        X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25
        , random_state=42)
```

Extracting MNIST_data/train-images-idx3-ubyte.gz

Extracting MNIST_data/train-labels-idx1-ubyte.gz

Extracting MNIST_data/t10k-images-idx3-ubyte.gz

Extracting MNIST_data/t10k-labels-idx1-ubyte.gz

```
In [3]: # (b)
from sklearn.preprocessing import StandardScaler
from sklearn.neural_network import MLPClassifier

# Standardization
stdsc = StandardScaler()
X_train_std = stdsc.fit_transform(X_train)
X_test_std = stdsc.fit_transform(X_test)

for num_layer in range(1, 9):

    for num_neuron in range(5, 13):
        mlp = MLPClassifier(hidden_layer_sizes = ((num_neuron,)*num_layer), max_iter=50, random_state=42, activation='relu', solver='adam', batch_size=200)
        mlp.fit(X_train_std, y_train)
        print("Number of hidden layers", num_layer)
        print("Number of Neurons per layer", num_neuron)
        print("Accuracy on test set: {:.5f}".format(mlp.score(X_test_std, y_test)))
    # print(mlp.coefs_)
```

```
/home/nbuser/anaconda3_501/lib/python3.6/site-packages/sklearn/neural_network/multilayer_perceptron.py:564: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (50) reached and the optimization hasn't converged yet.  
  % self.max_iter, ConvergenceWarning)
```

Number of hidden layers 1
Number of Neurons per layer 5
Accuracy on test set: 0.74713
Number of hidden layers 1
Number of Neurons per layer 6
Accuracy on test set: 0.77469
Number of hidden layers 1
Number of Neurons per layer 7
Accuracy on test set: 0.81978
Number of hidden layers 1
Number of Neurons per layer 8
Accuracy on test set: 0.84873
Number of hidden layers 1
Number of Neurons per layer 9
Accuracy on test set: 0.86204
Number of hidden layers 1
Number of Neurons per layer 10
Accuracy on test set: 0.87033
Number of hidden layers 1
Number of Neurons per layer 11
Accuracy on test set: 0.88080
Number of hidden layers 1
Number of Neurons per layer 12
Accuracy on test set: 0.88022
Number of hidden layers 2
Number of Neurons per layer 5
Accuracy on test set: 0.79040
Number of hidden layers 2
Number of Neurons per layer 6
Accuracy on test set: 0.82364
Number of hidden layers 2
Number of Neurons per layer 7
Accuracy on test set: 0.86407
Number of hidden layers 2
Number of Neurons per layer 8
Accuracy on test set: 0.87658
Number of hidden layers 2
Number of Neurons per layer 9
Accuracy on test set: 0.88640
Number of hidden layers 2
Number of Neurons per layer 10
Accuracy on test set: 0.89324
Number of hidden layers 2
Number of Neurons per layer 11
Accuracy on test set: 0.90153
Number of hidden layers 2
Number of Neurons per layer 12
Accuracy on test set: 0.90953
Number of hidden layers 3
Number of Neurons per layer 5
Accuracy on test set: 0.79556
Number of hidden layers 3
Number of Neurons per layer 6
Accuracy on test set: 0.84276
Number of hidden layers 3
Number of Neurons per layer 7
Accuracy on test set: 0.87607

Number of hidden layers 3
Number of Neurons per layer 8
Accuracy on test set: 0.89375
Number of hidden layers 3
Number of Neurons per layer 9
Accuracy on test set: 0.89716
Number of hidden layers 3
Number of Neurons per layer 10
Accuracy on test set: 0.90524
Number of hidden layers 3
Number of Neurons per layer 11
Accuracy on test set: 0.91135
Number of hidden layers 3
Number of Neurons per layer 12
Accuracy on test set: 0.91098
Number of hidden layers 4
Number of Neurons per layer 5
Accuracy on test set: 0.46305
Number of hidden layers 4
Number of Neurons per layer 6
Accuracy on test set: 0.83949
Number of hidden layers 4
Number of Neurons per layer 7
Accuracy on test set: 0.85687
Number of hidden layers 4
Number of Neurons per layer 8
Accuracy on test set: 0.88582
Number of hidden layers 4
Number of Neurons per layer 9
Accuracy on test set: 0.89113
Number of hidden layers 4
Number of Neurons per layer 10
Accuracy on test set: 0.90458
Number of hidden layers 4
Number of Neurons per layer 11
Accuracy on test set: 0.90873
Number of hidden layers 4
Number of Neurons per layer 12
Accuracy on test set: 0.91433
Number of hidden layers 5
Number of Neurons per layer 5
Accuracy on test set: 0.68393
Number of hidden layers 5
Number of Neurons per layer 6
Accuracy on test set: 0.83404
Number of hidden layers 5
Number of Neurons per layer 7
Accuracy on test set: 0.86175
Number of hidden layers 5
Number of Neurons per layer 8
Accuracy on test set: 0.87738
Number of hidden layers 5
Number of Neurons per layer 9
Accuracy on test set: 0.88902
Number of hidden layers 5
Number of Neurons per layer 10
Accuracy on test set: 0.90924

Number of hidden layers 5
Number of Neurons per layer 11
Accuracy on test set: 0.91324
Number of hidden layers 5
Number of Neurons per layer 12
Accuracy on test set: 0.91745
Number of hidden layers 6
Number of Neurons per layer 5
Accuracy on test set: 0.81025
Number of hidden layers 6
Number of Neurons per layer 6
Accuracy on test set: 0.65251
Number of hidden layers 6
Number of Neurons per layer 7
Accuracy on test set: 0.84175
Number of hidden layers 6
Number of Neurons per layer 8
Accuracy on test set: 0.88015
Number of hidden layers 6
Number of Neurons per layer 9
Accuracy on test set: 0.89527
Number of hidden layers 6
Number of Neurons per layer 10
Accuracy on test set: 0.90611
Number of hidden layers 6
Number of Neurons per layer 11
Accuracy on test set: 0.91011
Number of hidden layers 6
Number of Neurons per layer 12
Accuracy on test set: 0.90691
Number of hidden layers 7
Number of Neurons per layer 5
Accuracy on test set: 0.54880
Number of hidden layers 7
Number of Neurons per layer 6
Accuracy on test set: 0.83615
Number of hidden layers 7
Number of Neurons per layer 7
Accuracy on test set: 0.84800
Number of hidden layers 7
Number of Neurons per layer 8
Accuracy on test set: 0.87382
Number of hidden layers 7
Number of Neurons per layer 9
Accuracy on test set: 0.85789
Number of hidden layers 7
Number of Neurons per layer 10
Accuracy on test set: 0.90022
Number of hidden layers 7
Number of Neurons per layer 11
Accuracy on test set: 0.90495
Number of hidden layers 7
Number of Neurons per layer 12
Accuracy on test set: 0.90727
Number of hidden layers 8
Number of Neurons per layer 5
Accuracy on test set: 0.58625

```
Number of hidden layers 8
Number of Neurons per layer 6
Accuracy on test set: 0.76356
Number of hidden layers 8
Number of Neurons per layer 7
Accuracy on test set: 0.86007
Number of hidden layers 8
Number of Neurons per layer 8
Accuracy on test set: 0.87753
Number of hidden layers 8
Number of Neurons per layer 9
Accuracy on test set: 0.89789
Number of hidden layers 8
Number of Neurons per layer 10
Accuracy on test set: 0.89069
Number of hidden layers 8
Number of Neurons per layer 11
Accuracy on test set: 0.89811
Number of hidden layers 8
Number of Neurons per layer 12
Accuracy on test set: 0.90422
```

```
In [9]: mlp = MLPClassifier(hidden_layer_sizes = (12, 12, 12, 12, 12), max_iter=
50, random_state=42, activation='relu', solver='adam', batch_size=200)
mlp.fit(X_train_std, y_train)
weights = mlp.coefs_
print(len(weights))
```

6

```
In [10]: for i in range(6):
print(weights[i].shape)
```

```
(784, 12)
(12, 12)
(12, 12)
(12, 12)
(12, 12)
(12, 12)
(12, 10)
```

```
In [11]: print(784*12+12*12*4+12*10)
```

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