In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
```

Helpers

In [2]:
```
def sigmoid(z):
    return 1. / (1. + np.exp(-z))

def sigmoid_deriv(z):
    return z * (1. - z)

def forward_prop(X, w1,b1,w2,b2):
    Z1 = np.matmul(w1,X) + b1
    A1 = sigmoid(Z1) #sigmoid on hidden layer
    Z2 = np.matmul(w2,A1) + b2
    A2 = np.exp(Z2) / np.sum(np.exp(Z2), axis=0) #softmax on output

    return Z1, A1, Z2, A2

def backwards_prop(w1, w2, A1, A2, X, Y):
    m = X.shape[1]
    # this is the derivative of MSE
    dZ2 = A2-Y
    dw2 = (1./m) * np.matmul(dZ2, A1.T)
    db2 = (1./m) * np.sum(dZ2, axis=1, keepdims=True)
    dA1 = np.matmul(w2.T,dZ2)
    dZ1 = dA1 * sigmoid_deriv(A1)
    dw1 = (1./m) * np.matmul(dZ1, X.T)
    db1 = (1./m) * np.sum(dZ1, axis=1, keepdims=True)
    return dw1, dw2, db1, db2

def gradient_descent(w1,w2,b1,b2,dw1,dw2,db1,db2, learning_rate):
    w2 = w2 - learning_rate * dw2
    b2 = b2 - learning_rate * db2
    w1 = w1 - learning_rate * dw1
    b1 = b1 - learning_rate * db1
    return w2, b2, w1, b1
```

Hyperparameters

In [3]:
```
#set 2
#learning_rate = 0.1
#epochs = 3000
#hidden_layer_size = 64
#epoch_sizes = [1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000]
#hidden_layer_sizes = [1,2,4,8,16,32,64,128,256,512,1024,2048,4096]
#learning_rates = [0.0001, 0.001, 0.01, 0.1, 0.5, 0.75, 0.9, 1]

#set 1
learning_rate = 0.01
epochs = 1000
hidden_layer_size = 40
epoch_sizes = [1, 5, 10, 25,50,100,200,300,400,500,1000,2500, 5000]
hidden_layer_sizes = [1,2,3,4,5,6,7,8,9,10,15,20,25,30,40,50,60,80,100]
learning_rates = [0.0001, 0.001, 0.01, 0.1, 0.5, 0.75, 0.9, 1]
```

Data Preprocessing

In [4]:
```
train1 = np.loadtxt(open("train1.csv", "rb"), delimiter=",", skiprows=1)
# result is arranged x1, x2, x3, x4, x5, y1, y2
X_train = train1[:,:5].T
print(X_train.shape)
Y_train = train1[:, 5:].T
print(Y_train.shape)

test1 = np.loadtxt(open("test1.csv", "rb"), delimiter=",", skiprows=1)
X_test = test1[:,:5].T
print(X_test.shape)
Y_test = test1[:, 5:].T
print(Y_test.shape)
```

```
(5, 399)
(2, 399)
(5, 399)
(2, 399)
```

Changing HIDDEN LAYER NEURONS

In [5]:
```
scores = []
costs = []
for hidden_layer_num in hidden_layer_sizes:
    print('hidden layer size', hidden_layer_num)
    input_nodes = X_train.shape[0]
    hidden_nodes = hidden_layer_num
    output_nodes = Y_train.shape[0]

    np.random.seed(68)
    w1 = np.random.randn(hidden_nodes,input_nodes)
    b1 = np.zeros((hidden_nodes,1))
    w2 = np.random.randn(output_nodes,hidden_nodes)
    b2 = np.zeros((output_nodes,1))

    for epoch in range(epochs):
        # forward propagation
        Z1, A1, Z2, A2 = forward_prop(X_train,w1,b1,w2,b2)

        # mse loss
        mse_loss = np.mean((Y_train - A2) ** 2)

        # backwards propagation
        dw1, dw2, db1, db2 = backwards_prop(w1, w2, A1, A2, X_train, Y_trair

        # gradient descent
        w2, b2, w1, b1 = gradient_descent(w1,w2,b1,b2,dw1,dw2,db1,db2, learr

        if (epoch % 100 == 0):
            print("Epoch", epoch, "cost: ", mse_loss)

    # calculate training accuracy
    _, _, _, A2_test = forward_prop(X_train,w1,b1,w2,b2)
    predictions_train = np.round(A2_test)
    correct_train = 0
    for j in range(predictions_train.shape[1]): # this is dumb but it works
        if (predictions_train[0][j] == Y_train[0][j] and predictions_train[1
            correct_train = correct_train + 1
    print('Accuracy Train: ', correct_train * 1.0 / predictions_train.shape[

    # calculate test accuracy
    _, _, _, A2_test = forward_prop(X_test,w1,b1,w2,b2)
    predictions_test = np.round(A2_test)
    correct_test = 0
    for j in range(predictions_test.shape[1]):
        if (predictions_test[0][j] == Y_test[0][j] and predictions_test[1][j
            correct_test = correct_test + 1
    score = correct_test * 1.0 / predictions_test.shape[1]
    scores.append(score)
    costs.append(mse_loss)
    print('Accuracy Test ', score)
```

```
hidden layer size 1
Epoch 0 cost:  0.25561552357657974
Epoch 100 cost:  0.25276561775055023
Epoch 200 cost:  0.250553860576344
Epoch 300 cost:  0.24864588651678374
Epoch 400 cost:  0.2468920301941872
Epoch 500 cost:  0.24521540385767948
Epoch 600 cost:  0.24357343251296598
Epoch 700 cost:  0.24194385381806482
Epoch 800 cost:  0.24031825917500663
Epoch 900 cost:  0.23869767608499629
Accuracy Train:  0.656641604010025
Accuracy Test  0.6240601503759399
hidden layer size 2
Epoch 0 cost:  0.2963953341470414
Epoch 100 cost:  0.23654164627732807
Epoch 200 cost:  0.22239221802592424
Epoch 300 cost:  0.21786603941442398
Epoch 400 cost:  0.21490117939141953
Epoch 500 cost:  0.21219230151616866
Epoch 600 cost:  0.2095432544073853
Epoch 700 cost:  0.2069275989087533
Epoch 800 cost:  0.20434214205586723
Epoch 900 cost:  0.20178482160373273
Accuracy Train:  0.7543859649122807
Accuracy Test  0.7243107769423559
hidden layer size 3
Epoch 0 cost:  0.4717032170127107
Epoch 100 cost:  0.3498595264718739
Epoch 200 cost:  0.2874791381155239
Epoch 300 cost:  0.27569483045706855
Epoch 400 cost:  0.26985976485798896
Epoch 500 cost:  0.26468862650511066
Epoch 600 cost:  0.2595394432913096
Epoch 700 cost:  0.2541058196899535
Epoch 800 cost:  0.24803130263641276
Epoch 900 cost:  0.24103631212893342
Accuracy Train:  0.6441102756892231
Accuracy Test  0.5939849624060151
hidden layer size 4
Epoch 0 cost:  0.34233291230416507
Epoch 100 cost:  0.31079660156445
Epoch 200 cost:  0.29432267188321054
Epoch 300 cost:  0.2786066357309047
Epoch 400 cost:  0.2633047854780563
Epoch 500 cost:  0.2491051107158358
Epoch 600 cost:  0.23653979067275255
Epoch 700 cost:  0.2258216098885623
Epoch 800 cost:  0.2168615772925637
Epoch 900 cost:  0.20940467478194152
Accuracy Train:  0.6967418546365914
Accuracy Test  0.6591478696741855
hidden layer size 5
Epoch 0 cost:  0.48304271822932143
Epoch 100 cost:  0.27653993458889825
Epoch 200 cost:  0.2301608150208923
Epoch 300 cost:  0.22135955547083164
Epoch 400 cost:  0.21496343909251736
Epoch 500 cost:  0.20960560054947155
```

```
Epoch 600 cost:  0.20497110350957962
Epoch 700 cost:  0.2008428134372524
Epoch 800 cost:  0.19706992654629232
Epoch 900 cost:  0.19355132997845753
Accuracy Train:  0.7343358395989975
Accuracy Test  0.6842105263157895
hidden layer size 6
Epoch 0 cost:  0.4360893817939204
Epoch 100 cost:  0.28817805013353304
Epoch 200 cost:  0.2547664413615944
Epoch 300 cost:  0.23551844526713517
Epoch 400 cost:  0.22447980714970336
Epoch 500 cost:  0.21727554418431555
Epoch 600 cost:  0.21177543439014157
Epoch 700 cost:  0.20709253134146013
Epoch 800 cost:  0.20285165833558083
Epoch 900 cost:  0.19888405996388
Accuracy Train:  0.7117794486215538
Accuracy Test  0.7017543859649122
hidden layer size 7
Epoch 0 cost:  0.3618360180435311
Epoch 100 cost:  0.3388491638282496
Epoch 200 cost:  0.3137983029187168
Epoch 300 cost:  0.28515799355015276
Epoch 400 cost:  0.25956399190343854
Epoch 500 cost:  0.24128597027456913
Epoch 600 cost:  0.22840111047218492
Epoch 700 cost:  0.21786511048761062
Epoch 800 cost:  0.20807968880687158
Epoch 900 cost:  0.1986423285162282
Accuracy Train:  0.7142857142857143
Accuracy Test  0.6842105263157895
hidden layer size 8
Epoch 0 cost:  0.34136936766222126
Epoch 100 cost:  0.23071635664676507
Epoch 200 cost:  0.22423961169608617
Epoch 300 cost:  0.21908549247703815
Epoch 400 cost:  0.2142244601799949
Epoch 500 cost:  0.20963223945732848
Epoch 600 cost:  0.2052906554476002
Epoch 700 cost:  0.20118058174453982
Epoch 800 cost:  0.1972820531891894
Epoch 900 cost:  0.19357474281084983
Accuracy Train:  0.7694235588972431
Accuracy Test  0.7243107769423559
hidden layer size 9
Epoch 0 cost:  0.26486159418464694
Epoch 100 cost:  0.21206690453999097
Epoch 200 cost:  0.2052047901338781
Epoch 300 cost:  0.1990579474361857
Epoch 400 cost:  0.1933892507367164
Epoch 500 cost:  0.18812244470517958
Epoch 600 cost:  0.18319657253124227
Epoch 700 cost:  0.1785647874365616
Epoch 800 cost:  0.17419159507274012
Epoch 900 cost:  0.170050388605227
Accuracy Train:  0.7969924812030075
Accuracy Test  0.7593984962406015
hidden layer size 10
```

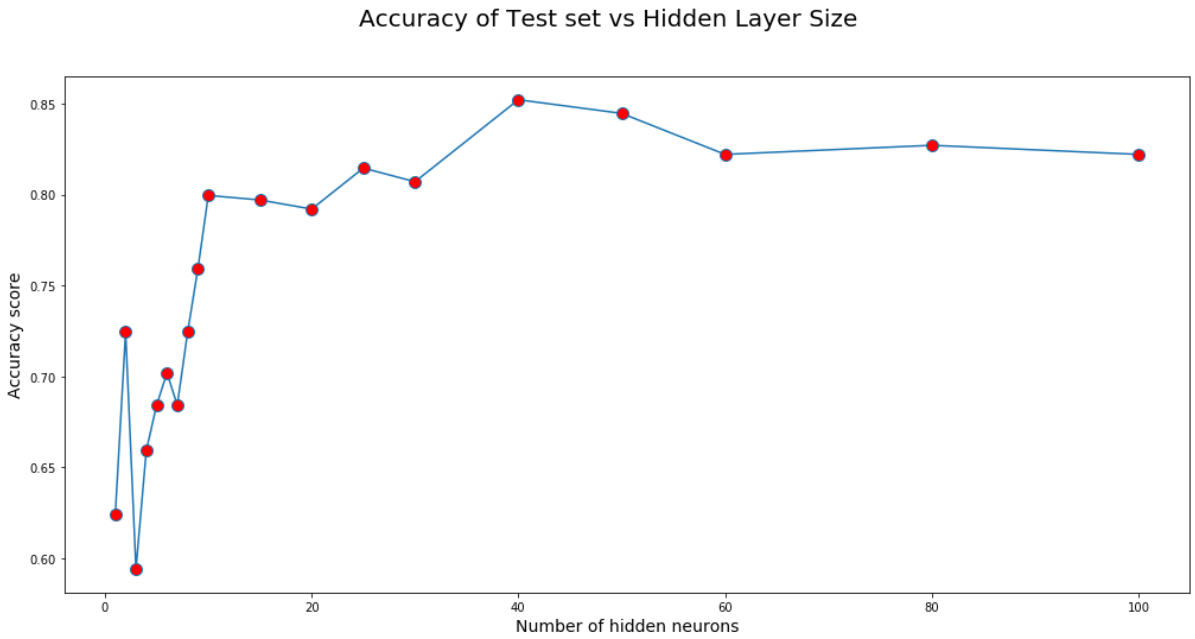
```
Epoch 0 cost:  0.355272648975788
Epoch 100 cost:  0.22863515252375705
Epoch 200 cost:  0.2050635296918924
Epoch 300 cost:  0.1896706837657421
Epoch 400 cost:  0.17789913861073214
Epoch 500 cost:  0.16877854691138933
Epoch 600 cost:  0.1616497846288389
Epoch 700 cost:  0.15589414353727918
Epoch 800 cost:  0.15104841181919085
Epoch 900 cost:  0.14681667327905046
Accuracy Train:  0.8170426065162907
Accuracy Test  0.7994987468671679
hidden layer size 15
Epoch 0 cost:  0.4590139096992968
Epoch 100 cost:  0.27453864399043326
Epoch 200 cost:  0.2521759073955279
Epoch 300 cost:  0.23212238325300028
Epoch 400 cost:  0.21353404544037732
Epoch 500 cost:  0.19676125450580648
Epoch 600 cost:  0.1826132525494493
Epoch 700 cost:  0.1714222526810834
Epoch 800 cost:  0.16270605140794855
Epoch 900 cost:  0.15573685223843797
Accuracy Train:  0.8095238095238095
Accuracy Test  0.7969924812030075
hidden layer size 20
Epoch 0 cost:  0.24941779938775718
Epoch 100 cost:  0.22020112309117026
Epoch 200 cost:  0.19976824653671837
Epoch 300 cost:  0.1845201195674096
Epoch 400 cost:  0.1729921314841523
Epoch 500 cost:  0.16405569217562666
Epoch 600 cost:  0.15693076567124334
Epoch 700 cost:  0.15109900188174005
Epoch 800 cost:  0.14621635429613014
Epoch 900 cost:  0.14205035208736752
Accuracy Train:  0.8170426065162907
Accuracy Test  0.7919799498746867
hidden layer size 25
Epoch 0 cost:  0.41649762300166265
Epoch 100 cost:  0.32630143191720135
Epoch 200 cost:  0.26821768271837904
Epoch 300 cost:  0.22528991558162154
Epoch 400 cost:  0.19533344365809302
Epoch 500 cost:  0.17309936284815672
Epoch 600 cost:  0.15646576093573053
Epoch 700 cost:  0.14402769756786732
Epoch 800 cost:  0.1346321023048168
Epoch 900 cost:  0.1274011936887108
Accuracy Train:  0.8471177944862155
Accuracy Test  0.8145363408521303
hidden layer size 30
Epoch 0 cost:  0.28672185805511086
Epoch 100 cost:  0.2284605413112099
Epoch 200 cost:  0.19128132797967853
Epoch 300 cost:  0.16687707384575437
Epoch 400 cost:  0.1502567821792885
Epoch 500 cost:  0.13893847182574218
Epoch 600 cost:  0.1312187014788597
```

```
Epoch 700 cost:  0.12583910101486118
Epoch 800 cost:  0.12193652423663566
Epoch 900 cost:  0.11896326822988554
Accuracy Train:  0.8345864661654135
Accuracy Test  0.8070175438596491
hidden layer size 40
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Epoch 400 cost:  0.18628393651429304
Epoch 500 cost:  0.16154685857944162
Epoch 600 cost:  0.14450969320383228
Epoch 700 cost:  0.1326668376657647
Epoch 800 cost:  0.12424321995123708
Epoch 900 cost:  0.11807627113500971
Accuracy Train:  0.8571428571428571
Accuracy Test  0.8521303258145363
hidden layer size 50
Epoch 0 cost:  0.5146900645120666
Epoch 100 cost:  0.3461363245913695
Epoch 200 cost:  0.26620745198341966
Epoch 300 cost:  0.20664277752400262
Epoch 400 cost:  0.1706143613366958
Epoch 500 cost:  0.14932366138195788
Epoch 600 cost:  0.13585094697076294
Epoch 700 cost:  0.12667333376167425
Epoch 800 cost:  0.12005427371936674
Epoch 900 cost:  0.11507940592773207
Accuracy Train:  0.8546365914786967
Accuracy Test  0.8446115288220551
hidden layer size 60
Epoch 0 cost:  0.4753304758408258
Epoch 100 cost:  0.3143553725664616
Epoch 200 cost:  0.22550646082398257
Epoch 300 cost:  0.16990873679148807
Epoch 400 cost:  0.1411145277708284
Epoch 500 cost:  0.1262800445382529
Epoch 600 cost:  0.11826376806778062
Epoch 700 cost:  0.11350448136356134
Epoch 800 cost:  0.11031408260094745
Epoch 900 cost:  0.10792931273777277
Accuracy Train:  0.8571428571428571
Accuracy Test  0.8220551378446115
hidden layer size 80
Epoch 0 cost:  0.45601961180843137
Epoch 100 cost:  0.24647387156952313
Epoch 200 cost:  0.15784639198036368
Epoch 300 cost:  0.1319451496822779
Epoch 400 cost:  0.12240653525481845
Epoch 500 cost:  0.11725100557434988
Epoch 600 cost:  0.11372539000024119
Epoch 700 cost:  0.1110081457634849
Epoch 800 cost:  0.10877736583287598
Epoch 900 cost:  0.10687500384937428
Accuracy Train:  0.8671679197994987
Accuracy Test  0.8270676691729323
hidden layer size 100
Epoch 0 cost:  0.49861374032383143
```

```
Epoch 100 cost:  0.1479068936180449
Epoch 200 cost:  0.12592328884469242
Epoch 300 cost:  0.11771278844128401
Epoch 400 cost:  0.11382968339742296
Epoch 500 cost:  0.11142769748648666
Epoch 600 cost:  0.10960089780738515
Epoch 700 cost:  0.10803993175333435
Epoch 800 cost:  0.10663106084655143
Epoch 900 cost:  0.1053278981875611
Accuracy Train:  0.8671679197994987
Accuracy Test  0.8220551378446115
```

In [6]:
```
fig = plt.figure()
fig.suptitle('Accuracy of Test set vs Hidden Layer Size', fontsize = 20)
fig.set_figwidth(17)
fig.set_figheight(8)
ax = fig.add_subplot(111)
ax.plot(hidden_layer_sizes, scores, '-o', markersize = 10, markerfacecolor =
ax.set_xlabel('Number of hidden neurons', fontsize = 14)
ax.set_ylabel('Accuracy score', fontsize = 14)
```

Out[6]:
```
Text(0, 0.5, 'Accuracy score')
```



Changing EPOCHS

In [7]:
```
scores = []
costs = []
for num_epochs in epoch_sizes:
    print('epoch size', num_epochs)
    input_nodes = X_train.shape[0]
    hidden_nodes = hidden_layer_size
    output_nodes = Y_train.shape[0]

    np.random.seed(68)
    w1 = np.random.randn(hidden_nodes,input_nodes)
    b1 = np.zeros((hidden_nodes,1))
    w2 = np.random.randn(output_nodes,hidden_nodes)
    b2 = np.zeros((output_nodes,1))

    for epoch in range(num_epochs):
        # forward propagation
        Z1, A1, Z2, A2 = forward_prop(X_train,w1,b1,w2,b2)

        # mse loss
        mse_loss = np.mean((Y_train - A2) ** 2)

        # backwards propagation
        dw1, dw2, db1, db2 = backwards_prop(w1, w2, A1, A2, X_train, Y_trair

        # gradient descent
        w2, b2, w1, b1 = gradient_descent(w1,w2,b1,b2,dw1,dw2,db1,db2, learr

        if (epoch % 100 == 0):
            print("Epoch", epoch, "cost: ", mse_loss)

    # calculate training accuracy
    _, _, _, A2_test = forward_prop(X_train,w1,b1,w2,b2)
    predictions_train = np.round(A2_test)
    correct_train = 0
    for j in range(predictions_train.shape[1]): # this is dumb but it works
        if (predictions_train[0][j] == Y_train[0][j] and predictions_train[1
            correct_train = correct_train + 1
    print('Accuracy Train: ', correct_train * 1.0 / predictions_train.shape[

    # calculate test accuracy
    _, _, _, A2_test = forward_prop(X_test,w1,b1,w2,b2)
    predictions_test = np.round(A2_test)
    correct_test = 0
    for j in range(predictions_test.shape[1]):
        if (predictions_test[0][j] == Y_test[0][j] and predictions_test[1][j
            correct_test = correct_test + 1
    score = correct_test * 1.0 / predictions_test.shape[1]
    scores.append(score)
    costs.append(mse_loss)
    print('Accuracy Test ', score)
```

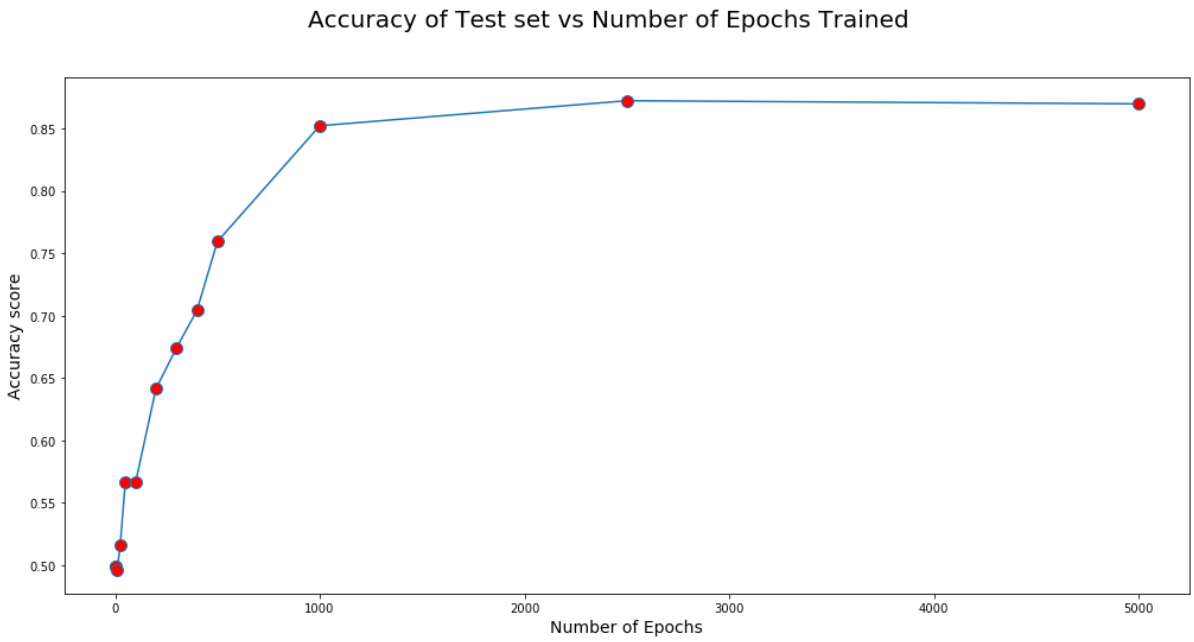
```
epoch size 1
Epoch 0 cost:  0.494646843732235
Accuracy Train:  0.49874686716791977
Accuracy Test  0.49874686716791977
epoch size 5
Epoch 0 cost:  0.494646843732235
Accuracy Train:  0.49874686716791977
Accuracy Test  0.49874686716791977
epoch size 10
Epoch 0 cost:  0.494646843732235
Accuracy Train:  0.49874686716791977
Accuracy Test  0.49624060150375937
epoch size 25
Epoch 0 cost:  0.494646843732235
Accuracy Train:  0.5087719298245614
Accuracy Test  0.5162907268170426
epoch size 50
Epoch 0 cost:  0.494646843732235
Accuracy Train:  0.5238095238095238
Accuracy Test  0.5664160401002506
epoch size 100
Epoch 0 cost:  0.494646843732235
Accuracy Train:  0.5388471177944862
Accuracy Test  0.5664160401002506
epoch size 200
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Accuracy Train:  0.5989974937343359
Accuracy Test  0.6416040100250626
epoch size 300
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Accuracy Train:  0.6541353383458647
Accuracy Test  0.6741854636591479
epoch size 400
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Accuracy Train:  0.7243107769423559
Accuracy Test  0.7042606516290727
epoch size 500
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Epoch 400 cost:  0.18628393651429304
Accuracy Train:  0.7994987468671679
Accuracy Test  0.7593984962406015
epoch size 1000
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Epoch 400 cost:  0.18628393651429304
Epoch 500 cost:  0.16154685857944162
Epoch 600 cost:  0.14450969320383228
Epoch 700 cost:  0.1326668376657647
```

```
Epoch 800 cost:  0.12424321995123708
Epoch 900 cost:  0.11807627113500971
Accuracy Train:  0.8571428571428571
Accuracy Test  0.8521303258145363
epoch size 2500
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Epoch 400 cost:  0.18628393651429304
Epoch 500 cost:  0.16154685857944162
Epoch 600 cost:  0.14450969320383228
Epoch 700 cost:  0.1326668376657647
Epoch 800 cost:  0.12424321995123708
Epoch 900 cost:  0.11807627113500971
Epoch 1000 cost:  0.11342485793003629
Epoch 1100 cost:  0.10981628285915747
Epoch 1200 cost:  0.10694457972424809
Epoch 1300 cost:  0.1046073781598438
Epoch 1400 cost:  0.10266753343921746
Epoch 1500 cost:  0.10102978103042817
Epoch 1600 cost:  0.09962635555033823
Epoch 1700 cost:  0.09840797015724154
Epoch 1800 cost:  0.0973380396993897
Epoch 1900 cost:  0.09638890027645097
Epoch 2000 cost:  0.09553928157856673
Epoch 2100 cost:  0.09477258150332703
Epoch 2200 cost:  0.09407566510474828
Epoch 2300 cost:  0.0934380130671769
Epoch 2400 cost:  0.0928511076216159
Accuracy Train:  0.8897243107769424
Accuracy Test  0.8721804511278195
epoch size 5000
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Epoch 400 cost:  0.18628393651429304
Epoch 500 cost:  0.16154685857944162
Epoch 600 cost:  0.14450969320383228
Epoch 700 cost:  0.1326668376657647
Epoch 800 cost:  0.12424321995123708
Epoch 900 cost:  0.11807627113500971
Epoch 1000 cost:  0.11342485793003629
Epoch 1100 cost:  0.10981628285915747
Epoch 1200 cost:  0.10694457972424809
Epoch 1300 cost:  0.1046073781598438
Epoch 1400 cost:  0.10266753343921746
Epoch 1500 cost:  0.10102978103042817
Epoch 1600 cost:  0.09962635555033823
Epoch 1700 cost:  0.09840797015724154
Epoch 1800 cost:  0.0973380396993897
Epoch 1900 cost:  0.09638890027645097
Epoch 2000 cost:  0.09553928157856673
Epoch 2100 cost:  0.09477258150332703
Epoch 2200 cost:  0.09407566510474828
Epoch 2300 cost:  0.0934380130671769
Epoch 2400 cost:  0.0928511076216159
Epoch 2500 cost:  0.09230798266875737
```

```
Epoch 2600 cost:  0.09180288937757745
Epoch 2700 cost:  0.09133104426771294
Epoch 2800 cost:  0.09088843707168211
Epoch 2900 cost:  0.09047168251107933
Epoch 3000 cost:  0.09007790473883902
Epoch 3100 cost:  0.08970464636556179
Epoch 3200 cost:  0.08934979618927007
Epoch 3300 cost:  0.08901153129918009
Epoch 3400 cost:  0.08868827033091496
Epoch 3500 cost:  0.0883786354496742
Epoch 3600 cost:  0.0880814212211763
Epoch 3700 cost:  0.08779556896041488
Epoch 3800 cost:  0.08752014546868835
Epoch 3900 cost:  0.0872543253102034
Epoch 4000 cost:  0.08699737596214516
Epoch 4100 cost:  0.08674864531167141
Epoch 4200 cost:  0.08650755108078978
Epoch 4300 cost:  0.08627357184348262
Epoch 4400 cost:  0.08604623936460894
Epoch 4500 cost:  0.08582513204135617
Epoch 4600 cost:  0.08560986926856856
Epoch 4700 cost:  0.08540010658156096
Epoch 4800 cost:  0.08519553145587731
Epoch 4900 cost:  0.0849958596642631
Accuracy Train:  0.8947368421052632
Accuracy Test  0.8696741854636592
```

In [8]:
```
fig = plt.figure()
fig.suptitle('Accuracy of Test set vs Number of Epochs Trained', fontsize =
fig.set_figwidth(17)
fig.set_figheight(8)
ax = fig.add_subplot(111)
ax.plot(epoch_sizes, scores, '-o', markersize = 10, markerfacecolor = 'r')
ax.set_xlabel('Number of Epochs', fontsize = 14)
ax.set_ylabel('Accuracy score', fontsize = 14)
```

Out[8]:
```
Text(0, 0.5, 'Accuracy score')
```



Changing LEARNING RATES

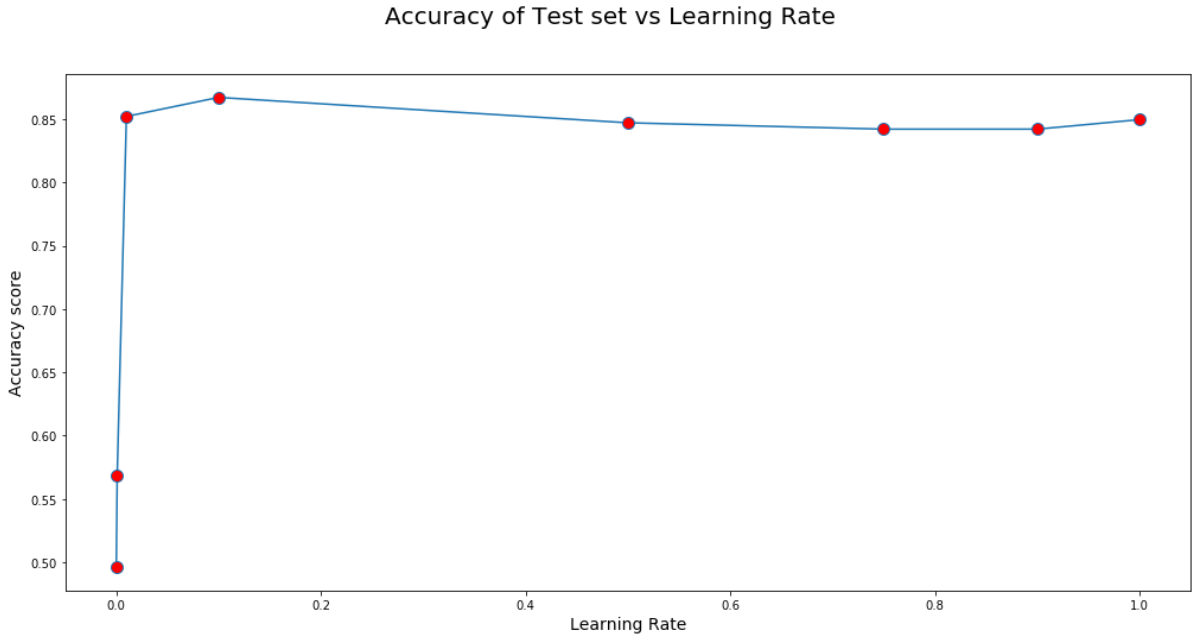
In [9]:
```
scores = []
costs = []
for learning_rate_it in learning_rates:
    print('learning rate',learning_rate_it)
    input_nodes = X_train.shape[0]
    hidden_nodes = hidden_layer_size
    output_nodes = Y_train.shape[0]

    np.random.seed(68)
    w1 = np.random.randn(hidden_nodes,input_nodes)
    b1 = np.zeros((hidden_nodes,1))
    w2 = np.random.randn(output_nodes,hidden_nodes)
    b2 = np.zeros((output_nodes,1))

    for epoch in range(epochs):
        # forward propagation
        Z1, A1, Z2, A2 = forward_prop(X_train,w1,b1,w2,b2)

        # mse loss
        mse_loss = np.mean((Y_train - A2) ** 2)

        # backwards propagation
        dw1, dw2, db1, db2 = backwards_prop(w1, w2, A1, A2, X_train, Y_trair

        # gradient descent
        w2, b2, w1, b1 = gradient_descent(w1,w2,b1,b2,dw1,dw2,db1,db2, learr

        if (epoch % 100 == 0):
            print("Epoch", epoch, "cost: ", mse_loss)

    # calculate training accuracy
    _, _, _, A2_test = forward_prop(X_train,w1,b1,w2,b2)
    predictions_train = np.round(A2_test)
    correct_train = 0
    for j in range(predictions_train.shape[1]): # this is dumb but it works
        if (predictions_train[0][j] == Y_train[0][j] and predictions_train[1
            correct_train = correct_train + 1
    print('Accuracy Train: ', correct_train * 1.0 / predictions_train.shape[

    # calculate test accuracy
    _, _, _, A2_test = forward_prop(X_test,w1,b1,w2,b2)
    predictions_test = np.round(A2_test)
    correct_test = 0
    for j in range(predictions_test.shape[1]):
        if (predictions_test[0][j] == Y_test[0][j] and predictions_test[1][j
            correct_test = correct_test + 1
    score = correct_test * 1.0 / predictions_test.shape[1]
    scores.append(score)
    costs.append(mse_loss)
    print('Accuracy Test ', score)
```

```
learning rate 0.0001
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.49357466284575613
Epoch 200 cost:  0.4923439462326721
Epoch 300 cost:  0.4909370300921532
Epoch 400 cost:  0.48933622668002075
Epoch 500 cost:  0.48752450285372284
Epoch 600 cost:  0.4854863031273879
Epoch 700 cost:  0.4832084788138402
Epoch 800 cost:  0.48068125550516166
Epoch 900 cost:  0.47789914529038013
Accuracy Train:  0.49874686716791977
Accuracy Test  0.49624060150375937
learning rate 0.001
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.47485450479945457
Epoch 200 cost:  0.4339709207513641
Epoch 300 cost:  0.3940423196459815
Epoch 400 cost:  0.3718654369786363
Epoch 500 cost:  0.3616267968259137
Epoch 600 cost:  0.3552366705630814
Epoch 700 cost:  0.3493981093360265
Epoch 800 cost:  0.3433358441394869
Epoch 900 cost:  0.33702979723084264
Accuracy Train:  0.5388471177944862
Accuracy Test  0.568922305764411
learning rate 0.01
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.3306136424840891
Epoch 200 cost:  0.26992970075780653
Epoch 300 cost:  0.22167300488916736
Epoch 400 cost:  0.18628393651429304
Epoch 500 cost:  0.16154685857944162
Epoch 600 cost:  0.14450969320383228
Epoch 700 cost:  0.1326668376657647
Epoch 800 cost:  0.12424321995123708
Epoch 900 cost:  0.11807627113500971
Accuracy Train:  0.8571428571428571
Accuracy Test  0.8521303258145363
learning rate 0.1
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.11329925521671372
Epoch 200 cost:  0.09553951762636517
Epoch 300 cost:  0.09009591766916993
Epoch 400 cost:  0.08701982424809669
Epoch 500 cost:  0.0848244174930287
Epoch 600 cost:  0.08308588336887876
Epoch 700 cost:  0.0816387696145691
Epoch 800 cost:  0.080402145250826
Epoch 900 cost:  0.07932855502213247
Accuracy Train:  0.9072681704260651
Accuracy Test  0.8671679197994987
learning rate 0.5
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.08679463749881278
Epoch 200 cost:  0.0798407772926563
Epoch 300 cost:  0.07605737724700898
Epoch 400 cost:  0.0734824587979813
Epoch 500 cost:  0.0712887662681112
```

```
Epoch 600 cost:  0.07790449994634825
Epoch 700 cost:  0.0692240600814496
Epoch 800 cost:  0.06587161048918438
Epoch 900 cost:  0.06307190485957637
Accuracy Train:  0.9323308270676691
Accuracy Test  0.8471177944862155
learning rate 0.75
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.10746658287795516
Epoch 200 cost:  0.09246516955965538
Epoch 300 cost:  0.08634494312397246
Epoch 400 cost:  0.08177971684263098
Epoch 500 cost:  0.07705116247655752
Epoch 600 cost:  0.07256810743842615
Epoch 700 cost:  0.06862559824466898
Epoch 800 cost:  0.06524151533756911
Epoch 900 cost:  0.060960782140692796
Accuracy Train:  0.9273182957393483
Accuracy Test  0.8421052631578947
learning rate 0.9
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.10213746407023207
Epoch 200 cost:  0.09232545621049248
Epoch 300 cost:  0.0852600226922824
Epoch 400 cost:  0.079396553017153
Epoch 500 cost:  0.07478222485446999
Epoch 600 cost:  0.07095822583138625
Epoch 700 cost:  0.06728440206187511
Epoch 800 cost:  0.0637601780416217
Epoch 900 cost:  0.06042082049237882
Accuracy Train:  0.9273182957393483
Accuracy Test  0.8421052631578947
learning rate 1
Epoch 0 cost:  0.494646843732235
Epoch 100 cost:  0.10361663965998252
Epoch 200 cost:  0.09085447152478784
Epoch 300 cost:  0.08340311487679555
Epoch 400 cost:  0.07789689785422257
Epoch 500 cost:  0.07309632324329657
Epoch 600 cost:  0.06904826448743027
Epoch 700 cost:  0.06558138314135752
Epoch 800 cost:  0.062326183311260934
Epoch 900 cost:  0.05908187405982046
Accuracy Train:  0.9223057644110275
Accuracy Test  0.849624060150376
```

In [10]:
```
fig = plt.figure()
fig.suptitle('Accuracy of Test set vs Learning Rate', fontsize = 20)
fig.set_figwidth(17)
fig.set_figheight(8)
ax = fig.add_subplot(111)
ax.plot(learning_rates, scores, '-o', markersize = 10, markerfacecolor = 'r'
ax.set_xlabel('Learning Rate', fontsize = 14)
ax.set_ylabel('Accuracy score', fontsize = 14)
```

Out[10]:
```
Text(0, 0.5, 'Accuracy score')
```


Accuracy of Test set vs Learning Rate
Accuracy score
Learning Rate
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.0
0.2
0.4
0.6
0.8
1.0

In [ ]: