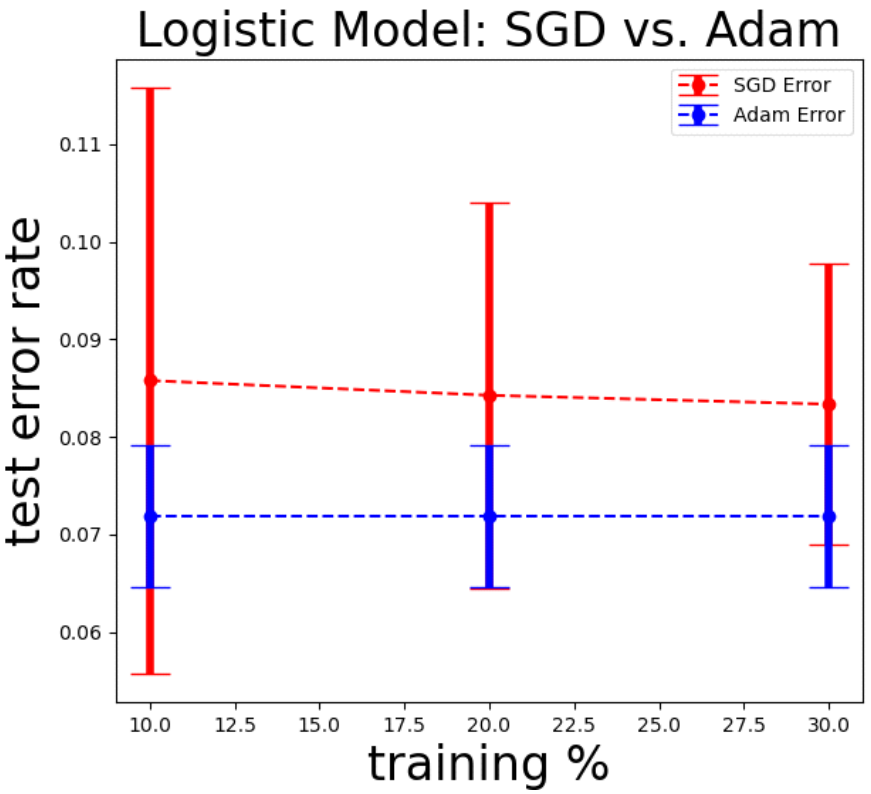
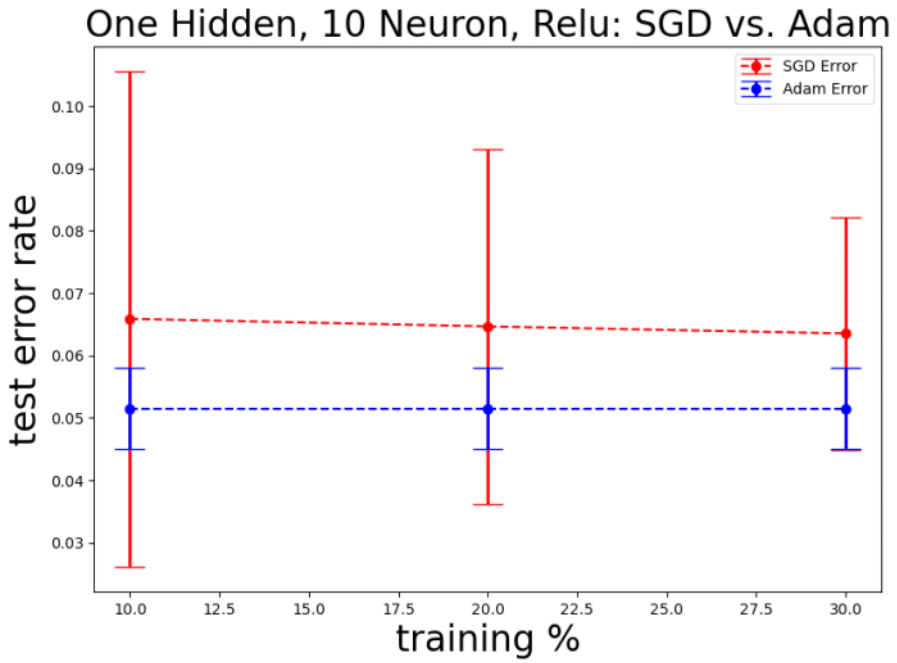
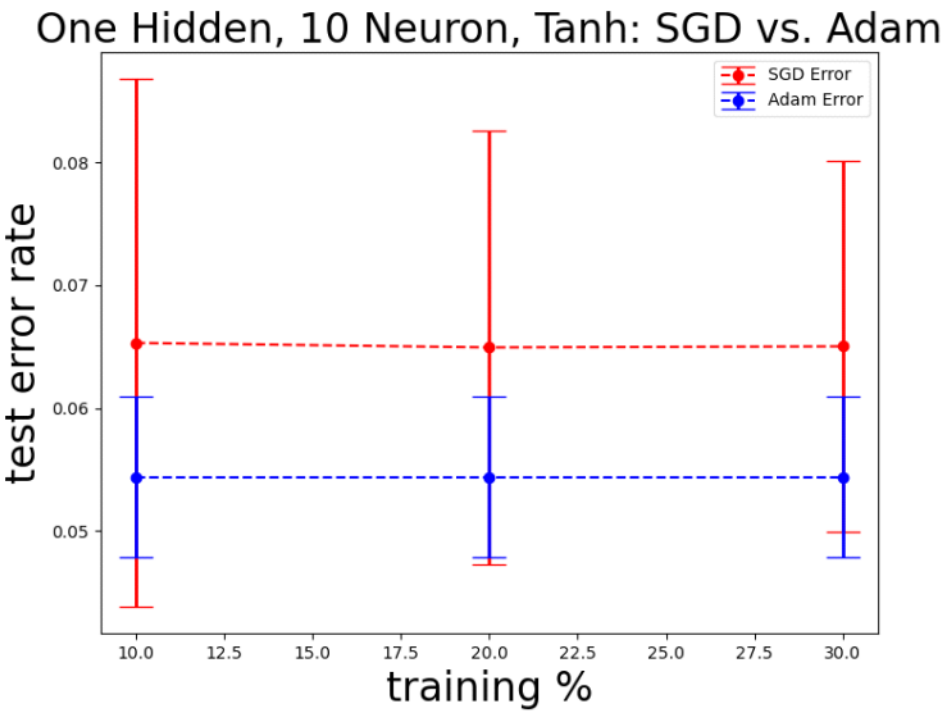
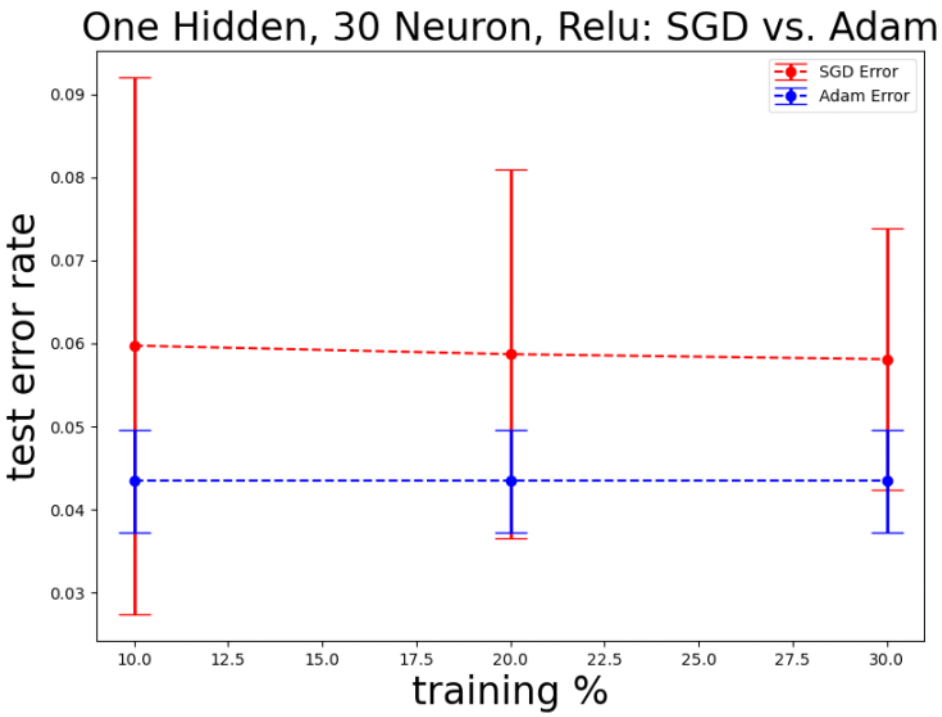
HW 6

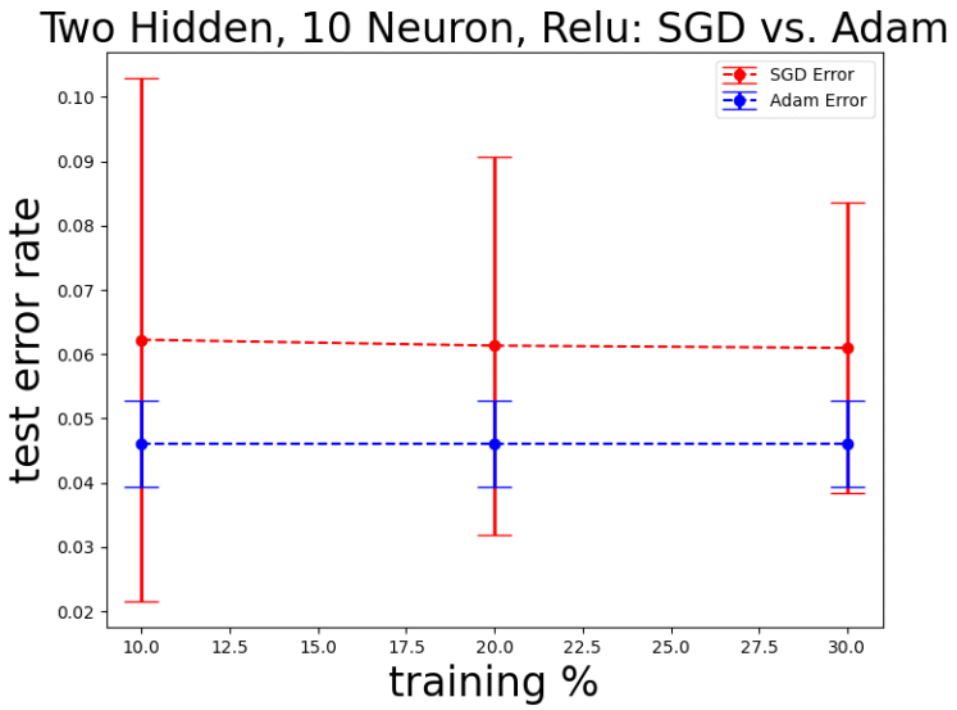
Tuesday, December 14, 2021 7:36 PM






One Hidden, 10 Neuron, Tanh: SGD vs. Adam
SGD Error
Adam Error
test error rate
0.08
0.07
0.06
0.05
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
training %


One Hidden, 30 Neuron, Relu: SGD vs. Adam
SGD Error
Adam Error
test error rate
0.09
0.08
0.07
0.06
0.05
0.04
0.03
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
training %



Summary:

The results are as follows. In terms of accuracy the order goes

$logisitic < 10_{relu} \approx 10_{tanh} < 30_{relu} \approx 10{,}10_{relu}$

Or in other terms

Logistic is the least accurate, followed by 10 relu and 10 tanh activiation, followed by 30 relu and 2 layer 10 relu activation.

On the spambase dataset all implementations were able to get reasonable accuracte after just a few epochs. And as expected they all got more accurate the more training data they received. Using the libraries like Tensorflow made running these algorithms very efficient. We did not record time but it was much faster than the first time analyzing the spambase dataset with our own implementation of logistic regression.

The neural network implementations were also fast. However the 2 hidden layer, and 30 neuron implementation were the slowest of the bunch. They however made up for that computation expense by being the most accuracte for both optimizers "SGD" and "Adam".

Adam optimizer was also consistently better than SGD. This gives reason as to why Adam optimizer is more standard in the field than SGD. However SGD is still a good way to ensure things are working.

The code used to generate the 80-20 splits and further training percentages from that were all from the hw3 solution. However the creation of the models and subsequent training were all written originally.

```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
import numpy as np
import pandas as pd
from sklearn.utils import shuffle
import matplotlib.pyplot as plt

#read data from hw3 solution
def read_data(filename='spambase.csv', d=57):
    # read data
    data_df = pd.read_csv(filename, header=None).dropna(axis=0)
    # preprocess
    X = np.array(data_df.iloc[:,:d])
    X = (X-np.mean(X, axis=0))/np.std(X, axis=0) # normalize
    y = np.array(data_df.iloc[:,d:])
    y = y.flatten()
    # seperate classes
    X1 = X[y==1]
    X0 = X[y==0]
    y1 = y[y==1]
    y0 = y[y==0]
    return X0, y0, X1, y1

#train test split from hw3 solution
def train_test_split(X0, y0, X1, y1, split_percent):
    # splitting id
    split_id0 = int(X0.shape[0]*split_percent*.01)
    split_id1 = int(X1.shape[0]*split_percent*.01)
    # random shuffle each class
    X00, y00 = shuffle(X0, y0)
    X11, y11 = shuffle(X1, y1)
    # train set

    Xtrain = np.concatenate((X00[:split_id0], X11[:split_id1]), axis=0)
    ytrain = np.concatenate((y00[:split_id0], y11[:split_id1]), axis=0)
    # test set
    Xtest = np.concatenate((X00[split_id0:], X11[split_id1:]), axis=0)
    ytest = np.concatenate((y00[split_id0:], y11[split_id1:]), axis=0)
    # random shuffle train set
    Xtrain, ytrain = shuffle(Xtrain, ytrain)
    return Xtrain, ytrain, Xtest, ytest

#train data from hw3 solution
def train_data(X, y, train_percent):
    N = X.shape[0]
    split_id = int(N*train_percent/100)
    return X[:split_id], y[:split_id]

def one_10_tanh(filename, num_splits, train_percent):
    #parse
    X0, y0, X1, y1 = read_data(filename)
    # init error
    test_errors = np.zeros((num_splits, len(train_percent)))
    #creat 1 hidden 10 neuron SGD model
```

```
    model = tf.keras.models.Sequential()
    model.add(tf.keras.layers.Dense(10,input_dim = len(X0[0,:]),activation='tanh'))
    model.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model.compile(loss = 'binary_crossentropy', optimizer = 'SGD',metrics = ['accuracy'])

    split_percent=80
    for i in range(num_splits):
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            model.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            loss, acc = model.evaluate(Xtest_i,ytest_i)

            test_errors[i][j] = 1-acc

    test2 = np.zeros((num_splits,len(train_percent)))
    #create 1 hidden, 10 neuron Adam Model
    model2= tf.keras.models.Sequential()
    model2.add(tf.keras.layers.Dense(10,input_dim = len(X0[0,:]),activation='tanh'))
    model2.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model2.compile(loss = 'binary_crossentropy', optimizer = 'Adam',metrics = ['accuracy'])
    for i in range(num_splits):
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            #create training percent data
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            #train
            model2.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            #test
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #store results
            test2[i][j] = 1-acc
    return test_errors,test2

def one_30_relu(filename, num_splits, train_percent):
    #parse
    X0, y0, X1, y1 = read_data(filename)
    # init error
    test_errors = np.zeros((num_splits, len(train_percent)))
    #create 1 hidden 30 neuron SGD model
    model = tf.keras.models.Sequential()
    model.add(tf.keras.layers.Dense(30,input_dim = len(X0[0,:]),activation='relu'))
    model.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model.compile(loss = 'binary_crossentropy', optimizer = 'SGD',metrics = ['accuracy'])

    split_percent=80
    for i in range(num_splits):
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            model.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            loss, acc = model.evaluate(Xtest_i,ytest_i)
```

```
            #print(loss)
            test_errors[i][j] = 1-acc
    print("halfway")
    test2 = np.zeros((num_splits,len(train_percent)))
    model2= tf.keras.models.Sequential()
    model2.add(tf.keras.layers.Dense(30,input_dim = len(X0[0,:]),activation='relu'))
    model2.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model2.compile(loss = 'binary_crossentropy', optimizer = 'Adam',metrics = ['accuracy'])
    for i in range(num_splits):
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            model2.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #print(loss)
            test2[i][j] = 1-acc
    return test_errors,test2

def one_10_relu(filename, num_splits, train_percent):
    #parse
    X0, y0, X1, y1 = read_data(filename)
    # init error
    test_errors = np.zeros((num_splits, len(train_percent)))
    #create 1 hidden 10 neuron relu model
    model = tf.keras.models.Sequential()
    model.add(tf.keras.layers.Dense(10,input_dim = len(X0[0,:]),activation='relu'))
    model.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model.compile(loss = 'binary_crossentropy', optimizer = 'SGD',metrics = ['accuracy'])

    split_percent=80
    for i in range(num_splits):
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            model.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #print(loss)
            test_errors[i][j] = 1-acc

    test2 = np.zeros((num_splits,len(train_percent)))
    #create 1 hidden 10 neuron Adam model
    model2= tf.keras.models.Sequential()
    model2.add(tf.keras.layers.Dense(10,input_dim = len(X0[0,:]),activation='relu'))
    model2.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model2.compile(loss = 'binary_crossentropy', optimizer = 'Adam',metrics = ['accuracy'])
    for i in range(num_splits):
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            model2.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #print(loss)
```

```
            test2[i][j] = 1-acc
    return test_errors,test2

def two_10_relu(filename, num_splits, train_percent):
    #parse
    X0, y0, X1, y1 = read_data(filename)

    test_errors = np.zeros((num_splits, len(train_percent)))
    #create 2 hidden layer 10 neuron sgd model
    model = tf.keras.models.Sequential()
    model.add(tf.keras.layers.Dense(10,input_dim = len(X0[0,:]),activation='relu'))
    model.add(tf.keras.layers.Dense(10,activation='relu'))
    model.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model.compile(loss = 'binary_crossentropy', optimizer = 'SGD',metrics = ['accuracy'])

    split_percent=80
    for i in range(num_splits):
        #create 80-20 split
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            #create percent training data
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            #train model
            model.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            #test model
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #store results
            test_errors[i][j] = 1-acc

    test2 = np.zeros((num_splits,len(train_percent)))
    #create 2 hidden layer 10 neuron Adam model
    model2= tf.keras.models.Sequential()
    model2.add(tf.keras.layers.Dense(10,input_dim = len(X0[0,:]),activation='relu'))
    model2.add(tf.keras.layers.Dense(10,activation='relu'))
    model2.add(tf.keras.layers.Dense(1,activation = "sigmoid"))
    model2.compile(loss = 'binary_crossentropy', optimizer = 'Adam',metrics = ['accuracy'])
    for i in range(num_splits):
        #create 80-20 split
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            #create training percent data
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            #train
            model2.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            #test
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #store results
            test2[i][j] = 1-acc
    return test_errors,test2


def logistic(filename, num_splits, train_percent):
```

```
    #parse
    X0, y0, X1, y1 = read_data(filename)

    test_errors = np.zeros((num_splits, len(train_percent)))

    #Create logistic regression SGD model
    model = tf.keras.models.Sequential()
    model.add(tf.keras.layers.Dense(1,input_dim = len(X0[0,:]),activation='sigmoid'))
    model.compile(loss = 'binary_crossentropy', optimizer = 'SGD',metrics = ['accuracy'])

    split_percent=80
    for i in range(num_splits):
        #create 80-20 Split
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for different train set sizes
        for j, percent in enumerate(train_percent):
            #create percent training data
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            #train model
            model.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            #test model
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #store results
            test_errors[i][j] = 1-acc

    test2 = np.zeros((num_splits,len(train_percent)))

    #Create logistic regression Adam model
    model2= tf.keras.models.Sequential()
    model2.add(tf.keras.layers.Dense(1,input_dim = len(X0[0,:]),activation='sigmoid'))
    model2.compile(loss = 'binary_crossentropy', optimizer = 'Adam',metrics = ['accuracy'])
    for i in range(num_splits):
        #create 80-20 split
        Xtrain_i, ytrain_i, Xtest_i, ytest_i = train_test_split(X0, y0, X1, y1,split_percent)
        # try for differnt train set sizes
        for j, percent in enumerate(train_percent):
            #create percent training data
            Xtrain_ij, ytrain_ij = train_data(Xtrain_i, ytrain_i, percent)
            #train model
            model2.fit(Xtrain_ij,ytrain_ij,epochs=2,batch_size=20,verbose=0)
            #test model
            loss, acc = model.evaluate(Xtest_i,ytest_i)
            #store results
            test2[i][j] = 1-acc
    return test_errors,test2

filename='spambase.csv'
num_splits=100
train_percent = [ 10,  20, 30]

#Comment Block For Running different moels

# sgd,adam = logistic(filename,num_splits,train_percent)
# sgd,adam = one_10_relu(filename,num_splits,train_percent)
# sgd,adam = one_10_tanh(filename,num_splits,train_percent)
```

```
# sgd,adam = one_30_relu(filename,num_splits,train_percent)
sgd,adam = two_10_relu(filename,num_splits,train_percent)


#plotting
sgd_mean = np.mean(sgd, axis=0)
adam_mean = np.mean(adam,axis=0)
sgd_stdev = np.std(sgd,axis=0)
adam_stdev =np.std(adam,axis=0)
plt.errorbar(train_percent, sgd_mean, yerr=sgd_stdev, fmt='ro--',capsize=10, elinewidth=2, label="SGD Error")
plt.errorbar(train_percent, adam_mean, yerr=adam_stdev, fmt='bo--', capsize=10, elinewidth=2, label="Adam Error"
)
plt.legend()

plt.xlabel('training %', fontsize=24)
plt.ylabel('test error rate', fontsize=24)
plt.title('Two Hidden, 10 Neuron, Relu: SGD vs. Adam', fontsize=24)
plt.show()
```