Name: Pham Minh Nghia

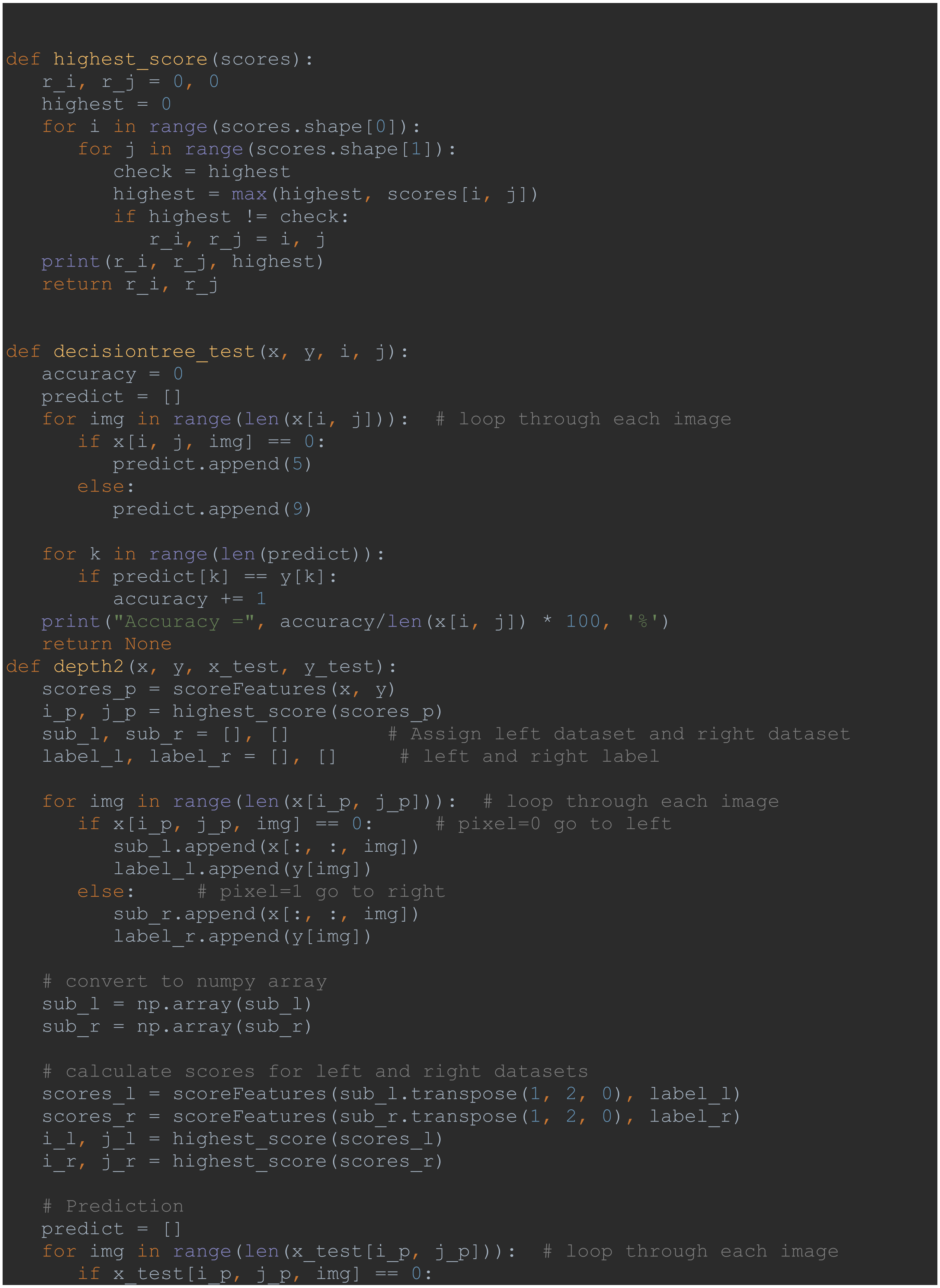
SID: 32507133

Problem 1:

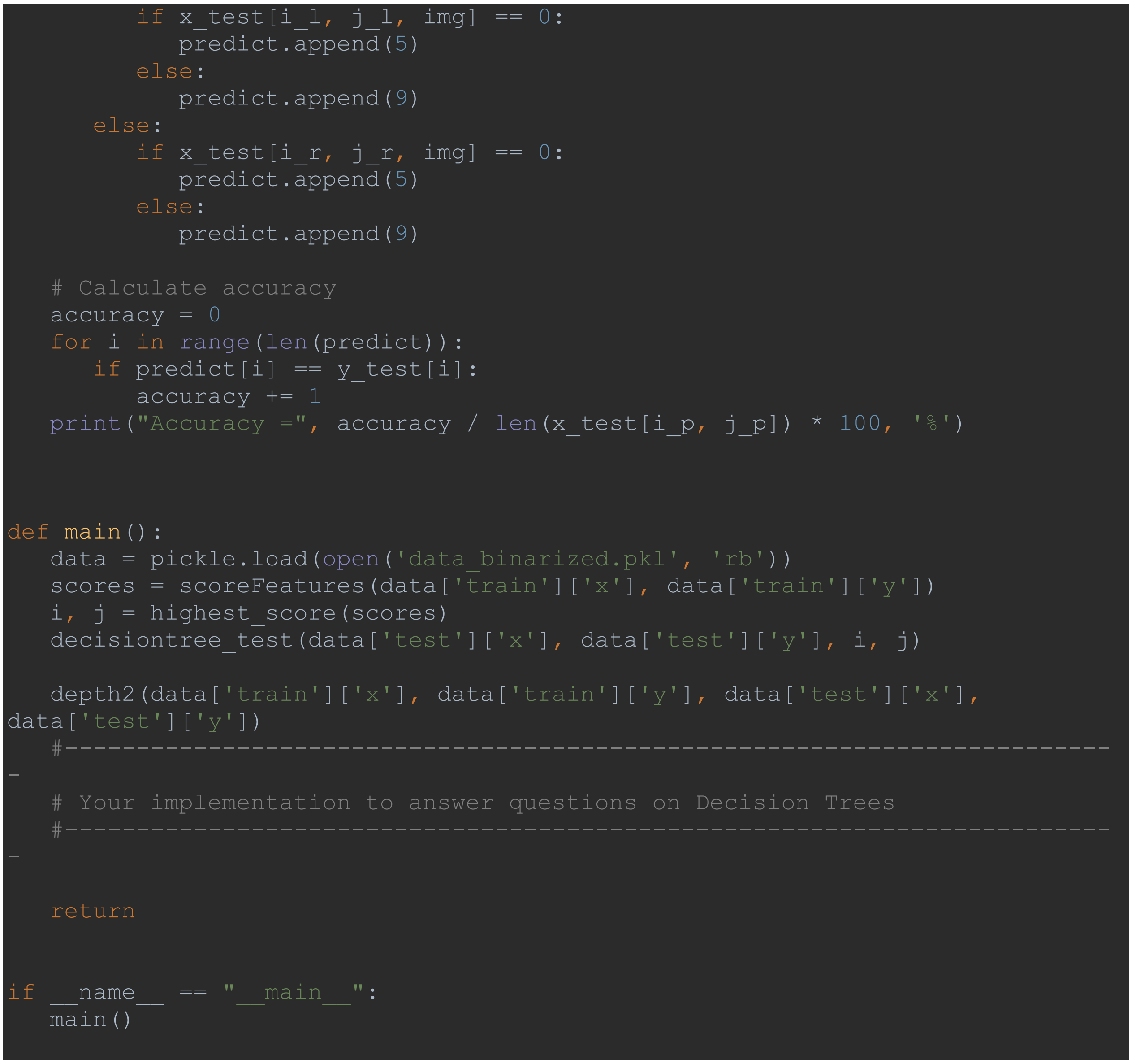
1. Because there are 50 '5's and 50 '9's, the accuracy of an empty decision tree on the training set is 50%. If the training set is a random set then the accuracy is number_of_majority/total. On this particular test set, accuracy is 50% with the same above explanation.

Code:

```
#This code is part of:
#
#   CMPSCI 370: Computer Vision, Spring 2021
#   University of Massachusetts, Amherst
#   Instructor: Subhransu Maji
#
#   Mini-Project 6

import pickle
import numpy as np
import matplotlib.pyplot as plt


def scoreFeatures(x, y):
   scores = np.zeros(x.shape[:2])
   five, nine = np.zeros(x.shape[:2]), np.zeros(x.shape[:2])
   #-------------------------------------------------------------------------
-
   # Calculate scores (Implement this)
   #-------------------------------------------------------------------------
-

   # Calculate each attribute
   for i in range(len(x[:, :, 1])):      # loop through each pixel feature
      for j in range(len(x[i, :, 1])):
         for img in range(len(x[i, j])):       # loop through each image
            if x[i, j, img] == 0:     # 1 is on and 0 is off
               if y[img] == 5:           # 5 is 'hated'
                  five[i, j] += 1
            else:
               if y[img] == 9:           # 9 is 'liked'
                  nine[i, j] += 1

   scores = five + nine
   plt.imshow(scores, cmap='gray')
   plt.axis('off')
   plt.show()
   return scores
```



```python
def highest_score(scores):
   r_i, r_j = 0, 0
   highest = 0
   for i in range(scores.shape[0]):
      for j in range(scores.shape[1]):
         check = highest
         highest = max(highest, scores[i, j])
         if highest != check:
            r_i, r_j = i, j
   print(r_i, r_j, highest)
   return r_i, r_j


def decisiontree_test(x, y, i, j):
   accuracy = 0
   predict = []
   for img in range(len(x[i, j])):  # loop through each image
      if x[i, j, img] == 0:
         predict.append(5)
      else:
         predict.append(9)

   for k in range(len(predict)):
      if predict[k] == y[k]:
         accuracy += 1
   print("Accuracy =", accuracy/len(x[i, j]) * 100, '%')
   return None
def depth2(x, y, x_test, y_test):
   scores_p = scoreFeatures(x, y)
   i_p, j_p = highest_score(scores_p)
   sub_l, sub_r = [], []        # Assign left dataset and right dataset
   label_l, label_r = [], []     # left and right label

   for img in range(len(x[i_p, j_p])):  # loop through each image
      if x[i_p, j_p, img] == 0:     # pixel=0 go to left
         sub_l.append(x[:, :, img])
         label_l.append(y[img])
      else:     # pixel=1 go to right
         sub_r.append(x[:, :, img])
         label_r.append(y[img])

   # convert to numpy array
   sub_l = np.array(sub_l)
   sub_r = np.array(sub_r)

   # calculate scores for left and right datasets
   scores_l = scoreFeatures(sub_l.transpose(1, 2, 0), label_l)
   scores_r = scoreFeatures(sub_r.transpose(1, 2, 0), label_r)
   i_l, j_l = highest_score(scores_l)
   i_r, j_r = highest_score(scores_r)

   # Prediction
   predict = []
   for img in range(len(x_test[i_p, j_p])):  # loop through each image
      if x_test[i_p, j_p, img] == 0:
```



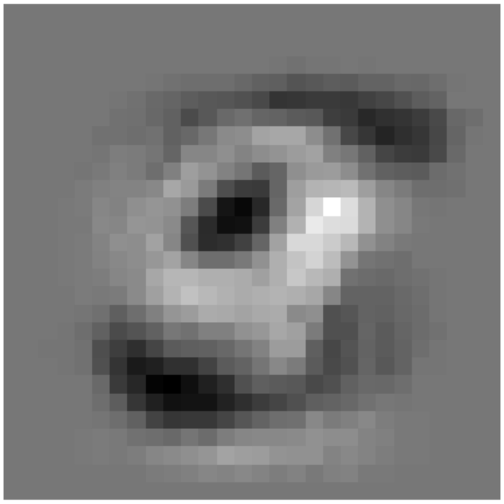
```
         if x_test[i_l, j_l, img] == 0:
            predict.append(5)
         else:
            predict.append(9)
      else:
         if x_test[i_r, j_r, img] == 0:
            predict.append(5)
         else:
            predict.append(9)

   # Calculate accuracy
   accuracy = 0
   for i in range(len(predict)):
      if predict[i] == y_test[i]:
         accuracy += 1
   print("Accuracy =", accuracy / len(x_test[i_p, j_p]) * 100, '%')



def main():
   data = pickle.load(open('data_binarized.pkl', 'rb'))
   scores = scoreFeatures(data['train']['x'], data['train']['y'])
   i, j = highest_score(scores)
   decisiontree_test(data['test']['x'], data['test']['y'], i, j)

   depth2(data['train']['x'], data['train']['y'], data['test']['x'],
data['test']['y'])
   #-------------------------------------------------------------------------
-
   # Your implementation to answer questions on Decision Trees
   #-------------------------------------------------------------------------
-

   return


if __name__ == "__main__":
   main()
```

Result:

Depth = 1

Highest Value: [11 18]= 163.0

Accuracy = 82.5 %



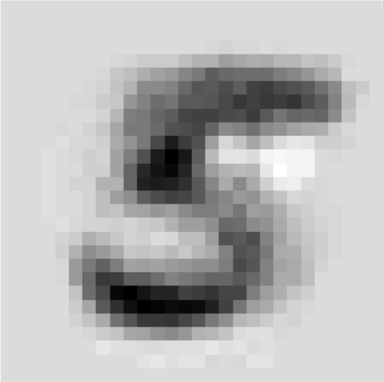
Depth = 2

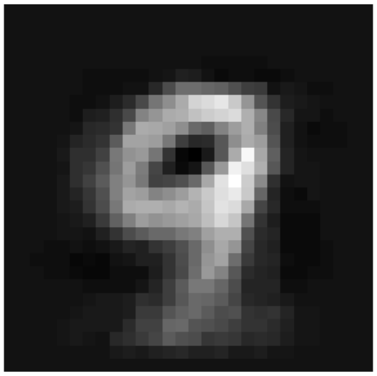
Parent: [11 18]= 163.0

Left: [12 20]= 100.0

Right: [13 17]= 74.0

Accuracy = 90.5 %



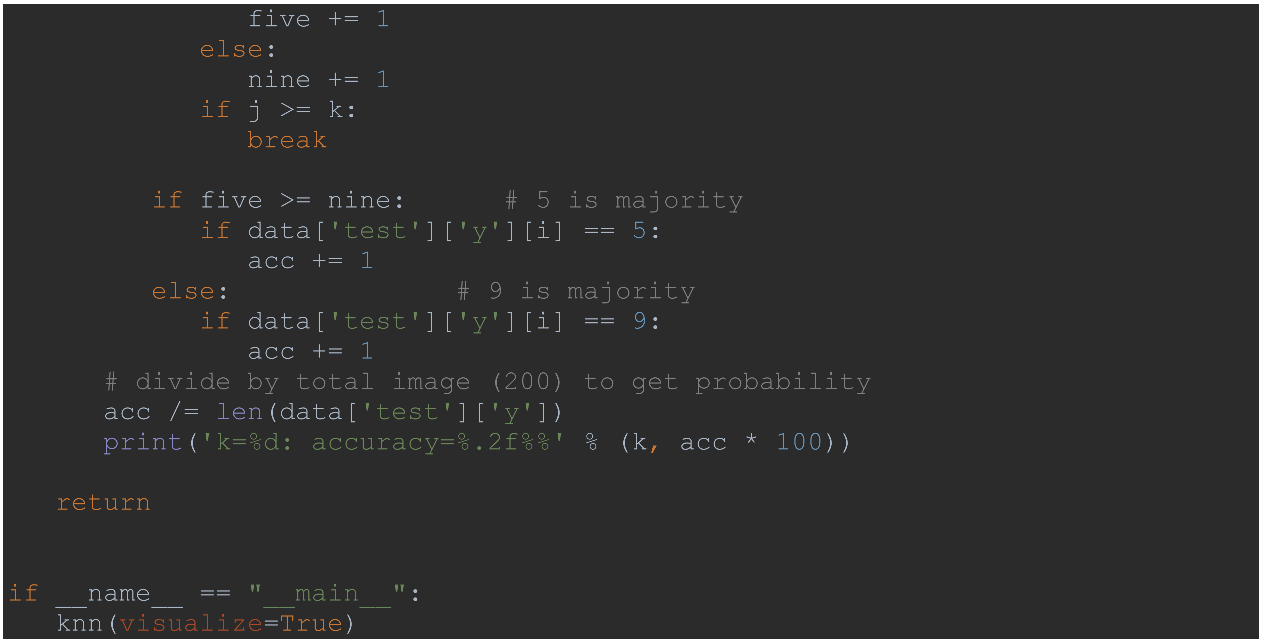


Problem 2:

Code:

```
#This code is part of:
#
#  CMPSCI 370: Computer Vision, Spring 2021
#  University of Massachusetts, Amherst
#  Instructor: Subhransu Maji
#
#  Mini-Project 6

import pickle
import numpy as np
import matplotlib.pyplot as plt


def visualizeNeighbors(imgs, topk_idxs, topk_distances, title):
   '''
   Visualize the query image as well as its nearest neighbors
   Input:
      imgs: a list or numpy array, with length k+1.
         imgs[0] is the query image with shape hxw
         imgs[k] is k-th nearest neighbor image
      topk_idxs: a list or numpy array, with length k+1.
         topk_idxs[k] is the index in training set of the k-th nearest image
         topk_idxs[0] is the query image index in the test set
      topk_distances: a list or numpy array, with length k+1.
         topk_idxs[k] is the distance of the k-th nearest image to the query
         topk_idxs[0] is 0
   '''
   n = len(imgs)
   fig, axs = plt.subplots(1, n, figsize=(2 * n, 3))
   fig.suptitle(title)
   for k in range(n):
      if k == 0:
         ax_title = 'query: test_idx=%d' % topk_idxs[0]
      else:
         ax_title = '%d: idx=%d,d=%.2e' %(k, topk_idxs[k], topk_distances[k])
      axs[k].set_title(ax_title)
      axs[k].imshow(imgs[k], cmap='gray')
      axs[k].axis('off')
   fig.tight_layout()
   plt.show()

   return


def knn(visualize):
   data = pickle.load(open('data_binarized.pkl','rb'))

   # distances = np.zeros((len(data['test']['y']), len(data['train']['y'])))

   # List of dictionary
   # element i-th is a dictionary with key [i-th, train img]
   # dict keys: [test img, train img]
   # dict value: Euclidean distance
   distances = [{}] * 200
   #-------------------------------------------------------------------------
```

```
-
   # Your implementation to calculate and sort distances
   #-------------------------------------------------------------------------
-
   x_train = data['train']['x']
   x_test = data['test']['x']
   for i in range(len(data['test']['y'])):       # loop through each image
      diction = {}
      for j in range(len(data['train']['y'])):
         # Apply Euclidean formula
         diction[i, j] = np.sqrt(np.sum(np.square(x_test[:, :, i] -
x_train[:, :, j])))
      # Sort dictionary by values
      diction = dict(sorted(diction.items(), key=lambda item: item[1]))
      distances[i] = diction

   if visualize:
      k = 5
      imgs = np.random.randint(2, size=(k+1, 28, 28))
      topk_idxs = [0] * (k+1)
      topk_distances = [0] * (k+1)
      for test_i in [10, 20, 110, 120]:
         topk_idxs[0] = test_i
         # Assign query img as test_i
         imgs[0] = x_test[:, :, test_i]
         #-------------------------------------------------------------------
         # Prepare imgs, topk_idxs and topk_distances
         #-------------------------------------------------------------------
         i = 0
         for key in distances[test_i]:
            i += 1    # Only go through k nearest neighbor
            imgs[i] = x_test[:, :, key[1]]    # key[1] is index for training
img of k-th neighbor
            topk_idxs[i] = key[1]
            topk_distances[i] = distances[test_i][key]
            if i >= k:
               break

         visualizeNeighbors(imgs, topk_idxs, topk_distances,
            title='Test img %d: Top %d Neighbors' % (test_i, k))

   k_list = [1, 3, 5, 7, 9]
   accuracy_list = [0.0] * len(k_list)
   #-------------------------------------------------------------------------
-
   # Your implementation to calculate knn accuracy
   #-------------------------------------------------------------------------
-
   for k, acc in zip(k_list, accuracy_list):
      # Go through all test imgages
      for i in range(len(data['test']['y'])):
         five, nine, j = 0, 0, 0
         for key in distances[i]:
            j += 1    # Only check k nearest neighbor

            # Finding majority
            if data['train']['y'][key[1]] == 5:
```



```
                    five += 1
                else:
                    nine += 1
                if j >= k:
                    break

            if five >= nine:         # 5 is majority
                if data['test']['y'][i] == 5:
                    acc += 1
            else:                # 9 is majority
                if data['test']['y'][i] == 9:
                    acc += 1
        # divide by total image (200) to get probability
        acc /= len(data['test']['y'])
        print('k=%d: accuracy=%.2f%%' % (k, acc * 100))

    return


if __name__ == "__main__":
    knn(visualize=True)
```

Result:

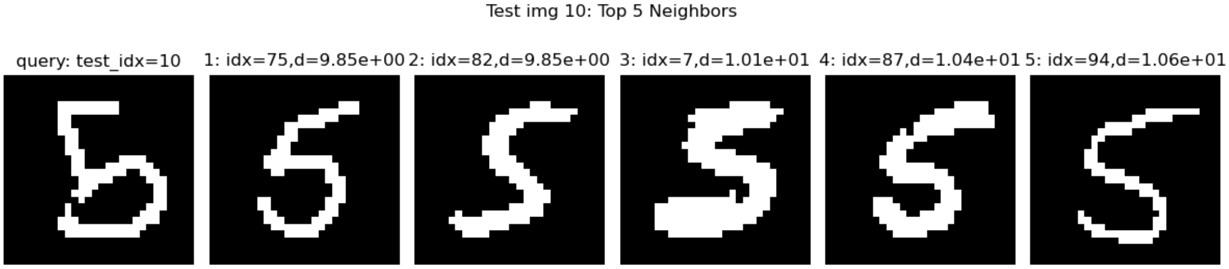
k=1: accuracy=98.00%

k=3: accuracy=97.50%

k=5: accuracy=97.50%

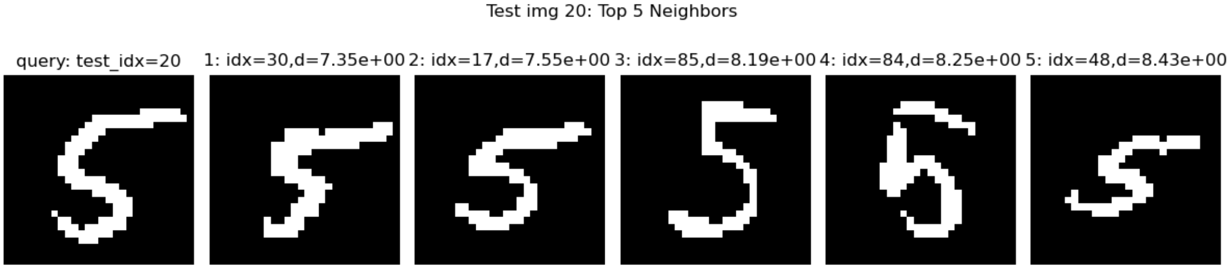
k=7: accuracy=97.50%

k=9: accuracy=98.00%



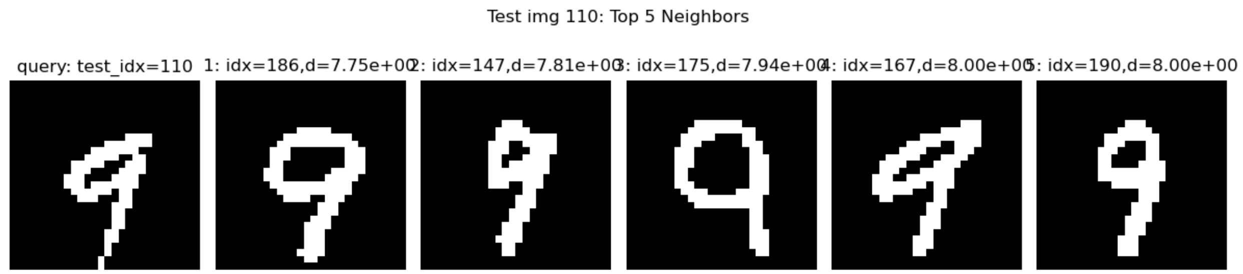
Test img 10: Top 5 Neighbors

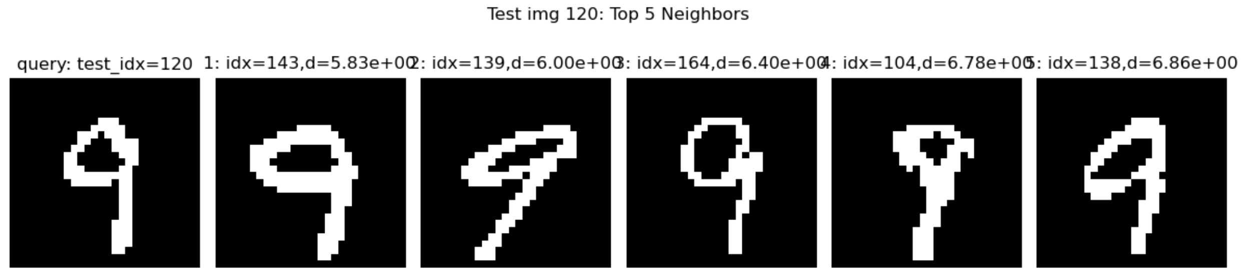
query: test_idx=10 1: idx=75,d=9.85e+00 2: idx=82,d=9.85e+00 3: idx=7,d=1.01e+01 4: idx=87,d=1.04e+01 5: idx=94,d=1.06e+01



Test img 20: Top 5 Neighbors

query: test_idx=20 1: idx=30,d=7.35e+00 2: idx=17,d=7.55e+00 3: idx=85,d=8.19e+00 4: idx=84,d=8.25e+00 5: idx=48,d=8.43e+00

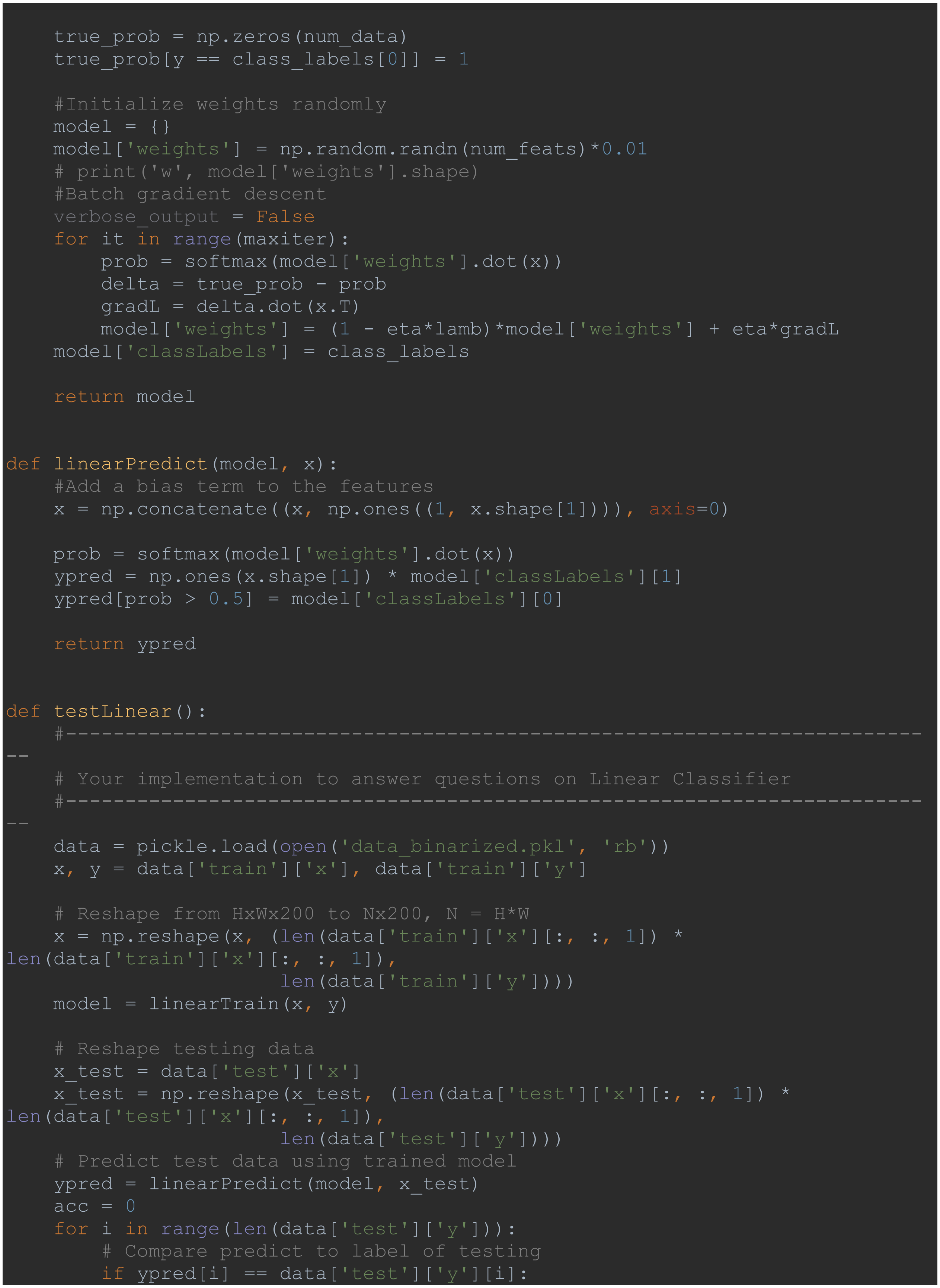




Problem 3:

Code:

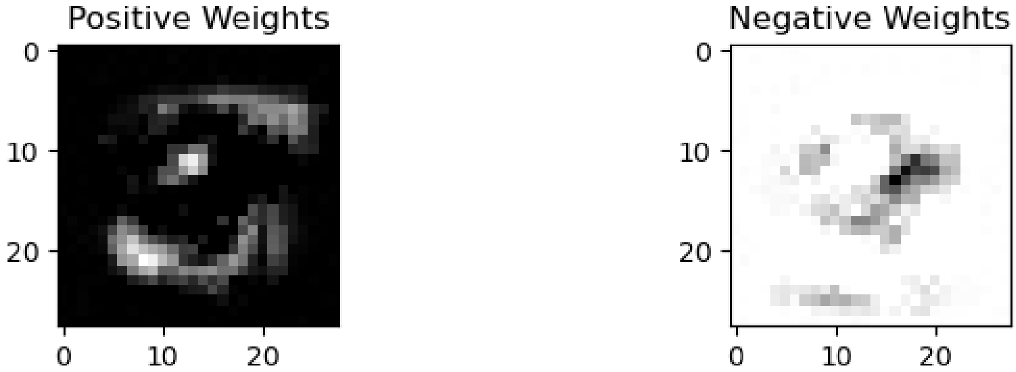
```
#This code is part of:
#
#  CMPSCI 370: Computer Vision, Spring 2021
#  University of Massachusetts, Amherst
#  Instructor: Subhransu Maji
#
#  Mini-Project 6

import pickle
import numpy as np
import matplotlib.pyplot as plt


def softmax(z):
    return 1.0/(1+np.exp(-z))

def linearTrain(x, y):
    #Training parameters
    maxiter = 50
    lamb = 0.01
    eta = 0.01

    #Add a bias term to the features
    x = np.concatenate((x, np.ones((1, x.shape[1]))), axis=0)

    class_labels = np.unique(y)
    num_class = class_labels.shape[0]
    assert(num_class == 2) # Binary labels
    num_feats = x.shape[0]
    num_data = x.shape[1]
```



```python
    true_prob = np.zeros(num_data)
    true_prob[y == class_labels[0]] = 1

    #Initialize weights randomly
    model = {}
    model['weights'] = np.random.randn(num_feats)*0.01
    # print('w', model['weights'].shape)
    #Batch gradient descent
    verbose_output = False
    for it in range(maxiter):
        prob = softmax(model['weights'].dot(x))
        delta = true_prob - prob
        gradL = delta.dot(x.T)
        model['weights'] = (1 - eta*lamb)*model['weights'] + eta*gradL
    model['classLabels'] = class_labels

    return model


def linearPredict(model, x):
    #Add a bias term to the features
    x = np.concatenate((x, np.ones((1, x.shape[1]))), axis=0)

    prob = softmax(model['weights'].dot(x))
    ypred = np.ones(x.shape[1]) * model['classLabels'][1]
    ypred[prob > 0.5] = model['classLabels'][0]

    return ypred


def testLinear():
    #-----------------------------------------------------------------------
--
    # Your implementation to answer questions on Linear Classifier
    #-----------------------------------------------------------------------
--
    data = pickle.load(open('data_binarized.pkl', 'rb'))
    x, y = data['train']['x'], data['train']['y']

    # Reshape from HxWx200 to Nx200, N = H*W
    x = np.reshape(x, (len(data['train']['x'][:, :, 1]) *
len(data['train']['x'][:, :, 1]),
                       len(data['train']['y'])))
    model = linearTrain(x, y)

    # Reshape testing data
    x_test = data['test']['x']
    x_test = np.reshape(x_test, (len(data['test']['x'][:, :, 1]) *
len(data['test']['x'][:, :, 1]),
                       len(data['test']['y'])))
    # Predict test data using trained model
    ypred = linearPredict(model, x_test)
    acc = 0
    for i in range(len(data['test']['y'])):
        # Compare predict to label of testing
        if ypred[i] == data['test']['y'][i]:
            acc += 1
    acc /= len(data['test']['y'])
    print(acc*100, '%')

    # Visualization part
    dimension = model["weights"][:len(model["weights"])-1]
    w = np.reshape(dimension, (int(np.sqrt(len(dimension))),
int(np.sqrt(len(dimension)))))
    wp = np.clip(w, 0, None)
    wn = np.clip(w, None, 0)
    plt.subplot(131)
    plt.title('Positive Weights')
    plt.imshow(wp, cmap='gray')
    plt.subplot(133)
    plt.title('Negative Weights')
    plt.imshow(wn, cmap='gray')
    plt.show()

    return None


if __name__ == "__main__":
    testLinear()
```

Result:

Accuracy= around 98%


Positive Weights
0
10
20
0
10
20
Negative Weights
0
10
20
0
10
20