EECE6036 - Homework 2

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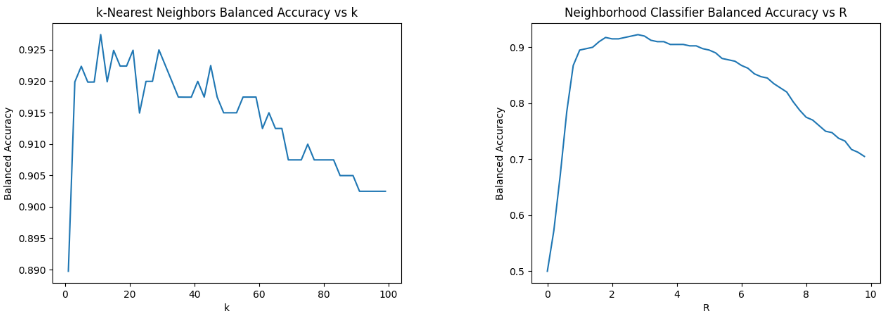
1 Problem 1

1.1 Problem Summary

1.2 Results



(a) (b)

Figure 1: Balanced accuracy for KNN (a) and Neighborhood Classifier (b).

1.3 Discussion

1.4 Conclusion

2 Problem 2

2.1 Problem Summary

2.2 Results

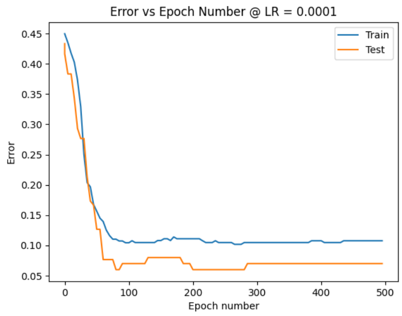


Figure 2: Training and testing error for a single perceptron.

2.3 Discussion

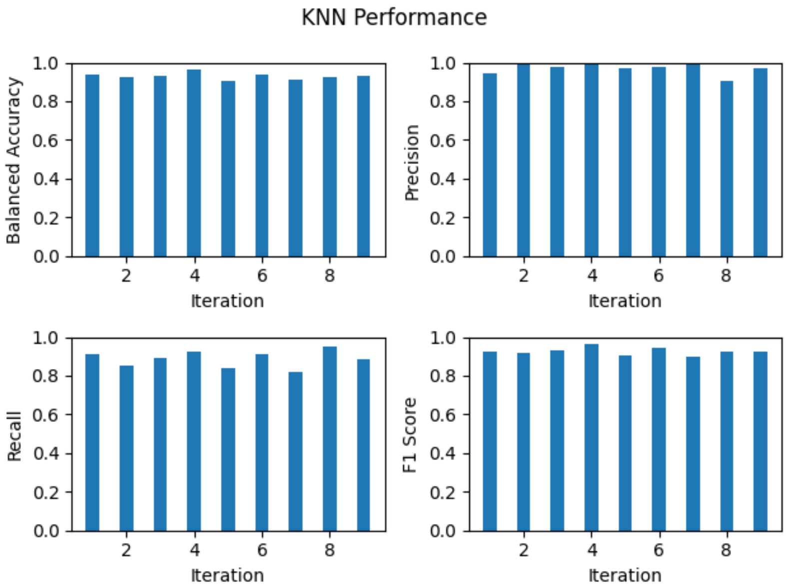
2.4 Conclusion

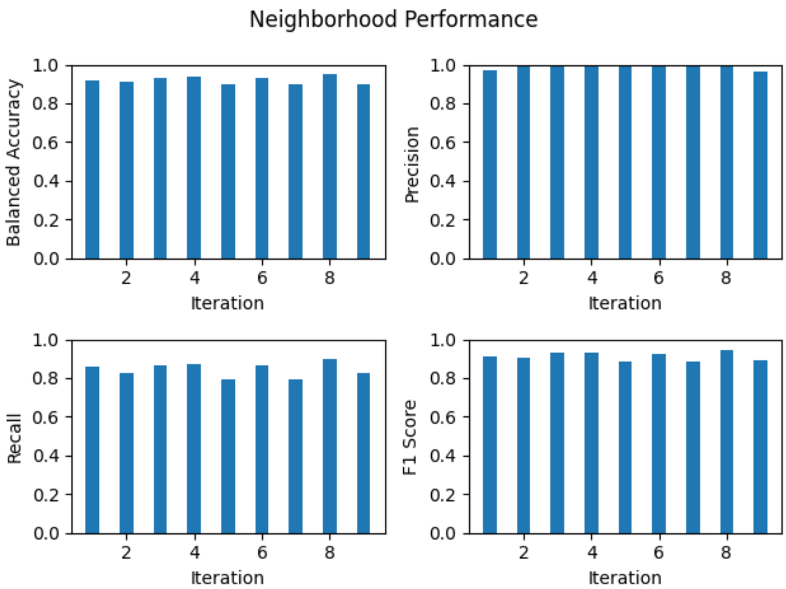
3 Problem 3

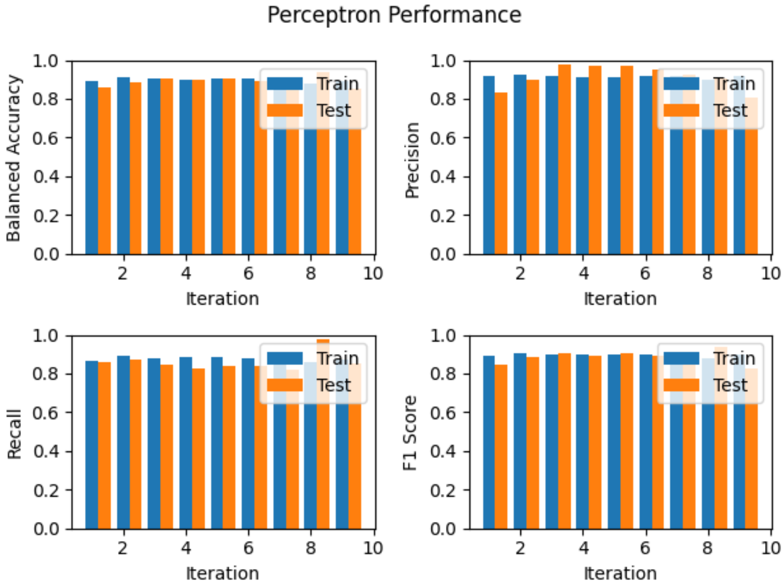
3.1 Problem Summary

3.2 Results

3.2.1 Performance on Individual Trials





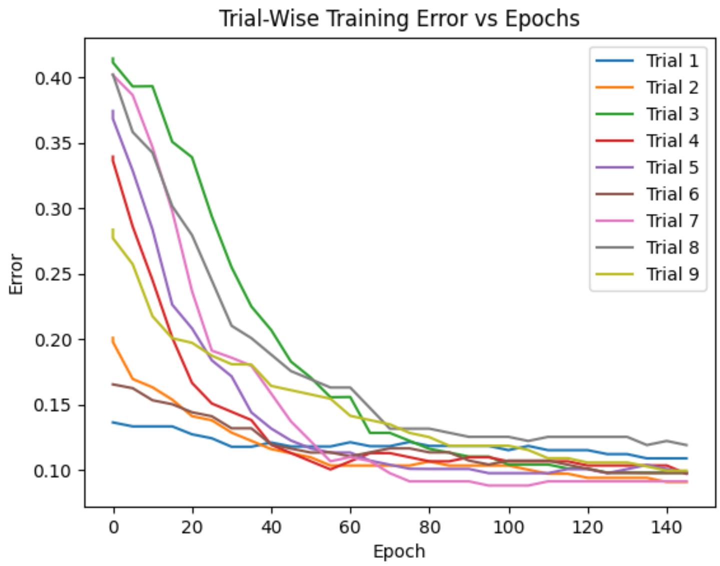


3.2.2 Average Performance

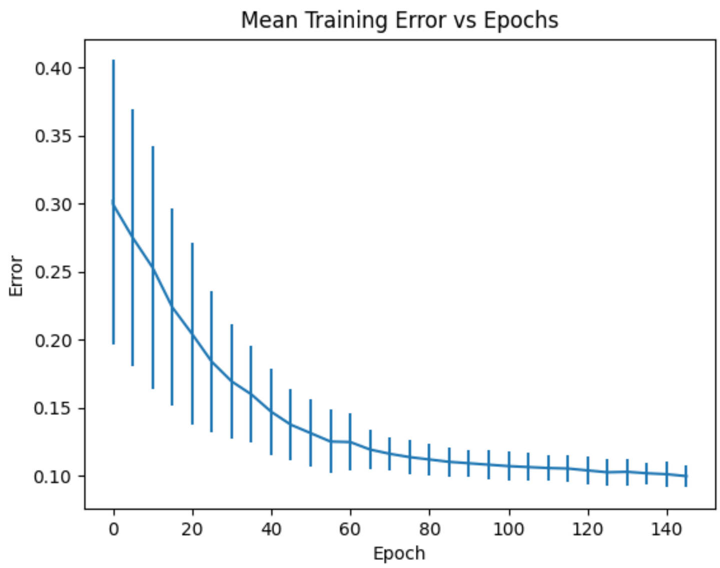
Table 1: Average performance of the classifiers.

	KNN	Neighborhood	Perceptron
Balanced Accuracy	0.929 ± 0.016	0.920 ± 0.018	0.890 ± 0.025
Precision	0.971 ± 0.030	0.993 ± 0.014	0.915 ± 0.058
Recall	0.887 ± 0.041	0.845 ± 0.034	0.859 ± 0.044
F1 Score	0.926 ± 0.018	0.912 ± 0.021	0.884 ± 0.031

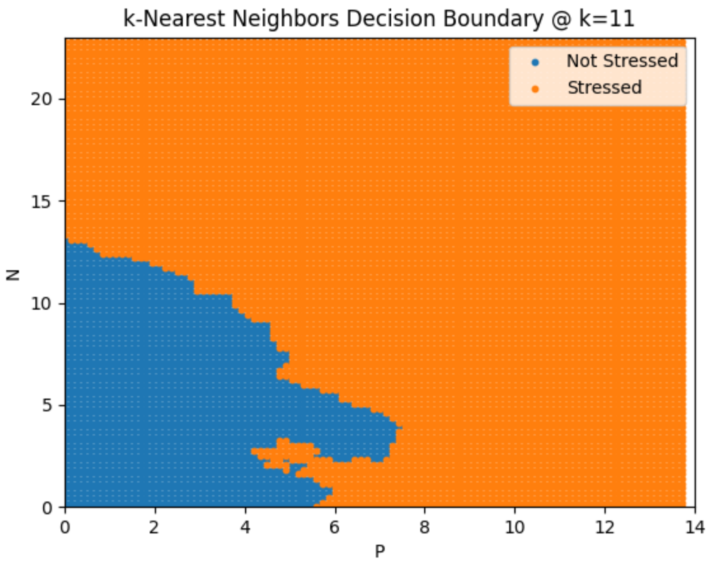
3.2.3 Trial-Wise Training Error for the Perceptrons



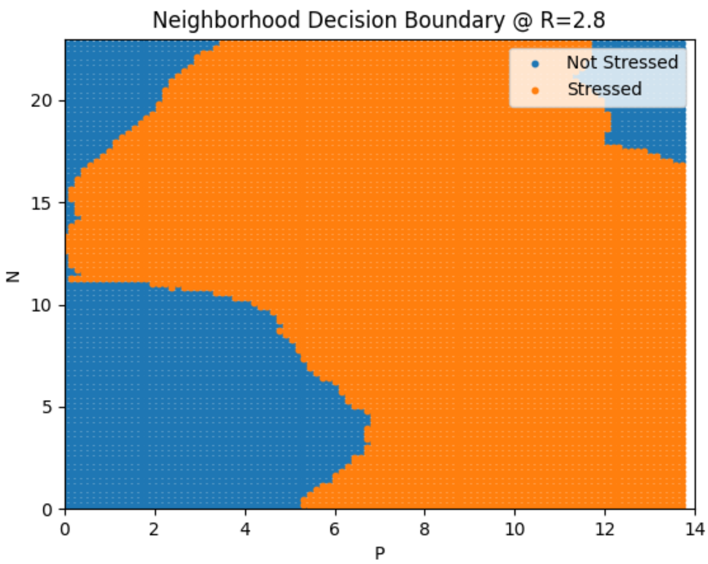
3.2.4 Mean Training Error for the Perceptron



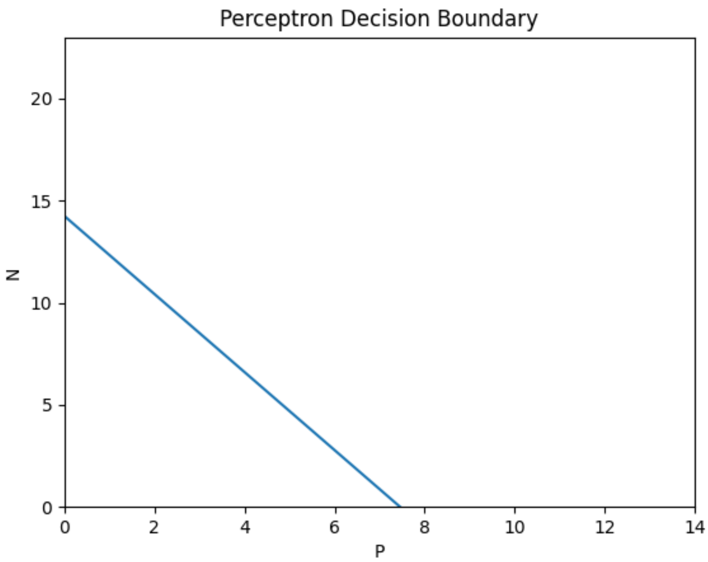
3.2.5 Best KNN Decision Boundary



3.2.6 Best Neighborhood Classifier Decision Boundary



3.2.7 Perceptron Decision Boundary



3.2.8 Analysis of Results

3.3 Discussion

3.4 Conclusion

A Code

A.1 dataset.py

```
################################################################################
# Imports
################################################################################
import numpy as np


class Dataset:
    def __init__(
            self,
            data_file = 'data.txt',
            classes = ['Not Stressed', 'Stressed'],
            shuffle_data = False,
    ):
        self.data_file = str(data_file)
        self.classes = classes
        self.importDataFile()
        if shuffle_data:
            self.shuffleData()

    def isFloat(self, test_str):
        '''Quick check if a string is a float value
        Parameters:
        -----------
            test_str : str
                String to test for float cast compatibility
        Returns:
            bool
                True if the string can cast to a float, else false
        '''
        try:
            float(test_str)
            return True
        except ValueError:
            return False

    def importDataFile(self):
        '''Imports data from the txt format Dr. Minai presented
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        print(f'Importing text data from {self.data_file}')
        self.data_points = list()
        # Read data from txt file
        with open(self.data_file) as data:
            class_id = 0
            for line in data.readlines():
                line = line[:-1] # Strip off newline
                # Check if line is new class definition
                if line in self.classes:
                    class_id = self.classes.index(line)
                    continue
                # Check if line is a set of data points
                line = line.split()
                if (len(line) == 2) and self.isFloat(line[0]) and self.isFloat(line[1]):
                    # Each data point will be [P, N, Truth]
                    new_item = np.array(
                        (float(line[0]), float(line[1]), float(class_id)),
                        dtype=np.float64
                    )
                    self.data_points.append(new_item)
        num_data_points = len(self.data_points)
        self.data_points = np.array(self.data_points, dtype=np.float64)

    def resizeDataPartitions(self, num_train_points):
        '''Size dataset partitions
        Parameters:
        -----------
            num_train_points : int
                Number of train data points
                The rest will be test points
        Returns:
        --------
            None
```

```
        '''
        num_test_points = len(self.data_points) - num_train_points
        self.train = np.empty((num_train_points, 3), dtype=np.float64)
        self.test = np.empty((num_test_points, 3), dtype=np.float64)

    def partitionAllTrain(self):
        '''Format entire dataset to training
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        # Allocate train and test numpy arrays
        num_train_points = len(self.data_points)
        self.resizeDataPartitions(num_train_points)
        # Iterate through data points
        for i in range(len(self.data_points)):
            self.train[i] = self.data_points[i]

    def partitionOneTest(self, skip_idx):
        '''Format all but one data point to training
        Parameters:
        -----------
            skip_idx : int
                Index of testing data point
        Returns:
        --------
            None
        '''
        num_train_points = len(self.data_points) - 1
        self.resizeDataPartitions(num_train_points)
        # Iterate through data points except for skip_idx
        for i in range(len(self.data_points)):
            if i == skip_idx:
                self.test[0] = self.data_points[i]
                continue
            item_idx = i
            if i > skip_idx:
                item_idx -= 1
            self.train[item_idx] = self.data_points[i]

    def partitionXTrain(self, train_portion):
        '''Format a portion of the dataset to training
        Parameters:
        -----------
            train_portion : float
                Portion of data to make train
        Returns:
        --------
            None
        '''
        num_train_points = int(train_portion * len(self.data_points))
        self.resizeDataPartitions(num_train_points)
        # Iterate through data_points and partition
        for i in range(len(self.data_points)):
            if i < num_train_points:
                self.train[i] = self.data_points[i]
            else:
                item_idx = i - num_train_points
                self.test[item_idx] = self.data_points[i]

    def shuffleData(self):
        '''Shuffle data in self.data_points
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        np.random.shuffle(self.data_points)


if __name__ == '__main__':
    from matplotlib import pyplot as plt
    import pathlib
    CODE_DIR = pathlib.Path(__file__).parent.absolute()
    ROOT_DIR = CODE_DIR.parent
    DATA_FILE = CODE_DIR.joinpath('data.txt')
    IMG_DIR = ROOT_DIR.joinpath('images')
    IMG_DIR.mkdir(mode=0o775, exist_ok=True)
    # Plot data points
```

```
    dataset = Dataset(data_file = DATA_FILE)
    dataset.partitionAllTrain()
    not_stressed = {'p': list(), 'n': list()}
    stressed = {'p': list(), 'n': list()}
    for point in dataset.train:
        if point[2] == 0: # Not stressed
            not_stressed['p'].append(point[0])
            not_stressed['n'].append(point[1])
        else: # Stressed
            stressed['p'].append(point[0])
            stressed['n'].append(point[1])
    plt.scatter(not_stressed['p'], not_stressed['n'], label='Not Stressed')
    plt.scatter(stressed['p'], stressed['n'], label='Stressed')
    plt.xlabel('P')
    plt.ylabel('N')
    plt.legend()
    data_plot = IMG_DIR.joinpath('dataset.png')
    plt.savefig(str(data_plot))
```

A.2 classifier.py

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

class Classifier():
    '''Abstract class for classifiers for Homework 2
    Used to calculate the accuracy metrics
    '''

    def __init__(self):
        '''Helps with autocomplete of parameters
        '''
        self.resetStats()

    def resetStats(self):
        '''Reset the true/false pos/neg stats
        '''
        self.true_pos = 0
        self.true_neg = 0
        self.false_pos = 0
        self.false_neg = 0

    def getSens(self):
        '''Return sensitivity (recall, true positive rate)
        '''
        return float(self.true_pos) / (self.true_pos + self.false_neg)

    def getSpec(self):
        '''Return specificity (selectivity, true negative rate)
        '''
        return float(self.true_neg) / (self.false_pos + self.true_neg)

    def getPPV(self):
        '''Return positive predictive value (precision)
        '''
        return float(self.true_pos) / (self.true_pos + self.false_pos)

    def getNPV(self):
        '''Return negative predictive value
        '''
        return float(self.true_neg) / (self.true_neg + self.false_neg)

    def getAcc(self):
        '''Return accuracy (unbalanced)
        '''
        total_true = self.true_pos + self.true_neg
        total_false = self.false_pos + self.false_neg
        return float(total_true) / (total_true + total_neg)

    def getBalAcc(self):
        '''Return balanced accuracy
        '''
        return (self.getSens() + self.getSpec()) / 2.0

    def getF1(self):
        '''Return F_1 score
        '''
        return 2 / ((1/self.getPPV()) + (1/self.getSens()))

    def getFbeta(self, beta):
        '''Return F_beta score
```

```
        '''
        beta2 = beta * beta
        return (1 + beta2) / (1/(beta2 * self.getPPV()) + (1/self.getSens()))

    def scoreResult(self, pred, truth):
        '''Classify results as true/false pos/neg
        Parameters:
        -----------
            pred : int
                Predicted class
            truth : int
                Truth class
        Returns:
        --------
            None
        '''
        if truth == 0:
            if pred == 0:
                self.true_neg += 1
            else:
                self.false_pos += 1
        else:
            if pred == 0:
                self.false_neg += 1
            else:
                self.true_pos += 1

    def drawDecision(
            self,
            div = 100,
            plot_name = 'knn_dec_bound.png',
            plot_title = 'Decision Boundary',
            max_p = 14,
            max_n = 23,
        ):
        '''Draw decision boundary
        Parameters:
        -----------
            div : int
                Number of divisions for the axis with maximal value
                In this case, the N axis
        Returns:
        --------
            None
        '''
        p_step = max_p / div
        n_step = max_n / div
        p_steps = int(max_p / p_step)
        n_steps = int(max_n / n_step)
        stressed_p = list()
        stressed_n = list()
        not_stressed_p = list()
        not_stressed_n = list()
        for p_idx in range(p_steps):
            for n_idx in range(n_steps):
                p = p_idx * p_step
                n = n_idx * n_step
                # test_points[p_step][n_step][0] = p
                # test_points[p_step][n_step][1] = n
                test_point = np.array([p, n], dtype=np.float64)
                pred = self.predict(test_point)
                if pred == 0.0:
                    not_stressed_p.append(p)
                    not_stressed_n.append(n)
                if pred == 1.0:
                    stressed_p.append(p)
                    stressed_n.append(n)
        plt.figure()
        plt.scatter(not_stressed_p, not_stressed_n, s=10, label='Not Stressed')
        plt.scatter(stressed_p, stressed_n, s=10, label='Stressed')
        plt.title(plot_title)
        plt.xlabel('P')
        plt.ylabel('N')
        plt.legend(loc='upper right')
        plt.xlim([0, max_p])
        plt.ylim([0, max_n])
        plt.savefig(str(plot_name))
        plt.close()
```

A.3 knn.py

```
################################################################################
```

```python
# Imports
###############################################################################
from dataset import Dataset
from classifier import Classifier
import numpy as np
from matplotlib import pyplot as plt


class KNN(Classifier):
    def __init__(
            self,
            dataset,
            k = 11,
    ):
        self.k = k
        self.dataset = dataset
        self.resetStats()

    def setK(self, k):
        '''Set value of k
        Parameters:
        -----------
            k : int
                Value of k
        Returns:
        --------
            None
        '''
        self.k = k

    def getDistance(self, x, y):
        '''Get Euclidean distance between 2 points
        Parameters:
        -----------
            x, y : np.array of float
                Points to calculate distance between
        Returns:
        --------
            float
                Euclidean distance between x and y
        '''
        # What a one-line beauty
        return np.sqrt(np.sum(np.square(x - y)))

    def predict(self, test):
        '''Predict a value for test based on dataset.train points
        Parameters:
        -----------
            test : np.array of float
                Point to predict class of
        Returns:
        --------
            int (or maybe float, haven't decided yet)
                Class prediction for test
        '''
        distances = list()
        for i in range(len(self.dataset.train)):
            # Store truth and distance
            new_point = dict()
            new_point['truth'] = self.dataset.train[i][2]
            new_point['dist'] = self.getDistance(test, self.dataset.train[i][:2])
            distances.append(new_point)
        # Sort distances and only keep the lowest k
        distances.sort(key=lambda x: x['dist'])
        distances = distances[:self.k]
        closest_classes = {0.: 0, 1.: 0}
        for d in distances:
            closest_classes[d['truth']] += 1
        return max(closest_classes, key = lambda x: closest_classes[x])

    def evalAll(self):
        '''Predict on all data points in dataset.data_points
        For question 1
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.resetStats()
        # Iterate through all data points as the test points
        for i in range(len(self.dataset.data_points)):
            self.dataset.partitionOneTest(i)
```

```
            test_point = self.dataset.test[0][:2]
            test_truth = self.dataset.test[0][2]
            test_pred = self.predict(test_point)
            self.scoreResult(test_pred, test_truth)

    def evalTest(self):
        '''Predict on all data points in the test set
        For question 3
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.resetStats()
        # Iterate through all data points as the test points
        for p in self.dataset.test:
            test_point = p[:2]
            test_truth = p[2]
            test_pred = self.predict(test_point)
            self.scoreResult(test_pred, test_truth)


if __name__ == '__main__':
    '''
    Fulfils problem 1 part 1
    '''
    # Seed RNG for repeatability
    np.random.seed(69420)
    # Additional imports
    import pathlib
    # File locations
    CODE_DIR = pathlib.Path(__file__).parent.absolute()
    ROOT_DIR = CODE_DIR.parent # Root project dir
    IMG_DIR = ROOT_DIR.joinpath('images')
    IMG_DIR.mkdir(mode=0o775, exist_ok=True)
    DATA_IN_FILE = CODE_DIR.joinpath('data.txt')
    DATA_OUT_DIR = ROOT_DIR.joinpath('data')
    DATA_OUT_DIR.mkdir(mode=0o775, exist_ok=True)
    DATA_OUT_FILE = DATA_OUT_DIR.joinpath('knn_acc')
    BAL_ACC_PLOT = IMG_DIR.joinpath('knn_bal_acc.png')
    # Get dataset
    dataset = Dataset(data_file = DATA_IN_FILE, shuffle_data = True)
    knn = KNN(dataset, k=1)
    # Iterate through k values
    k_vals = range(1, 100, 2)
    bal_acc = list()
    for k in k_vals:
        knn.setK(k)
        knn.evalAll()
        bal_acc.append(knn.getBalAcc())
        print(f'k = {k}\tBalanced accuracy: {knn.getBalAcc()}')
    max_k = k_vals[np.argmax(bal_acc)]
    print(f'Maximum accuracy: {np.max(bal_acc)}\tk = {max_k}')
    # Plot data points
    plt.figure()
    plt.plot(k_vals, bal_acc)
    plt.title('k-Nearest Neighbors Balanced Accuracy vs k')
    plt.xlabel('k')
    plt.ylabel('Balanced Accuracy')
    plt.savefig(str(BAL_ACC_PLOT))
    plt.close()
    # Get accuracy at optimal k
    knn.setK(max_k)
    knn.evalAll()
    with open(str(DATA_OUT_FILE), 'w') as data_f:
        data_f.write(f'bestk = {max_k}\n')
        knn.evalAll()
        acc = 100 * knn.getBalAcc()
        data_f.write(f'acc = {acc:0.2f}\n')
```

A.4 neighborhood.py

```
###############################################################################
# Imports
###############################################################################
from dataset import Dataset
from classifier import Classifier
import numpy as np
from matplotlib import pyplot as plt
```

```python
class Neighborhood(Classifier):
    def __init__(
            self,
            dataset,
            R = 1,
    ):
        self.R = R
        self.dataset = dataset
        self.resetStats()

    def setR(self, R):
        '''Set value of R
        Parameters:
        -----------
            R : int
                Value of R
        Returns:
        --------
            None
        '''
        self.R = R

    def getDistance(self, x, y):
        '''Get Euclidean distance between 2 points
        Parameters:
        -----------
            x, y : np.array of float
                Points to calculate distance between
        Returns:
        --------
            float
                Euclidean distance between x and y
        '''
        return np.sqrt(np.sum(np.square(x - y)))

    def predict(self, test):
        '''Predict a value for test based on dataset.train points
        Parameters:
        -----------
            test : np.array of float
                Point to predict class of
        Returns:
        --------
            int (or maybe float, haven't decided yet)
                Class prediction for test
        '''
        distances = list()
        for i in range(len(self.dataset.train)):
            # Store truth and distance
            new_point = dict()
            new_point['truth'] = self.dataset.train[i][2]
            new_point['dist'] = self.getDistance(test, self.dataset.train[i][:2])
            distances.append(new_point)
        # Sort distances and only keep the lowest R
        distances = [x for x in distances if x['dist'] <= self.R]
        closest_classes = {0.: 0, 1.: 0}
        for d in distances:
            closest_classes[d['truth']] += 1
        # TODO - If classes are equal it returns 0.0
        return max(closest_classes, key = lambda x: closest_classes[x])

    def evalAll(self):
        '''Predict on all data points in dataset.data_points
        For question 1
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.resetStats()
        # Iterate through all data points as the test points
        for i in range(len(self.dataset.data_points)):
            self.dataset.partitionOneTest(i)
            test_point = self.dataset.test[0][:2]
            test_truth = self.dataset.test[0][2]
            test_pred = self.predict(test_point)
            self.scoreResult(test_pred, test_truth)

    def evalTest(self):
        '''Predict on all data points in the test set
```

```
        For question 3
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.resetStats()
        # Iterate through all data points as the test points
        for p in self.dataset.test:
            test_point = p[:2]
            test_truth = p[2]
            test_pred = self.predict(test_point)
            self.scoreResult(test_pred, test_truth)


if __name__ == '__main__':
    '''
    Fulfils problem 1 part 2
    '''
    # Seed RNG for repeatability
    np.random.seed(69420)
    # Additional imports
    import pathlib
    # File locations
    CODE_DIR = pathlib.Path(__file__).parent.absolute()
    ROOT_DIR = CODE_DIR.parent # Root project dir
    IMG_DIR = ROOT_DIR.joinpath('images')
    IMG_DIR.mkdir(mode=0o775, exist_ok=True) # Create images dir if needed
    BAL_ACC_PLOT = IMG_DIR.joinpath('neighborhood_bal_acc.png')
    DATA_IN_FILE = CODE_DIR.joinpath('data.txt')
    DATA_OUT_DIR = ROOT_DIR.joinpath('data')
    DATA_OUT_DIR.mkdir(mode=0o775, exist_ok=True)
    DATA_OUT_FILE = DATA_OUT_DIR.joinpath('neighborhood_acc')
    # Get dataset
    dataset = Dataset(data_file = DATA_IN_FILE, shuffle_data = True)
    neighborhood = Neighborhood(dataset, R=1)
    # Iterate through R values
    R_vals = np.arange(0, 10, 0.2)
    bal_acc = list()
    for R in R_vals:
        neighborhood.setR(R)
        neighborhood.evalAll()
        bal_acc.append(neighborhood.getBalAcc())
        print(f'R = {R:0.1f}\tBalanced accuracy: {neighborhood.getBalAcc()}')
    max_r = R_vals[np.argmax(bal_acc)]
    print(f'Maximum accuracy: {np.max(bal_acc)}\tr = {max_r:0.1f}')
    # Plot data points
    plt.plot(R_vals, bal_acc)
    plt.title('Neighborhood Classifier Balanced Accuracy vs R')
    plt.xlabel('R')
    plt.ylabel('Balanced Accuracy')
    plt.savefig(str(BAL_ACC_PLOT))
    # Get accuracy at optimal R
    neighborhood.setR(max_r)
    neighborhood.evalAll()
    with open(str(DATA_OUT_FILE), 'w') as data_f:
        data_f.write(f'bestr = {max_r:0.1f}\n')
        neighborhood.evalAll()
        acc = 100 * neighborhood.getBalAcc()
        data_f.write(f'acc = {acc:0.2f}\n')
```

A.5 perceptron.py

```
################################################################################
# Imports
################################################################################
from dataset import Dataset
from classifier import Classifier
import numpy as np
from matplotlib import pyplot as plt


class Perceptron(Classifier):
    def __init__(
            self,
            dataset,
            num_inputs = 2,
            learning_rate = 0.1,
    ):
```

```
        self.num_inputs = num_inputs
        self.learning_rate = learning_rate
        self.init_weights()
        self.dataset = dataset
        self.resetStats()
        self.resetAcc()

    def resetAcc(self):
        '''Reset accuracy metrics
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.train_acc = list()
        self.test_acc = list()
        self.epoch_nums = list()

    def init_weights(self):
        '''Initialize weights for the perceptron
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.weights = np.empty(self.num_inputs + 1, dtype=np.float64)
        # Initialize bias weight
        self.weights[0] = np.random.uniform(-10, -50)
        # Initialize input weights
        for i in range(len(self.weights) - 1):
            self.weights[i+1] = np.random.uniform(2, 5)

    def get_weights(self):
        '''Return weights array
        Parameters:
        -----------
            None
        Returns:
        --------
            np.array of float64
                Array of weight values
        '''
        return self.weights

    def predict(self, input_val):
        '''Predict a value for test based on self.weights
        Parameters:
        -----------
            input_val : np.array of float64
                Point to predict class of
        Returns:
        --------
            int (or maybe float, haven't decided yet)
                Class prediction for test
        '''
        # Concatenate bias value
        input_val = np.concatenate(([1], input_val))
        score = np.sum(input_val * self.weights)
        if score > 0:
            return 1
        return 0

    def trainSingleVal(self, input_val):
        '''Change weights based on a single point
        Parameters:
        -----------
            input_val : np.array of float64
                Point to learn on, ending with truth value
        Returns:
        --------
            None
        '''
        point = input_val[:-1]
        truth = input_val[-1]
        # Calculate weight change based on pred and point
        pred = self.predict(point)
        change_scalar = self.learning_rate * (truth - pred)
        self.weights += change_scalar * np.concatenate([[1], point])

    def trainEpoch(self):
```

```
        '''Change weights based on the training set
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        for point in self.dataset.train:
            self.trainSingleVal(point)

    def train(self, epochs=10):
        '''Change weights for a desired number of epochs
        Parameters:
        -----------
            epochs : int
                Amount of epochs to train
        Returns:
        --------
            None
        '''
        # Log initial accuracies
        self.resetAcc()
        self.logAll(0)
        for e in range(epochs):
            # Perform epoch training
            self.trainEpoch()
            if (e % 5) == 0:
                self.logAll(e)

    def evalTrain(self):
        '''
        '''
        self.resetStats()
        for point in self.dataset.train:
            p = point[:-1]
            truth = point[-1]
            self.scoreResult(self.predict(p), truth)

    def evalTest(self):
        '''
        '''
        self.resetStats()
        for point in self.dataset.test:
            p = point[:-1]
            truth = point[-1]
            self.scoreResult(self.predict(p), truth)

    def logAll(self, epoch_num):
        '''Evaluate test and train dataset partitions
        Parameters:
        -----------
            None
        Returns:
        --------
            None
        '''
        self.evalTrain()
        self.train_acc.append(self.getBalAcc())
        self.evalTest()
        self.test_acc.append(self.getBalAcc())
        self.epoch_nums.append(epoch_num)

    def plotError(self, plot_name = 'epoch_error.png'):
        plt.figure()
        plt.plot(self.epoch_nums, np.subtract(1, self.train_acc))
        plt.plot(self.epoch_nums, np.subtract(1, self.test_acc))
        plt.legend(['Train', 'Test'])
        plt.title(f'Error vs Epoch Number @ LR = {self.learning_rate}')
        plt.xlabel('Epoch number')
        plt.ylabel('Error')
        plt.savefig(str(plot_name))
        plt.close()

    def drawDecision(
            self,
            div = None,
            plot_name = 'knn_dec_bound.png',
            plot_title = 'Decision Boundary',
            max_p = 14,
            max_n = 23,
    ):
        '''Draw decision boundary
        Parameters:
```

```
        -----------
            div : int
                Number of divisions for the axis with maximal value
                In this case, the N axis
        Returns:
        --------
            None
        '''
        p_axis_point = -self.weights[0]/self.weights[1]
        n_axis_point = -self.weights[0]/self.weights[2]
        plt.figure()
        plt.plot([p_axis_point, 0], [0, n_axis_point])
        plt.title(plot_title)
        plt.xlabel('P')
        plt.ylabel('N')
        plt.xlim([0, max_p])
        plt.ylim([0, max_n])
        plt.savefig(str(plot_name))
        plt.close()

if __name__ == '__main__':
    '''
    Fulfils problem 2
    '''
    # Seed RNG for repeatability
    np.random.seed(80085)
    # Additional imports
    import pathlib
    # File locations
    CODE_DIR = pathlib.Path(__file__).parent.absolute()
    ROOT_DIR = CODE_DIR.parent # Root project dir
    IMG_DIR = ROOT_DIR.joinpath('images')
    IMG_DIR.mkdir(mode=0o775, exist_ok=True)
    DATA_IN_FILE = CODE_DIR.joinpath('data.txt')
    DATA_OUT_DIR = ROOT_DIR.joinpath('data')
    DATA_OUT_DIR.mkdir(mode=0o775, exist_ok=True)
    DATA_OUT_FILE = DATA_OUT_DIR.joinpath('perceptron_err')
    ERR_PLOT = IMG_DIR.joinpath('perceptron_err.png')
    # Get dataset
    dataset = Dataset(data_file = DATA_IN_FILE, shuffle_data = True)
    perc = Perceptron(dataset, learning_rate = .0001)
    perc.dataset.partitionXTrain(0.8)
    perc.train(epochs = 500)
    perc.plotError(ERR_PLOT)
    with open(str(DATA_OUT_FILE), 'w') as data_f:
        # Log train accuracy
        perc.evalTrain()
        train_err = 1 - perc.getBalAcc()
        data_f.write(f'train_err = {train_err:0.3f}\n')
        # Log test accuracy
        perc.evalTest()
        test_err = 1 - perc.getBalAcc()
        data_f.write(f'test_err = {test_err:0.3f}\n')
```

A.6 problem_3.py

```
################################################################################
# Imports
################################################################################
from dataset import Dataset
from knn import KNN
from neighborhood import Neighborhood
from perceptron import Perceptron
import numpy as np
from matplotlib import pyplot as plt
import pathlib


################################################################################
# Best Metrics / Constants
################################################################################
K = 11
R = 2.8
LEARNING_RATE = 0.0001
EPOCHS = 150
# File locations
CODE_DIR = pathlib.Path(__file__).parent.absolute()
ROOT_DIR = CODE_DIR.parent # Root project dir
IMG_DIR = ROOT_DIR.joinpath('images')
IMG_DIR.mkdir(mode=0o775, exist_ok=True)
KNN_PERF = IMG_DIR.joinpath('knn_performance.png')
```

```
KNN_DEC_BOUND = IMG_DIR.joinpath('knn_dec_bound.png')
NEIGHBOR_DEC_BOUND = IMG_DIR.joinpath('neighborhood_dec_bound.png')
NEIGHBOR_PERF = IMG_DIR.joinpath('neighborhood_performance.png')
PERC_DEC_BOUND = IMG_DIR.joinpath('perceptron_dec_bound.png')
PERC_PERF = IMG_DIR.joinpath('perceptron_performance.png')
TRIAL_ERR = IMG_DIR.joinpath('trial_wise_error.png')
MEAN_ERR = IMG_DIR.joinpath('mean_error.png')
DATA_IN_FILE = CODE_DIR.joinpath('data.txt')
DATA_OUT_DIR = ROOT_DIR.joinpath('data')
DATA_OUT_DIR.mkdir(mode=0o775, exist_ok=True)
AVG_PERF_TAB = DATA_OUT_DIR.joinpath('avg_perf.csv')


################################################################################
# Problem 3
################################################################################
# Function definitions
def logMetrics(classifier, key):
    '''Log performance metrics for the given classifier
    Parameters:
    -----------
        classifier : Classifier
            Classifier object to get metrics from
            Should be KNN, Neighborhood, or Perceptron
        key : str
            Key for list to store metrics in
    '''
    bal_acc[key].append(classifier.getBalAcc())
    precision[key].append(classifier.getPPV())
    recall[key].append(classifier.getSens())
    f1[key].append(classifier.getF1())

def bestDecision(classifier, key, plot_name, plot_title):
    if classifier.getBalAcc() > maxAcc[key]:
        print('* New best accuracy')
        maxAcc[key] = classifier.getBalAcc()
        classifier.drawDecision(plot_name=plot_name,
                plot_title=plot_title)

def plotPerf(keys, plot_name, plot_title = '', legend = None):
    bar_width = .4
    x = np.arange(1, 10)
    plt.figure()
    plt.suptitle(plot_title)
    # Balanced Accuracy
    plt.subplot(221)
    plt.xlabel('Iteration')
    plt.ylabel('Balanced Accuracy')
    plt.ylim([0, 1])
    for i, key in enumerate(keys):
        plt.bar((i * bar_width) + x, bal_acc[key], width = bar_width)
    # Precision
    plt.subplot(222)
    plt.xlabel('Iteration')
    plt.ylabel('Precision')
    plt.ylim([0, 1])
    for i, key in enumerate(keys):
        plt.bar((i * bar_width) + x, precision[key], width = bar_width)
    # Recall
    plt.subplot(223)
    plt.xlabel('Iteration')
    plt.ylabel('Recall')
    plt.ylim([0, 1])
    for i, key in enumerate(keys):
        plt.bar((i * bar_width) + x, recall[key], width = bar_width)
    # F1
    plt.subplot(224)
    plt.xlabel('Iteration')
    plt.ylabel('F1 Score')
    plt.ylim([0, 1])
    for i, key in enumerate(keys):
        plt.bar((i * bar_width) + x, f1[key], width = bar_width)
    if legend != None:
        for idx in range(221, 225):
            plt.subplot(idx)
            plt.legend(legend)
    plt.tight_layout()
    plt.savefig(str(plot_name))
    plt.close()

# Seed RNG for repeatability
np.random.seed(69420)
# Store results for later graphing
bal_acc = {
```

```
    'knn': list(),
    'neighborhood': list(),
    'perc_train': list(),
    'perc_test': list(),
}
precision = {
    'knn': list(),
    'neighborhood': list(),
    'perc_train': list(),
    'perc_test': list(),
}
recall = {
    'knn': list(),
    'neighborhood': list(),
    'perc_train': list(),
    'perc_test': list(),
}
f1 = {
    'knn': list(),
    'neighborhood': list(),
    'perc_train': list(),
    'perc_test': list(),
}
train_err = list()
maxAcc = {
    'knn': 0,
    'neighborhood': 0,
    'perceptron': 0,
}
# Test 9 versions of the dataset/algorithms
for i in range(9):
    print(f'* * * Starting iteration {i+1} of 9 * * *')
    dataset = Dataset(data_file=DATA_IN_FILE, shuffle_data=True)
    dataset.partitionXTrain(0.8)
    print(f'Starting KNN')
    knn = KNN(dataset, k=K)
    knn.evalTest()
    logMetrics(knn, 'knn')
    bestDecision(knn, 'knn', KNN_DEC_BOUND,
            f'k-Nearest Neighbors Decision Boundary @ k={knn.k}')
    print(f'Starting Neighborhood')
    neighborhood = Neighborhood(dataset, R=R)
    neighborhood.evalTest()
    logMetrics(neighborhood, 'neighborhood')
    bestDecision(neighborhood, 'neighborhood', NEIGHBOR_DEC_BOUND,
            f'Neighborhood Decision Boundary @ R={neighborhood.R}')
    print(f'Starting Perceptron')
    perceptron = Perceptron(dataset, learning_rate=LEARNING_RATE)
    perceptron.train(epochs=EPOCHS)
    perceptron.evalTrain()
    logMetrics(perceptron, 'perc_train')
    perceptron.evalTest()
    logMetrics(perceptron, 'perc_test')
    train_err.append(np.subtract(1, perceptron.train_acc))
    bestDecision(perceptron, 'perceptron', PERC_DEC_BOUND,
            f'Perceptron Decision Boundary')
# Individual trial performance
plotPerf(['knn'], KNN_PERF, 'KNN Performance')
plotPerf(['neighborhood'], NEIGHBOR_PERF, 'Neighborhood Performance')
plotPerf(['perc_train', 'perc_test'], PERC_PERF, 'Perceptron Performance',
        legend=['Train', 'Test'])
# Average performance
metrics = [bal_acc, precision, recall, f1]
labels = ['Balanced Accuracy', 'Precision', 'Recall', 'F1 Score']
keys = ['knn', 'neighborhood', 'perc_test']
with open(str(AVG_PERF_TAB), 'w') as csv:
    csv.write(',KNN,Neighborhood,Perceptron\n')
    for metric, metric_l in zip(metrics, labels):
        write_str = f'{metric_l},'
        for i in range(len(keys)):
            mean = np.mean(metric[keys[i]])
            std = np.std(metric[keys[i]])
            write_str += f'${mean:0.3f} \pm {std:0.3f}$'
            if i == (len(keys) - 1):
                write_str += '\n'
            else:
                write_str += ','
        csv.write(write_str)
# Trial-wise training error
plt.figure()
plt.xlabel('Epoch')
plt.ylabel('Error')
plt.title('Trial-Wise Training Error vs Epochs')
for err in train_err:
```

```
    plt.plot(perceptron.epoch_nums, err)
plt.legend([f'Trial {i}' for i in range(1, 10)], loc='upper right')
plt.savefig(str(TRIAL_ERR))
plt.close()
# Mean training error
mean_err = []
std_err = []
for i in range(len(train_err[0])):
    points = []
    for j in range(len(train_err)):
        points.append(train_err[j][i])
    mean_err.append(np.mean(points))
    std_err.append(np.std(points))
plt.figure()
plt.errorbar(perceptron.epoch_nums, mean_err, yerr=std_err)
plt.xlabel('Epoch')
plt.ylabel('Error')
plt.title('Mean Training Error vs Epochs')
plt.savefig(str(MEAN_ERR))
plt.close()
```