

HW6 programming problem 14 ~ 20

This document aims to implement decision tree(CA&R tree) and random forest algorithm

In [1]:

```
import numpy as np
from scipy.stats import mode
import pandas as pd
import time
```

In [2]:

```
train = pd.read_csv("hw6_train.dat.txt", sep=" ", header=None)
test = pd.read_csv("hw6_test.dat.txt", sep=" ", header=None)
```

In [3]:

```
# Gini_index definition
```

```
def impurity(y):
    mu_pos = np.count_nonzero(y == 1) / len(y)
    return 1 - mu_pos ** 2 - (1 - mu_pos) ** 2
```

In [4]:

```
# Terminal Criterion
```

```
def terminal(X: np.array, y: np.array) -> int:
```

```
    # If all the y is the same
```

```
    if len(np.unique(y)) == 1:
```

```
        return True
```

```
    # If all the x is the same
```

```
    elif len(np.unique(X, axis=0)) == 1:
```

```
        print("All Xn are the same")
```

```
        return True
```

```
    else:
```

```
        return False
```

In [5]:

```
# Branch condition, output decision stump, choosing a cutting point theta and
```

```
# using this cut to deduce impurity as quick as possible
```

```
def branch_learning(X, y):
```

```
    # Combine X and y to df
```

```
    df = np.insert(X, X.shape[1], y, axis=1)
```

```
    bEin, btheta, feature = 99999, 0, 0
```

```
    leftX, rightX, lefty, righty = None, None, None, None
```

```
    # For every column
```

```
    for i in range(X.shape[1]):
```

```
        # The whole df sort by ith column
```

```
        ith_df = df[df[:, i].argsort()]
```

```
        x_ith = ith_df[:, i]
```

```
        # Create thetas as a list with n - 1 length
```

```
        theta = [(a + b) / 2 for a, b in zip(x_ith[:-1], x_ith[1:])]
```

```
    # For every theta
```

```
    for j in range(1, len(y)):
```

```
        # Divide dataset to twopart
```

```
        y1, y2 = ith_df[:, j, -1], ith_df[j:, -1]
```

```
    # Calculate the score
```

```
    Ein = len(y1) * impurity(y1) + len(y2) * impurity(y2)
```

```
    # Find the smallest, and record the relative theta, feature, two groups of data
```

```
    if Ein < bEin:
```

```
        bEin = Ein
```

```
        btheta = theta[j - 1]
```

```
        feature = i
```

```
        leftX, rightX, lefty, righty = ith_df[:, j, :-1], ith_df[j:, :-1], y1, y2
```

```
    return feature, btheta, leftX, rightX, lefty, righty
```

In [6]:

```
# Class Tree(root, subtree)
```

```
class node():
```

```
    def __init__(self):
```

```

self.feature = None # record branch criteria
self.threshold = None # record branch criteria
self.left = None # record the left subtree address
self.right = None # record the right subtree address
self.value = None # If this node is a leaf, value record the base hypothesis

# Define training process
def train(self, X: np.array, y: np.array):
    # If terminal criterion met, return the most frequent y
    if terminal(X, y):
        self.value = mode(y)[0][0]

    # If not
    else:
        # learn the branch criterion
        self.feature, self.threshold, X1, X2, y1, y2 = branch_learning(
            X, y)

        # let left child and right child train new datasets
        self.left, self.right = node(), node()
        self.left.train(X1, y1)
        self.right.train(X2, y2)

# Define predict process
def predict(self, X: np.array) -> int:
    # If this node is leaf, return the base algorithm
    if self.value != None:
        return self.value

    # If this node is not leaf, choose whether go left or right
    else:
        if X[self.feature] < self.threshold:
            return self.left.predict(X)
        else:
            return self.right.predict(X)

def problem14(train, test):
    print("Problem 14: ")

    # Separate each X, y dataset
    trainX, trainy = train.iloc[:, :-1], train.iloc[:, -1]
    testX, testy = test.iloc[:, :-1], test.iloc[:, -1]

    # Train DecisionTree
    DecisionTree = node()
    before = time.time()

    DecisionTree.train(np.array(trainX),
                       np.array(trainy))

    after = time.time()
    print(f"Training cost {after - before:.2f}")

    before = time.time()

    # Predict DecisionTree
    y_pred = [DecisionTree.predict(x) for x in np.array(testX)]

    after = time.time()
    print(f"Testing cost {after - before:.2f} sec")

    # Calc. Eout
    Eout = sum([y != y_hat for y, y_hat in zip(y_pred, testy)]) / len(y_pred)
    print(f"In pb14, Eout is {Eout:.2f}")

    return

problem14(train, test)

Problem 14:
Training cost 0.97
Testing cost 0.01 sec
In pb14, Eout is 0.17

def problem15(train, test, n):
    print("Problem 15: ")

```

In [7]:

In [8]:

```

# Prepare n length Eoutlist and Forest
Eoutlist = []
Forest = []

before = time.time()
for _ in range(n):
    # Bagging while  $N' = 0.5 N$ 
    train_15, test_15 = train.sample(
        int(len(train) / 2), replace=True), test

    # Separate datasets
    trainX, trainy = train_15.iloc[:, :-1], train_15.iloc[:, -1]
    testX, testy = test_15.iloc[:, :-1], test_15.iloc[:, -1]

    # Train DecisionTree
    DecisionTree = node()

    DecisionTree.train(np.array(trainX),
                       np.array(trainy))

    # Add it to the forest
    Forest.append(DecisionTree)

    # Predict y
    y_pred = [DecisionTree.predict(x) for x in np.array(testX)]

    # Calc. Eout
    Eout = sum([y != y_hat for y, y_hat in zip(
        y_pred, testy)]) / len(y_pred)
    Eoutlist.append(Eout)

after = time.time()
print(f"Total cost {after - before:.2f} sec")

avgEout = sum(Eoutlist) / n

print(f"In pb15, average Eout is {avgEout:.2f}")

return Forest

```

```
Forest = problem15(train, test, 2000)
```

Problem 15:

Total cost 690.09 sec

In pb15, average Eout is 0.23

In [9]:

```

def problem16(train, Forest):
    print("Problem 16: ")
    # G is the blending function
    G = []
    before = time.time()

    # Separate dataset
    trainX, trainy = train.iloc[:, :-1], train.iloc[:, -1]
    for tree in Forest:
        y_pred = [tree.predict(x) for x in np.array(trainX)]
        G.append(y_pred)

    # If  $\text{sign}(g_1 + g_2 \dots g_n) == 1$ : then G predict 1
    G = np.array(G)
    y_pred_G = [1 if i == 1 else -
                 1 for i in np.apply_along_axis(sum, 0, G) > 0]

    # Calc. Ein
    Ein = sum([y != y_hat for y, y_hat in zip(
        y_pred_G, trainy)]) / len(y_pred_G)

    after = time.time()
    print(f"Total cost {after - before:.2f} sec")
    print(f"In pb16, Ein is {Ein:.2f}")

```

```
problem16(train, Forest)
```

Problem 16:

Total cost 8.47 sec

In pb16, Ein is 0.01

In [10]:

```
def problem17(test, Forest):
    print("Problem 17: ")
    # G is the blending function
    G = []
    testX, testy = test.iloc[:, :-1], test.iloc[:, -1]

    # Using every tree to predict each x and return an N * 2000 matrix
    for tree in Forest:
        y_pred = [tree.predict(x) for x in np.array(testX)]
        G.append(y_pred)

    # Aggregate along column axis, if sum > 0, then return 1 else -1
    G = np.array(G)
    y_pred_G = [1 if i == 1 else -
                 1 for i in np.apply_along_axis(sum, 0, G) > 0]

    # Calc. Eout
    Eout = sum([y != y_hat for y, y_hat in zip(
        y_pred_G, testy)]) / len(y_pred_G)

    print(f"In pbl7, Eout is {Eout:.2f}")
```

```
problem17(test, Forest)
```

Problem 17:

In pbl7, Eout is 0.15

In [11]:

```
def problem18(train, n):
    print("Problem 18: ")
    # Forest will save all trees, index_dict record: index_dict[train.index] = set(Which tree has used i
    Forest = []
    index_dict = {}

    # Validation error
    Eval = 0

    # Initialize index_dict as empty set for all n
    for i in range(len(train)):
        index_dict[i] = set()

    # Run n times
    for i in range(n):
        # Separate dataset
        train_18 = train.sample(int(len(train) / 2), replace=True)
        trainX, trainy = train_18.iloc[:, :-1], train_18.iloc[:, -1]

        # Record whether xn has been used for tree i
        used_index = set(train_18.index)
        for chosen in used_index:
            index_dict[chosen].add(i)

        # Train DecisionTree
        DecisionTree = node()

        DecisionTree.train(np.array(trainX),
                           np.array(trainy))

        # Add it to the Forest
        Forest.append(DecisionTree)

    # CompleteSet: A set from 0 to n integers
    completeSet = set([i for i in range(n)])

    # for every xn
    for i in range(len(train)):
        # For xn, find trees don't pick it, is the complement of index_dict[n]
        G_minus = completeSet.difference(index_dict[i])
        y_pred = 0

        # If xn has been used in every tree, return constant hypothesis -1
        if len(G_minus) == 0:
            y_pred = -1

        # else, create G- predict G-(xn)
```

```

else:
    y_pred_list = []
    for j in G_minus:
        y_pred_list.append(Forest[j].predict(np.array(train.iloc[i, :-1])))

    y_pred = 1 if sum(y_pred_list) > 0 else -1

# Calc. Eval
if y_pred != train.iloc[:, -1][i]:
    Eval += 1

Eval /= len(train)
print(f"Eval is {Eval:.2f}")

```

```
problem18(train, 2000)
```

Problem 18:

Eval is 0.07

Problem 19: (d) aggregation models: AdaBoost and Gradient Boosting

老師在上課講的例子很生動，演算法邏輯也符合人性，況且實用性又高，透過alpha和un 的相對關係，又可以知道機器在哪個地方學得不好。

我認為我在這個演算法上收益良多，是老師講解得足夠清楚的功勞

Problem 20: (b) matrix factorization

我認為他很靠近neuron network，事實上好像也是這樣，況且即使了解他的規則，要如何加入新xn和ym (新成員和新電影)，以及中間的neuron該放幾個，怎麼validation，都不是很明朗

感覺是最不清楚的一個部分

In [67]:

```
print("end of document")
```

```
end of document
```