Assignment 1

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In [ ]:
```
# import all the necessary libraries here
import pandas as pd
import numpy as np
from matplotlib import pyplot as plt
import graphviz
```

In [ ]:
```
df = pd.read_csv('../../dataset/decision-tree.csv')
print(df.shape)
```

```
(768, 9)
```

In [ ]:
```
df.head()
```

Out[ ]:

	Pregnancies	Glucose	BloodPressure	SkinThickness	Insulin	BMI	DiabetesPedigreeFunction	Age	Outcome
0	6	148	72	35	0	33.6	0.627	50	1
1	1	85	66	29	0	26.6	0.351	31	0
2	8	183	64	0	0	23.3	0.672	32	1
3	1	89	66	23	94	28.1	0.167	21	0
4	0	137	40	35	168	43.1	2.288	33	1

In [ ]:
```
y = df['Outcome']
y.head()
```

Out[ ]:
```
0    1
1    0
2    1
3    0
4    1
Name: Outcome, dtype: int64
```

In [ ]:
```
df = df.drop(['Outcome'], axis = 1)
df.head()
```

Out[ ]:

	Pregnancies	Glucose	BloodPressure	SkinThickness	Insulin	BMI	DiabetesPedigreeFunction	Age
0	6	148	72	35	0	33.6	0.627	50
1	1	85	66	29	0	26.6	0.351	31
2	8	183	64	0	0	23.3	0.672	32
3	1	89	66	23	94	28.1	0.167	21
4	0	137	40	35	168	43.1	2.288	33

Creating Train and Test Sets

In [ ]:
```
train_df = df.sample(frac = 0.8, random_state = 218)
test_df = df.drop(train_df.index)
```

In [ ]:
```
print(train_df.shape)
print(test_df.shape)
```

```
(614, 8)
(154, 8)
```

In [ ]:
```
y_train = y[train_df.index]
y_test = y[test_df.index]
```

In [ ]:
```
train_df.reset_index(drop = True, inplace=True)
test_df.reset_index(drop = True, inplace=True)
y_train.reset_index(drop = True, inplace=True)
y_test.reset_index(drop = True, inplace=True)
```

In [ ]:
```
X_train = np.array(train_df)
X_test = np.array(test_df)
```

Creating Decision Tree

In [ ]:
```
class TreeNode:
    def __init__(self, is_leaf, label, feature_index, threshold, left, right, ID):
        self.is_leaf = is_leaf
        self.label = label
        self.feature_index = feature_index
        self.threshold = threshold
        self.left = left
        self.right = right
        self.ID = ID

class DecisionTree:

    def __init__(self, X_test, y_test):
        self.root = None
        self.test_acc = {}
        self.X_test = X_test
        self.y_test = y_test
        self.total_ID = 0

    def count_nodes(self, node):
        if node.is_leaf:
            return 1
        return 1 + self.count_nodes(node.left) + self.count_nodes(node.right)

    def fit(self, X, y):
        self.root = self.build_tree(X, y)

    def entropy(self, y):
        unique_classes, counts = np.unique(y, return_counts = True)
        num_total = len(y)
```

```
        entropy = 0

        for i in range(len(unique_classes)):
            prob = counts[i]/num_total
            entropy += prob*np.log2(prob)

        return -entropy

    def information_gain(self, X, y, threshold):
        H = self.entropy(y)

        y_left = y[X <= threshold]
        y_right = y[X > threshold]

        H_left = self.entropy(y_left)
        H_right = self.entropy(y_right)

        num_left = len(y_left)
        num_right = len(y_right)
        num_total = num_left + num_right

        gain = H - (num_left/num_total)*H_left - (num_right/num_total)*H_right

        return gain

    def build_tree(self, X, y):

        num_samples, num_features = X.shape;
        unique_classes, counts = np.unique(y, return_counts = True)
        dominant_class = unique_classes[np.argmax(counts)]

        if num_samples < 10 or len(unique_classes) == 1:
            self.total_ID += 1
            return TreeNode(True, dominant_class, None, None, None, None, self.total_ID)

        best_gain = 0
        best_feature_index = None
        best_threshold = None

        for feature_index in range(num_features):
            X_curr = X[:, feature_index]

            thresholds = np.unique(X_curr)
            if len(thresholds) < 2:
                continue

            thresholds = (thresholds[1:] + thresholds[:-1]) / 2

            for threshold in thresholds:
                gain = self.information_gain(X_curr, y, threshold)

                if gain > best_gain:
                    best_gain = gain
                    best_feature_index = feature_index
                    best_threshold = threshold

        if best_gain == 0:
            self.total_ID += 1
            return TreeNode(True, dominant_class, None, None, None, None, self.total_ID)

        X_left = X[X[:, best_feature_index] <= best_threshold]
        y_left = y[X[:, best_feature_index] <= best_threshold]
        X_right = X[X[:, best_feature_index] > best_threshold]
        y_right = y[X[:, best_feature_index] > best_threshold]

        left = self.build_tree(X_left, y_left)
        right = self.build_tree(X_right, y_right)

        self.total_ID += 1
        return TreeNode(False, None, best_feature_index, best_threshold, left, right, self.total_ID)

    def predict(self, X):
        return self.predict_helper(X, self.root)

    def predict_helper(self, X, node):
        if node.is_leaf:
            return node.label

        if X[node.feature_index] <= node.threshold:
            return self.predict_helper(X, node.left)
        else:
            return self.predict_helper(X, node.right)

    def multi_predict(self, X, node):
        return np.array([self.predict_helper(x, node) for x in X])

    def reduced_error_pruning(self, X_test, y_test):
        self.root = self.reduced_error_pruning_helper(self.root, X_test, y_test)
        total_nodes = self.count_nodes(self.root)
        total_accuracy = np.sum(self.multi_predict(self.X_test, self.root) == self.y_test)/len(self.y_test)
        self.test_acc[total_nodes] = total_accuracy

    def reduced_error_pruning_helper(self, node, X_test, y_test):
        if node.is_leaf:
            return node

        X_test_left = X_test[X_test[:, node.feature_index] <= node.threshold]
        X_test_left = X_test_left.reshape(-1, X_test.shape[1])
        y_test_left = y_test[X_test[:, node.feature_index] <= node.threshold]
        X_test_right = X_test[X_test[:, node.feature_index] > node.threshold]
        X_test_right = X_test_right.reshape(-1, X_test.shape[1])
        y_test_right = y_test[X_test[:, node.feature_index] > node.threshold]

        if len(y_test_left) == 0 or len(y_test_right) == 0:
            return node

        node.left = self.reduced_error_pruning_helper(node.left, X_test_left, y_test_left)
        node.right = self.reduced_error_pruning_helper(node.right, X_test_right, y_test_right)

        y_pred = self.multi_predict(X_test, node)
        accuracy = np.sum(y_pred == y_test)/len(y_test)

        max_label = np.argmax(np.unique(y_test, return_counts = True)[1])
        leaf_pred = np.array([max_label]*len(y_test))
        accuracy_leaf = np.sum(leaf_pred == y_test)/len(y_test)

        if accuracy_leaf > accuracy:
```

```
            total_nodes = self.count_nodes(self.root)
            total_accuracy = np.sum(self.multi_predict(self.X_test, self.root) == self.y_test)/len(self.y_test)
            self.test_acc[total_nodes] = total_accuracy

            return TreeNode(True, max_label, None, None, None, None, node.ID)

        return node
```

In [ ]:
```
tree = DecisionTree(X_test, y_test)
```

In [ ]:
```
tree.fit(X_train, y_train)
print(tree.count_nodes(tree.root))
```

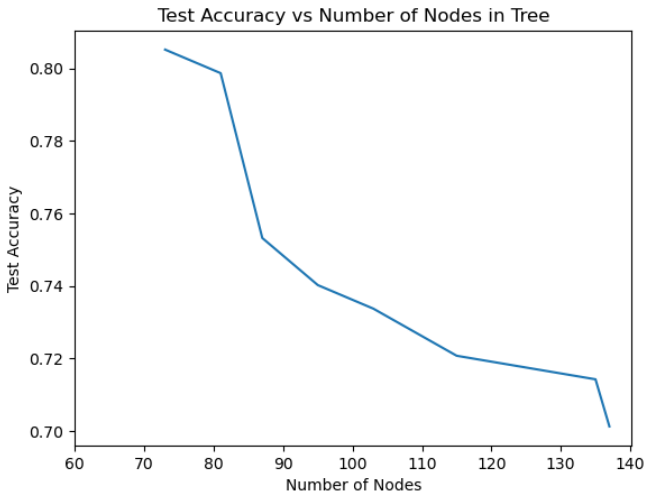
```
137
```

Pruning Decision Tree

In [ ]:
```
tree.reduced_error_pruning(X_test, y_test)
print(tree.count_nodes(tree.root))
```

```
73
```

In [ ]:
```
plt.plot(tree.test_acc.keys(), tree.test_acc.values())
plt.title('Test Accuracy vs Number of Nodes in Tree')
plt.xticks(np.arange(60, 150, 10))
plt.xlabel('Number of Nodes')
plt.ylabel('Test Accuracy')
plt.show()
```



Creating Graph of Tree

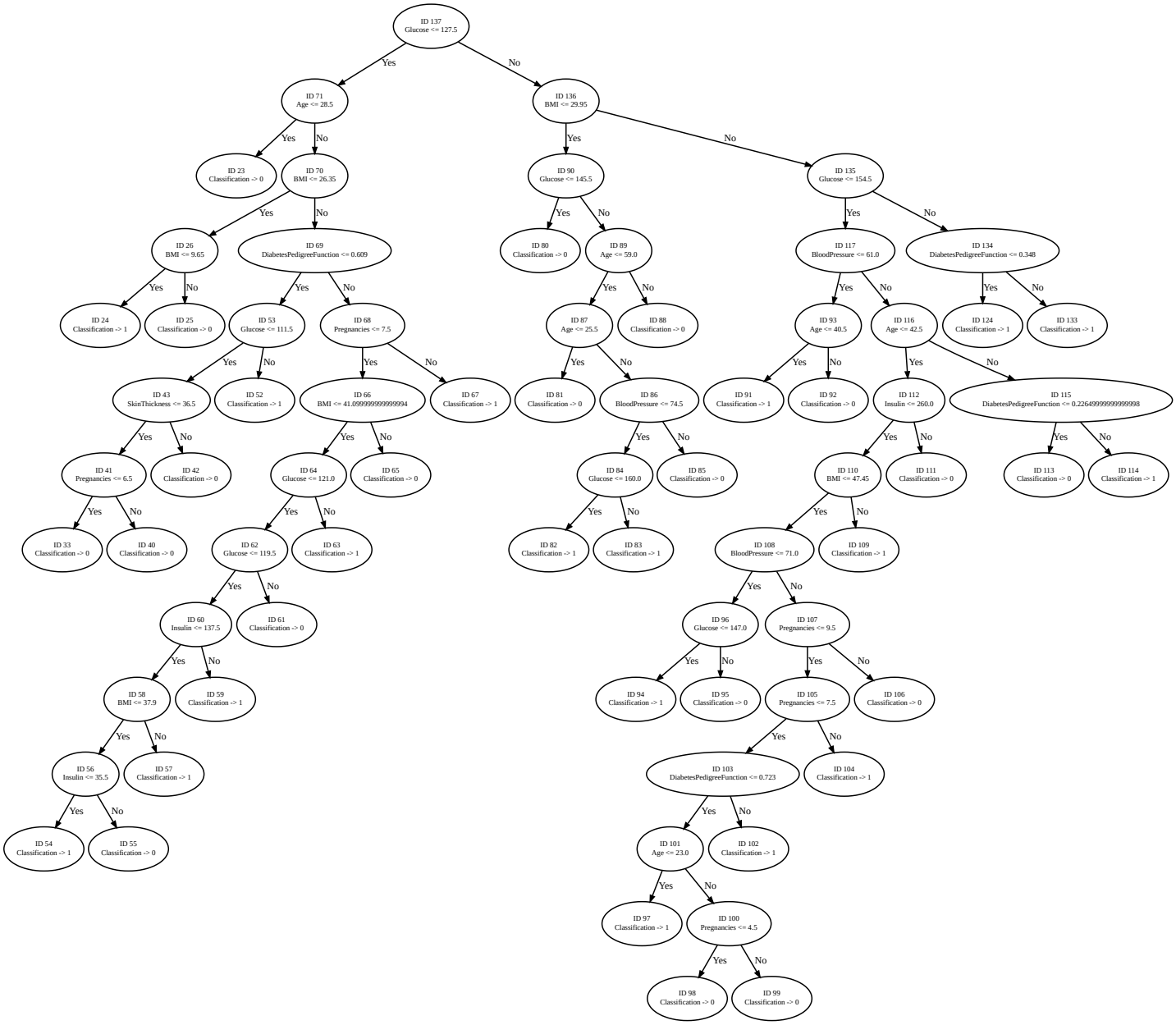
In [ ]:
```
dot = graphviz.Digraph(graph_attr={'size': '20,20', 'ranksep': '0.02', 'nodesep': '0.05'}, node_attr={'fontsize': '6', 'margin' : '0.005'}, edge_attr={'fontsize': '8

def print_tree(node, dot):
    if node.is_leaf:
        dot.node(str(node), "ID " + str(node.ID) + "\n Classification -> " + str(node.label))
        return

    attr = df.columns[node.feature_index]
    dot.node(str(node), "ID " + str(node.ID) + "\n" + str(attr) + " <= " + str(node.threshold))
    print_tree(node.left, dot)
    print_tree(node.right, dot)
    dot.edge(str(node), str(node.left), label = "Yes")
    dot.edge(str(node), str(node.right), label = "No")
```

In [ ]:
```
print_tree(tree.root, dot)
dot
```

Out[ ]:



Calculating Metrics

In [ ]:
```
def mean_macro_accuracy(y_pred, y_test):
    return np.sum(y_pred == y_test)/len(y_pred)

def mean_macro_precision(y_pred, y_test):
    unique_classes = np.unique(y_test)
    precision = 0

    for i in range(len(unique_classes)):
        class_indices = y_pred == unique_classes[i]
        precision += np.sum(y_pred[class_indices] == y_test[class_indices])/len(y_pred[class_indices])

    return precision/len(unique_classes)

def mean_macro_recall(y_pred, y_test):
    unique_classes = np.unique(y_test)
    recall = 0

    for i in range(len(unique_classes)):
        class_indices = y_test == unique_classes[i]
        recall += np.sum(y_pred[class_indices] == y_test[class_indices])/len(y_test[class_indices])

    return recall/len(unique_classes)
```

In [ ]:
```
y_pred = tree.multi_predict(X_test, tree.root)
```

In [ ]:
```
print('Mean Macro Accuracy:', mean_macro_accuracy(y_pred, y_test))
print('Mean Macro Precision:', mean_macro_precision(y_pred, y_test))
print('Mean Macro Recall:', mean_macro_recall(y_pred, y_test))
```

```
Mean Macro Accuracy: 0.8051948051948052
Mean Macro Precision: 0.7887166075098075
Mean Macro Recall: 0.7838383838383838
```