# Assignment 1

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```
# import all the necessary libraries here
import pandas as pd
import numpy as np
import math
import graphviz
from IPython.display import Image, display
from matplotlib import pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler

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

```
(768, 9)
```

```
df.head()
```

```
   Pregnancies  Glucose  BloodPressure  SkinThickness  Insulin
BMI  \
0            6      148             72             35        0  33.6

1            1       85             66             29        0  26.6

2            8      183             64              0        0  23.3

3            1       89             66             23       94  28.1

4            0      137             40             35      168  43.1


   DiabetesPedigreeFunction  Age  Outcome
0                     0.627   50        1
1                     0.351   31        0
2                     0.672   32        1
3                     0.167   21        0
4                     2.288   33        1
```

```
df.describe()
```

```
       Pregnancies     Glucose  BloodPressure  SkinThickness
Insulin  \
count   768.000000  768.000000     768.000000     768.000000
768.000000
mean      3.845052  120.894531      69.105469      20.536458
```

```
79.799479
std       3.369578   31.972618      19.355807      15.952218
115.244002
min       0.000000    0.000000       0.000000       0.000000
0.000000
25%       1.000000   99.000000      62.000000       0.000000
0.000000
50%       3.000000  117.000000      72.000000      23.000000
30.500000
75%       6.000000  140.250000      80.000000      32.000000
127.250000
max      17.000000  199.000000     122.000000      99.000000
846.000000
```

```
               BMI  DiabetesPedigreeFunction         Age     Outcome
count  768.000000                768.000000  768.000000  768.000000
mean    31.992578                  0.471876   33.240885    0.348958
std      7.884160                  0.331329   11.760232    0.476951
min      0.000000                  0.078000   21.000000    0.000000
25%     27.300000                  0.243750   24.000000    0.000000
50%     32.000000                  0.372500   29.000000    0.000000
75%     36.600000                  0.626250   41.000000    1.000000
max     67.100000                  2.420000   81.000000    1.000000
```

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 768 entries, 0 to 767
Data columns (total 9 columns):
 #   Column                    Non-Null Count  Dtype
---  ------                    --------------  -----
 0   Pregnancies               768 non-null    int64
 1   Glucose                   768 non-null    int64
 2   BloodPressure             768 non-null    int64
 3   SkinThickness             768 non-null    int64
 4   Insulin                   768 non-null    int64
 5   BMI                       768 non-null    float64
 6   DiabetesPedigreeFunction  768 non-null    float64
 7   Age                       768 non-null    int64
 8   Outcome                   768 non-null    int64
dtypes: float64(2), int64(7)
memory usage: 54.1 KB
```

```
# Test train Split
frac_1 = 0.8
df = df.sample(frac=1.0).reset_index(drop=True)
ind = int(len(df.index) * frac_1)
Train = df.iloc[:ind, :].reset_index(drop=True)
Test = df.iloc[ind:, :].reset_index(drop=True)
```

```
X_train = Train.iloc[:,:-1]
Y_train = Train.iloc[:,-1]
X_test = Test.iloc[:,:-1]
Y_test = Test.iloc[:,-1]

print(X_train.shape, Y_train.shape)
print(X_test.shape, Y_test.shape)
```

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

```
prediction = []

#Utils
def split_df_col(df):
    data = df.iloc[:, :-1]
    labels = df.iloc[:, -1]
    return (data, labels)

def entropy(labels):
    total = len(labels)
    diff_vals = labels.value_counts().tolist()
    diff_vals = [-1*(x/total)*math.log2(x/total) for x in diff_vals]
    return sum(diff_vals)



def information_gain(data,labels,attr,split_val):
    filt = data[attr] < split_val
    left_labels = labels[filt]
    right_labels = labels[~filt]
    gain = entropy(labels) -  (len(left_labels) * entropy(left_labels)
+ len(right_labels) * entropy(right_labels))/len(labels)
    return gain


def find_best_split(data,labels,attr):
    vals = np.sort(data[attr].unique())
    best_gain = 0;
    best_split_val = None
    for i in range(len(vals) - 1):
        split_val = (vals[i] + vals[i + 1])/2
        gain = information_gain(data,labels,attr,split_val)
        if best_gain < gain:
            best_gain = gain
            best_split_val = split_val
    return (best_split_val,best_gain)

def get_pred_accuracy(tree,test):
    test_data,test_labels = split_df_col(test)
    preds = tree.predict(test_data)
```

```
    accuracy = np.mean(preds == test_labels)*100
    return accuracy
# def get_accuracy_list(tree,root,data):
#     if root.is_leaf():
#         return
#     get_accuracy_list(tree,root.left,data)
#     get_accuracy_list(tree,root.right,data)
#     left,right = root.left,root.right
#     root.left = None
#     root.right = None
#     predict = get_pred_accuracy(tree,data)
#     prediction.append(predict)
#     root = root_temp
#     return
```

For finding the Accuracy, i did it inside the Prunning function.

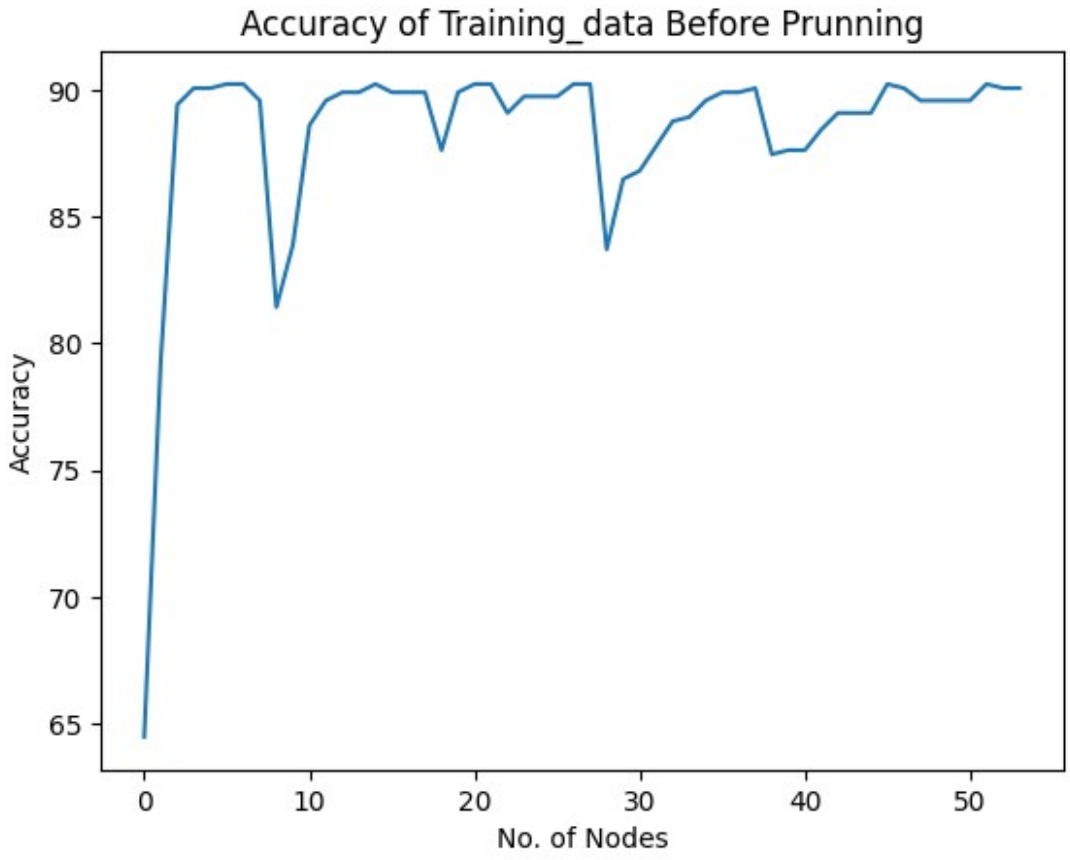
```
class Node:
    def __init__(self, attr,split_val,prob_label):
        self.attr = attr
        self.split_val = split_val
        self.prob_label = prob_label
        self.left = None
        self.right = None
    def is_leaf(self):
        return (self.left == None) and (self.right == None)
    def node_count(self):
        left_count,right_count = 0,0
        if self.left != None:
            left_count = self.left.node_count()
        if self.right != None:
            right_count = self.right.node_count()
        return 1 + left_count + right_count
    def prune(self,tree,accuracy,valid,pred = False):
        new_acc = 0

        if self.left == None and self.right==None:
            return accuracy

        if self.left != None:
            new_acc = self.left.prune(tree,accuracy,valid,pred)
        if self.right != None:
            new_acc = self.right.prune(tree,accuracy,valid,pred)

        left,right = self.left,self.right
        self.right = None
        self.left = None
```

```
        temp_acc = get_pred_accuracy(tree,valid)

        if pred == True:
            prediction.append(temp_acc)
            self.left,self.right = left,right
            return temp_acc

        if temp_acc < new_acc or tree.root.node_count() <= 5:
            self.left,self.right = left,right
        else:
            new_acc = temp_acc
            self.attr = 'Outcome'
        return new_acc
    def format_string(self):
        if self.is_leaf():
            outcome = 'Yes' if self.prob_label == 1 else 'No'
            return f'{self.attr}\n{outcome}'
        else:
            if self.attr == 'DiabetesPedigreeFunction':
                return f'{self.attr} <\n {self.split_val:.4f}'
            elif self.attr == 'BMI':
                return f'{self.attr} < {self.split_val:.4f}'
            else:
                return f'{self.attr} < {self.split_val}'

class DecisionTree:
    def __init__(self,max_depth = 10,min_sample = 10):
        self.root = None
        self.max_depth = max_depth
        self.min_samples = min_sample
        self.tree_depth = 0

    def train(self,X_train,Y_train):
        train_data , train_labels = X_train,Y_train
        self.root = self.built_tree(train_data,train_labels)

    def built_tree(self,train_data,train_labels,depth = 0):
        if (depth >= self.max_depth) or (len(train_data) <=
self.min_samples) or (len(train_labels.unique()) == 1):
            return self.create_leaf(train_labels)

        attr,split_val =
self.get_best_attribute(train_data,train_labels)
        node =
Node(attr,split_val,train_labels.value_counts().idxmax())

        mask = train_data[attr] < split_val
        left_data = train_data[mask]
        left_labels = train_labels[mask]
        if split_val == None:
```

```
            print(attr,",",len(train_data))
        node.left = self.built_tree(left_data,left_labels,depth + 1)

        right_data = train_data[~mask]
        right_labels = train_labels[~mask]
        node.right = self.built_tree(right_data,right_labels,depth+1)

        self.tree_depth = max(self.tree_depth,depth)
        return node

    def create_leaf(self,train_labels):
        prob_label  =train_labels.value_counts().idxmax()
        node = Node('Outcome',None,prob_label)
        return node
    def get_best_attribute(self,train_data,train_labels):
        attributes = train_data.columns
        max_gain = -10**20
        best_attr = None
        best_split_val = None

        for attr in attributes:
            split_val, gain =
find_best_split(train_data,train_labels,attr)
            if gain < max_gain and gain < -10**20:
                print(gain)

            if gain > max_gain:
                max_gain = gain
                best_attr = attr
                best_split_val = split_val
        return (best_attr,best_split_val)

    def predict_one(self,test_data,root):
        if root == None:
            return None
        if root.is_leaf():
            return root.prob_label
        if test_data[root.attr] <= root.split_val:
            return self.predict_one(test_data,root.left)
        else:
            return self.predict_one(test_data,root.right)

    def predict(self,test_data):
        predictions = pd.Series([self.predict_one(row,self.root) for
row in test_data.to_dict(orient='records')])
        return predictions
    def print_tree(self, file):
        tree = graphviz.Digraph(filename=file, format='png',
node_attr={'shape': 'box'})
```

```
        root = self.root
        queue = []
        queue.append(root)
        root.id = 0
        tree.node(str(root.id), label=root.format_string())
        uid = 1
        edge_labels = ['True', 'False']
        while(len(queue) > 0):
            node = queue.pop(0)
            for i, child in enumerate([node.left, node.right]):
                if child != None:
                    child.id = uid
                    uid += 1
                    queue.append(child)
                    tree.node(str(child.id),
label=child.format_string())
                    tree.edge(str(node.id), str(child.id),
label=edge_labels[i])

        tree.render(file, view=True)


tree = DecisionTree()
tree.train(X_train,Y_train)

accuracy = get_pred_accuracy(tree,Train)

print(f"The Accuracy on the Train Data ::{accuracy}")

The Accuracy on the Train Data ::90.22801302931596

test_accuracy = get_pred_accuracy(tree,Test)
print(f"The Accuracy on the Test Data ::{test_accuracy}")

The Accuracy on the Test Data ::70.12987012987013

tree.print_tree('before_pruning.gv')
last_accu = tree.root.prune(tree,accuracy,Train,True)

last_accu = tree.root.prune(tree,test_accuracy,Test)

tree.print_tree('after_pruning.gv')


prediction_temp = np.array(prediction)
prediction_temp = np.flip(prediction_temp)
figure, ax1 = plt.subplots()
nums = np.arange(len(prediction_temp))
ax1.plot(nums,np.array(prediction_temp).reshape((len(prediction,))))
ax1.set_xlabel('No. of Nodes')
ax1.set_ylabel('Accuracy')
```

```
ax1.set_title('Accuracy of Training_data Before Prunning')
plt.show()
```



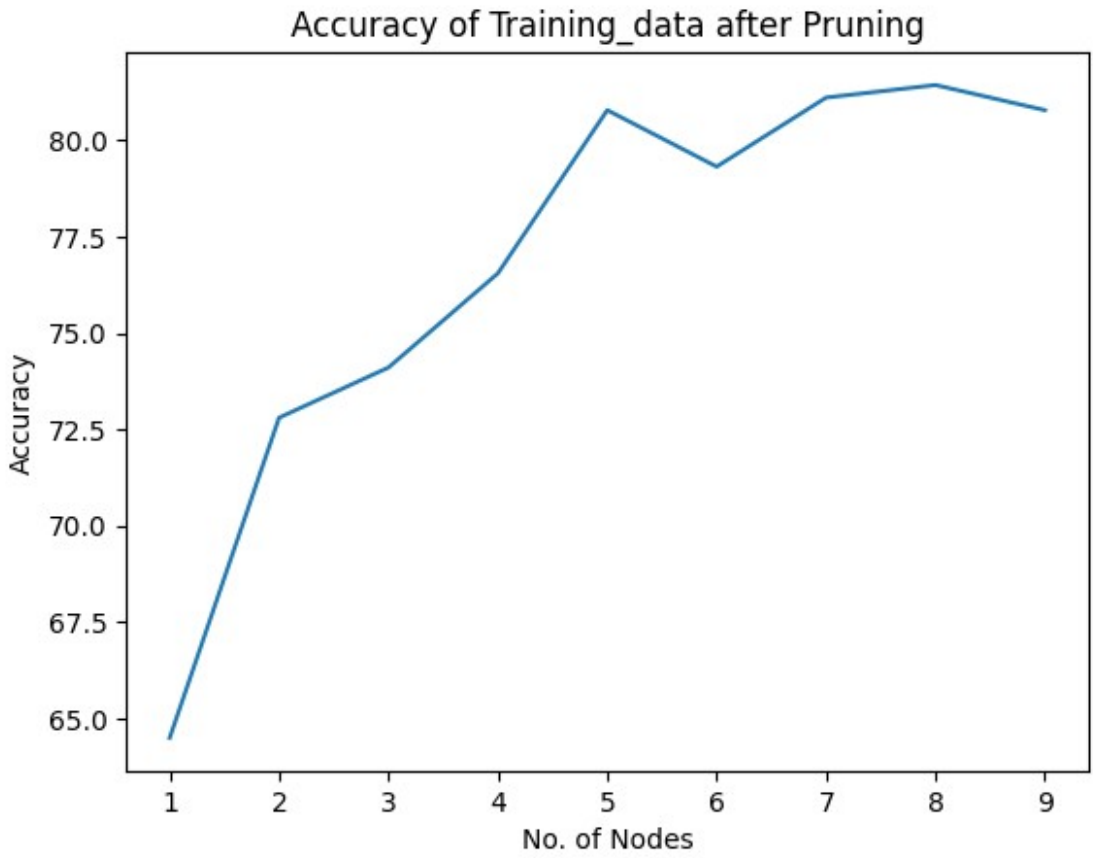

```
accuracy = get_pred_accuracy(tree,Train)

print(f"Accuracy on Training set after Prunning {accuracy}")
```

```
Accuracy on Training set after Prunning 81.43322475570032
```

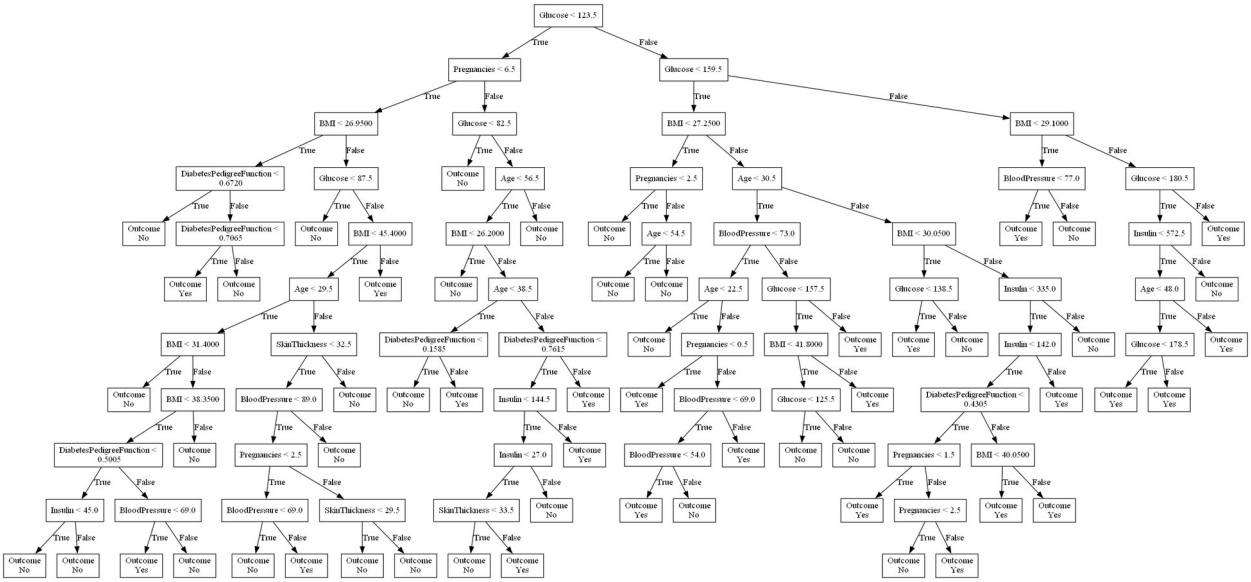
```
prediction.clear()

last_accu = tree.root.prune(tree,accuracy,Train,True)

prediction
```

```
[80.78175895765473,
 81.43322475570032,
 81.10749185667753,
 79.31596091205212,
 80.78175895765473,
 76.54723127035831,
 74.1042345276873,
```

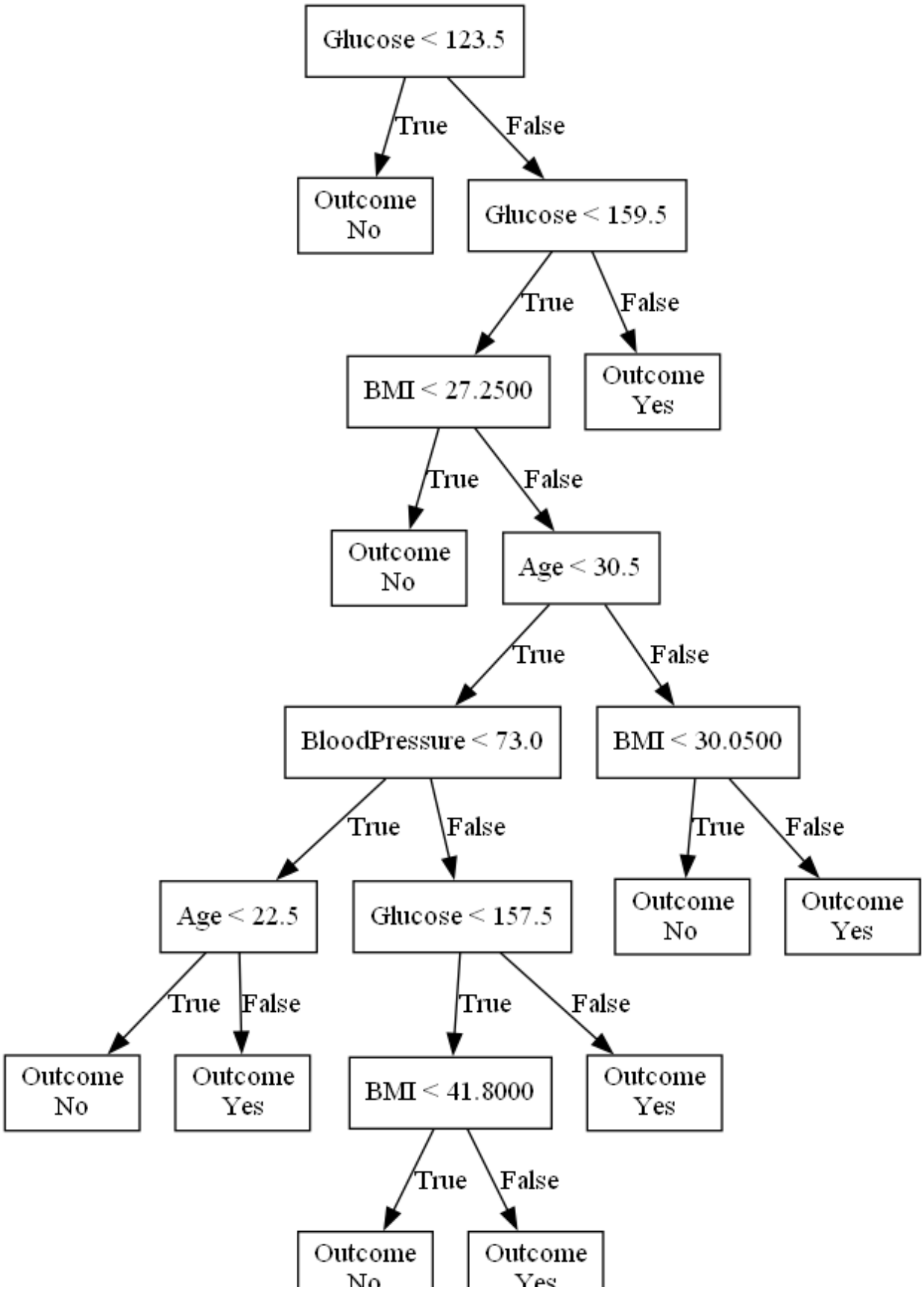
```
 72.80130293159608,
 64.49511400651465]

prediction_temp = np.array(prediction)
prediction_temp = np.flip(prediction_temp)
figure, ax1 = plt.subplots()
nums = 1 + np.arange(len(prediction_temp))
ax1.plot(nums,np.array(prediction_temp).reshape((len(prediction,))))
ax1.set_xlabel('No. of Nodes')
ax1.set_ylabel('Accuracy')
ax1.set_title('Accuracy of Training_data after Pruning')
plt.show()
```




```
display(Image(filename='before_pruning.gv.png'))
```




```
display(Image(filename='after_pruning.gv.png'))
```


Glucose < 123.5
True
False
Outcome No
Glucose < 159.5
True
False
BMI < 27.2500
Outcome Yes
True
False
Outcome No
Age < 30.5
True
False
BloodPressure < 73.0
BMI < 30.0500
True
False
True
False
Age < 22.5
Glucose < 157.5
Outcome No
Outcome Yes
True
False
True
False
Outcome No
Outcome Yes
BMI < 41.8000
Outcome Yes
True
False
Outcome No
Outcome Yes