In [ ]:
```
# Project 3

                                Automated Classification using Decision Trees

           This program gernerates a decision tree by the training dataset via ID3 algorithm,
           and uses the tree to predict the test data outcomes.
```

In [6]:
```
import pandas as pd
import math
```

In [141]:
```
# construct dataframe from data file
# Pandas's dataframe is used for store dataset.
fishing = pd.read_csv('fishing.data',sep=' ', header = None, skiprows=8,
     names = ["Wind", "Water", "Air", "Forecast","Oracle"])

fishing.index= range(0,len(fishing.index))   # change index

lenses = pd.read_csv('contact-lenses.data',sep=' ', header = None, skiprows=8,
      names = ["age", "prescription", "astigmatism", "tearrate","Oracle"])
lenses.index = range(0,len(lenses.index))
```

In [75]:
```
fishing.head()
```

Out[75]:

	Wind	Water	Air	Forecast	Oracle
0	Strong	Warm	Warm	Sunny	Yes
1	Weak	Warm	Warm	Sunny	No
2	Strong	Warm	Warm	Cloudy	Yes
3	Strong	Moderate	Warm	Rainy	Yes
4	Strong	Cold	Cool	Rainy	No

In [12]:
```
lenses.head()
```

Out[12]:

	age	prescription	astigmatism	tearrate	Oracle
0	young	myope	no	reduced	none
1	young	myope	no	normal	soft
2	young	myope	yes	reduced	none
3	young	myope	yes	normal	hard
4	young	hypermetrope	no	reduced	none

In [13]:
```
# Calculate probability
def getProb(seri):
    prob = pd.Series()
    for key in seri.keys():
        prob[key]=seri[key]/seri.sum()
    return prob
```

In [14]:
```
# Calculate entropy
def getEntr(seri):
    e = 0
    for key in seri.keys():
        e -= (seri[key]/seri.sum()) * math.log(seri[key]/seri.sum(),2)
    return e
```

In [15]:
```python
# Calculate S
def getBigS(dataframe):
    oracle = dataframe.Oracle.value_counts()
    total = oracle.sum()
    bigS = getEntr(oracle)
    return bigS,total
```

In [16]:
```python
# Return the feature which has max information gain
def maxGain(df):
    oracle = df.Oracle.value_counts()
    bisS,total = getBigS(df)
    features = df.columns.drop('Oracle')
    gain = pd.Series()
    for f in features:
        temp = df[[f,'Oracle']].groupby(f)
        entrophy = pd.Series()
        gain[f] = getEntr(oracle)
        for type in df[f].unique():
            temp2 = temp.get_group(type)['Oracle'].value_counts()
            entrophy[type] = getEntr(temp2)
            gain[f] -= temp2.sum()/total * entrophy[type]
    return gain.idxmax()
```

In [17]:
```python
# Implement ID3 algorithm
def createTree(tree,datafm):
    selFeature = maxGain(datafm)
    tree[selFeature]={}
    types = datafm[selFeature].value_counts()
    for key in types.keys():
        decision = datafm['Oracle'][datafm[selFeature]==key]
        #if all examples in S in the same class
        if len(decision.unique())==1:
            decisionLeaf = decision.max()
        #return a leaf
            tree[selFeature][key]= decisionLeaf
        #If there is no more attributes
        elif len(datafm.columns)<=3:
            decisionLeaf = decision.max()
            tree[selFeature][key]= decisionLeaf
        else:
            tree[selFeature][key]={}  #Else recursively create the tree
            newdf = datafm[datafm[selFeature]==key].drop(selFeature,axis = 1)
            createTree(tree[selFeature][key],newdf)
```

In [18]:
```python
def treeDict(datafm):
    tr = {}
    createTree(tr,datafm)
    return tr
```

In [19]:
```python
# Get tree dictionary for dataset fishing and lenses:
fishingDict = treeDict(fishing)
lensesDict = treeDict(lenses)
```

In [20]:
```python
fishingDict
```

Out[20]:
```
{'Forecast': {'Cloudy': 'Yes',
  'Rainy': {'Air': {'Cool': 'No',
    'Warm': {'Wind': {'Strong': 'Yes', 'Weak': 'No'}}}},
  'Sunny': {'Wind': {'Strong': 'Yes',
    'Weak': {'Water': {'Cold': 'No', 'Moderate': 'Yes', 'Warm': 'No'}}}}}}
```

In [21]:
```
lensesDict
```

Out[21]:
```
{'tearrate': {'normal': {'astigmatism': {'no': {'age': {'pre-presbyopic': 'soft',
      'presbyopic': 'soft',
      'young': 'soft'}},
    'yes': {'prescription': {'hypermetrope': 'none', 'myope': 'hard'}}}},
  'reduced': 'none'}}
```

In [22]:
```
#Visualize the tree

import pydotplus as pydot
```

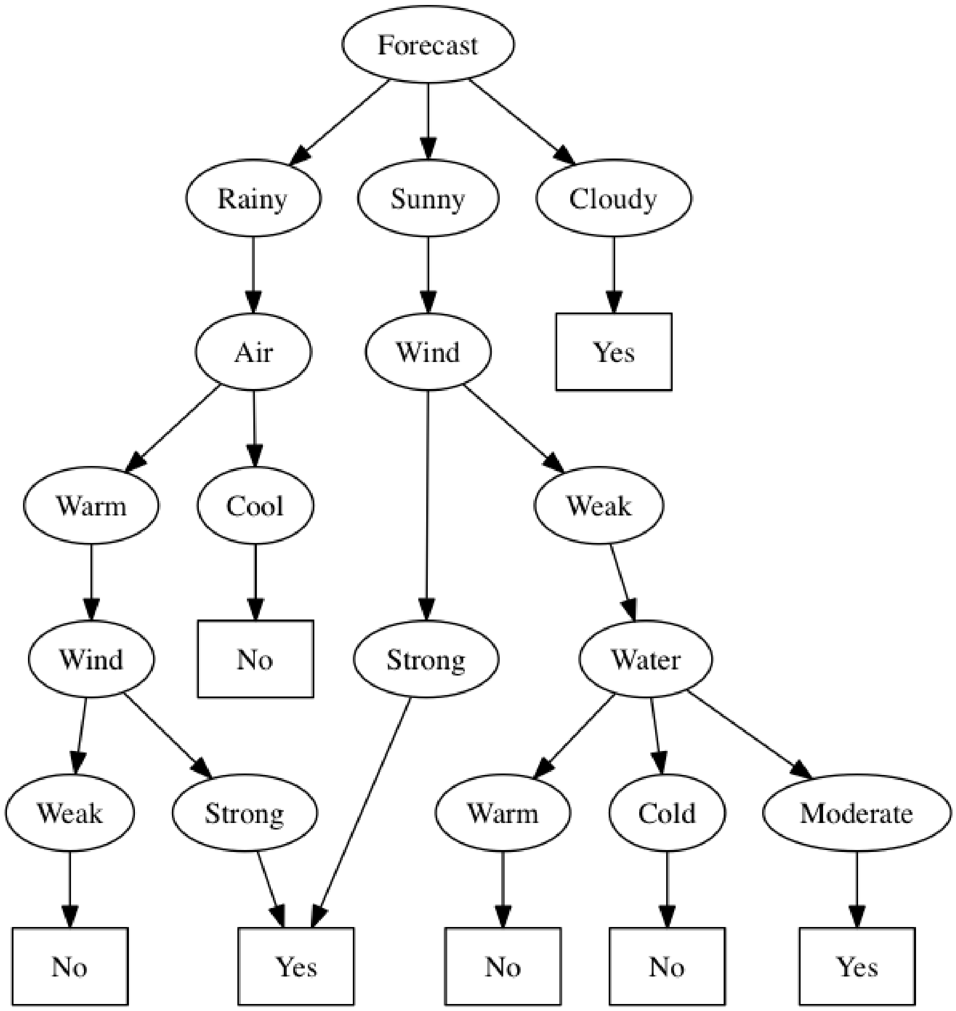
In [23]:
```
def plotDict(graph, treedict, parentNode=None):
    for k in treedict.keys():
        if parentNode is not None:
            from_name = parentNode.get_name() + '_' + str(k)
            from_label = str(k)
            node_from = pydot.Node(from_name, label=from_label)
            graph.add_node(node_from)
            graph.add_edge( pydot.Edge(parentNode, node_from) )
            if isinstance(treedict[k], dict):
                plotDict(graph, treedict[k], node_from)
            else:
                to_name = str(k) + '_' + str(treedict[k])
                to_label = treedict[k]
                node_to = pydot.Node(to_name, label=to_label, shape='box')
                graph.add_node(node_to)
                graph.add_edge(pydot.Edge(node_from, node_to))
        else:
            from_name =  k
            from_label = k
            node_from = pydot.Node(from_name, label=from_label)
            plotDict(graph, treedict[k], node_from)
```

In [24]:
```
def plotTree(tree, name):
    graph = pydot.Dot(graph_type='digraph')
    plotDict(graph, tree)
    graph.write_png(name+'.png')

plotTree(fishingDict,'fishing')
plotTree(lensesDict,"lenses")
```

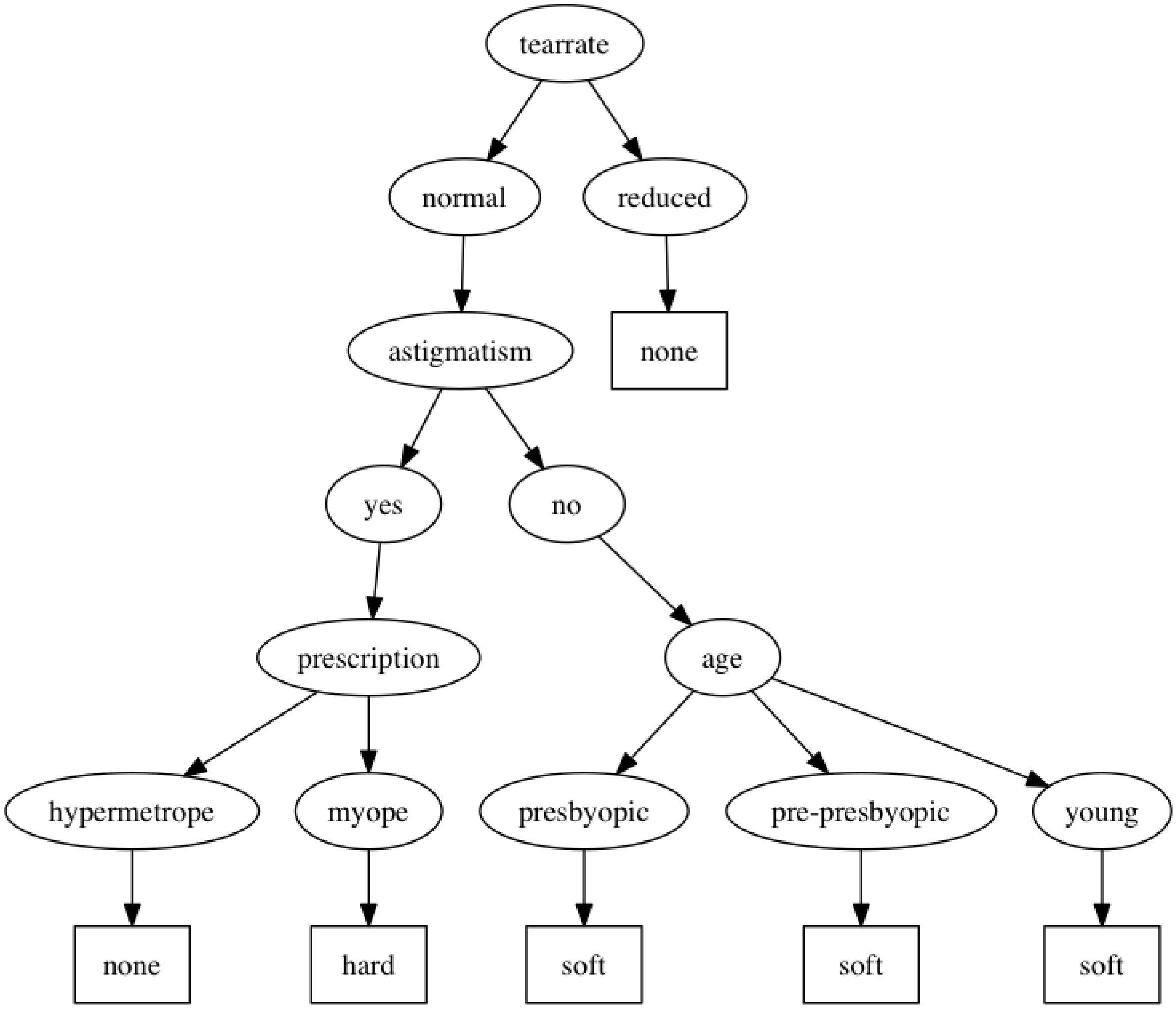
In [25]:
```
from IPython.display import Image
Image(filename='fishing.png')
```

Out[25]:



In [26]:
```
Image(filename='lenses.png')
```

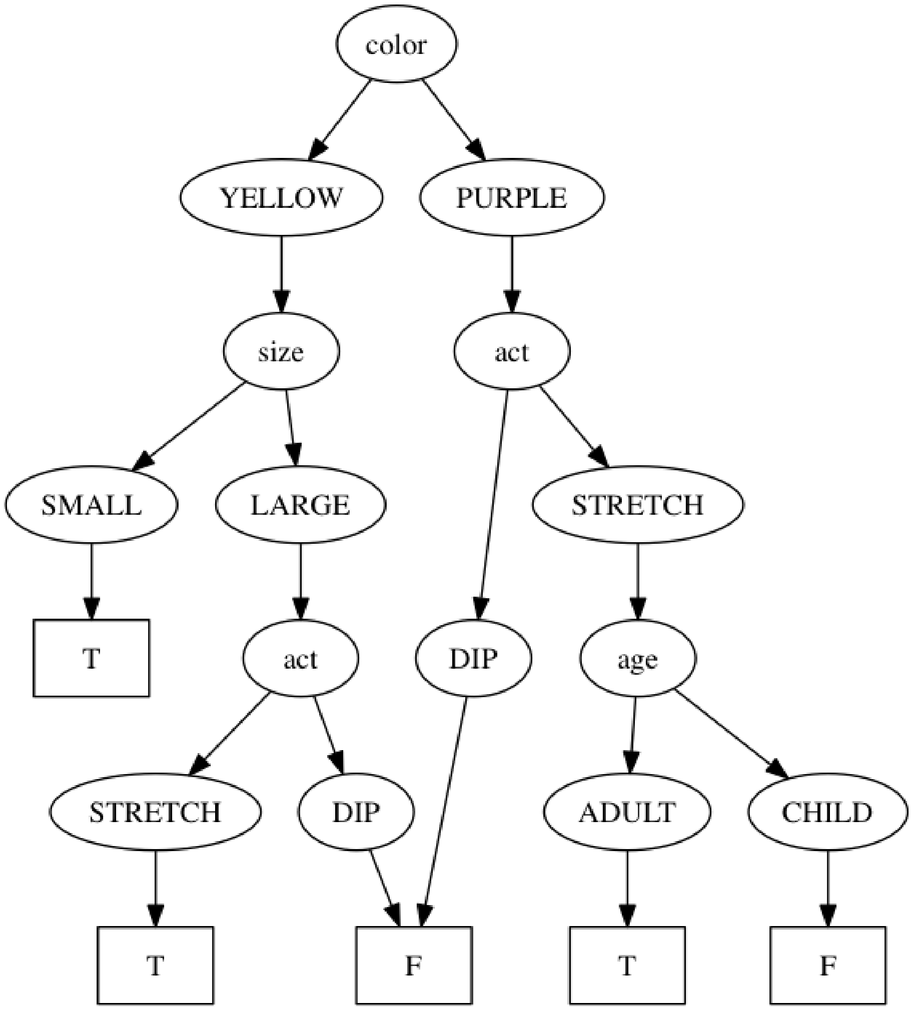
Out[26]:



In [32]:
```
# try more dataset: https://archive.ics.uci.edu/ml/datasets/Balloons
balloon_s = pd.read_csv( 'yellow-small+adult-stretch.data',sep=',', header = None,index_col=False,
                    names = ['color','size','act','age','Oracle'])
```

In [33]:
```
balloonsDict = treeDict(balloon_s)
plotTree(balloonsDict,'balloons')
Image(filename='balloons.png')
```

Out[33]:



In [218]:

```
#Classify the test dataset by tree dictionary
# get single row
def splitRow(datafm):
    a = {}
    for i in datafm.index:
        a[i] = datafm.ix[i]
    return a
# Predict outcome for one row data
def classify(treeDict, testrow):
    for k in treeDict.keys():
        selFeat = k
        testval = testrow[selFeat]
        if testval not in treeDict[selFeat].keys():
            print("Error..")
        else:
            outcome = treeDict[selFeat][testval]
            if type(outcome) == dict:
                return classify(outcome,testrow)
            else:
                return outcome

# Predict the outcomes for the whole dataset
def classifyDF (treeDict,testdf):
    testrow = splitRow(testdf)
    predict ={}
    err = 0
    for key in testrow.keys():
        label = testrow[key]['Oracle']
        print("Label: ",label)
        predict[key] = classify(treeDict, testrow[key])
        print("Predict outcome is: ", predict[key])
        print("\n")
        if str(predict[key]) != str(label):
            err+=1
    errrate = float(err / len(testrow.keys()))*100
    print("Error rate:", errrate)
```

In [35]:

```
import numpy as np
```

In [214]:

```
# Radomly create test set of fishing dataset
msk1 = np.random.rand(len(lenses)) < 0.8
test_lenses = lenses[~msk1]
train_lenses = lenses[msk1]
```

In [215]:

```
len(test_lenses)
```

Out[215]: 7

In [216]:

```
# get tree dictionary for future predict
lensesDict = treeDict(train_lenses)
```

In [219]:
```
classifyDF (lensesDict,test_lenses)
```

```
Label:  none
Predict outcome is:  none


Label:  none
Predict outcome is:  none


Label:  none
Predict outcome is:  none


Label:  soft
Predict outcome is:  none


Label:  none
Predict outcome is:  none


Label:  soft
Predict outcome is:  soft


Label:  none
Predict outcome is:  none


Error rate: 14.285714285714285
```

In [144]:
```
# https://archive.ics.uci.edu/ml/machine-learning-databases/car/car.data
car = pd.read_csv('car.data',sep=',', header = None, skiprows=8,
     names = ["buying", "maint", "doors", "persons","lug_boot","safety","Oracle"])

car.index= range(0,len(car.index))
```

In [145]:
```
car.head()
```

Out[145]:

	buying	maint	doors	persons	lug_boot	safety	Oracle
0	vhigh	vhigh	2	2	big	high	unacc
1	vhigh	vhigh	2	4	small	low	unacc
2	vhigh	vhigh	2	4	small	med	unacc
3	vhigh	vhigh	2	4	small	high	unacc
4	vhigh	vhigh	2	4	med	low	unacc

In [147]:
```
# Radomly create test set of car dataset
msk = np.random.rand(len(car)) < 0.8
test_car = car[~msk]
train_car = car[msk]
```

In [149]:
```
carDict = treeDict(train_car)
```

In [152]:
```
len(train_car)    # number of training samples
```

Out[152]: 1392

In [153]:
```
len(test_car)     #number of test samples
```

Out[153]: 328

In [155]:
```
classifyDF (carDict,test_car)
```

```
Error rate: 8.231707317073171
```

In [156]:
```
msk = np.random.rand(len(car)) < 0.8
test_car = car[~msk]
train_car = car[msk]
```

In [157]:
```
carDict = treeDict(train_car)
```

In [158]:
```
len(train_car)
```

Out[158]: 1405

In [159]:
```
len(test_car)
```

Out[159]: 315

In [160]:
```
# Error rate for car dataset prediction
classifyDF (carDict,test_car)
```

```
Error rate: 7.301587301587302
```

In [161]:
```
# continuous attributes:
# iris dataset: https://archive.ics.uci.edu/ml/machine-learning-databases/iris/
iris = pd.read_csv( 'iris.data',sep=',', header = None,index_col=False,
                     names = ['sepal_len','sepal_wid','petal_len','petal_wid','Oracle'])
```

In [162]:
```
iris.head()
```

Out[162]:

	sepal_len	sepal_wid	petal_len	petal_wid	Oracle
0	5.1	3.5	1.4	0.2	Iris-setosa
1	4.9	3.0	1.4	0.2	Iris-setosa
2	4.7	3.2	1.3	0.2	Iris-setosa
3	4.6	3.1	1.5	0.2	Iris-setosa
4	5.0	3.6	1.4	0.2	Iris-setosa

In [163]:
```
iris.describe()
```

Out[163]:

	sepal_len	sepal_wid	petal_len	petal_wid
count	150.000000	150.000000	150.000000	150.000000
mean	5.843333	3.054000	3.758667	1.198667
std	0.828066	0.433594	1.764420	0.763161
min	4.300000	2.000000	1.000000	0.100000
25%	5.100000	2.800000	1.600000	0.300000
50%	5.800000	3.000000	4.350000	1.300000
75%	6.400000	3.300000	5.100000	1.800000
max	7.900000	4.400000	6.900000	2.500000

In [164]:
```python
# choose the split point for each feature:
# sepal_len split pts[5.0,6.0,7.0]
# sepal_wid split pts[2.0,3.0,4.0]
# petal_len split pts[2.0,4.0,6.0]
# petal_wid split pts[0.8,1.6,2.4]
# reconstruct the new dataframe:
def newDF(oldDF,name,spp):
    temp1 = oldDF[oldDF[name]<spp[0]]
    temp1[name] = "<"+ str(spp[0])
    temp2 = oldDF[(oldDF[name]>=spp[0]) & (oldDF[name]<spp[1])]
    temp2[name] = str(spp[0])+"~"+ str(spp[1])
    temp3 = oldDF[(oldDF[name]>=spp[1]) & (oldDF[name]<spp[2])]
    temp3[name] = str(spp[1])+"~"+ str(spp[2])
    temp4 = oldDF[oldDF[name]>spp[2]]
    temp4[name] = ">"+ str(spp[2])
    newDF = temp1.append(temp2).append(temp3).append(temp4)
    return newDF
```

In [165]:
```python
iris1 = newDF(iris,"sepal_len",[5.0,6.0,7.0])
iris2 = newDF(iris1,"sepal_wid",[2.0,3.0,4.0])
iris3 = newDF(iris2,"petal_len",[2.0,4.0,6.0])
newiris = newDF(iris3,"petal_wid",[0.8,1.6,2.4])
```

...

In [220]:
```python
newiris.tail()
```

Out[220]:

	sepal_len	sepal_wid	petal_len	petal_wid	Oracle
117	>7.0	3.0~4.0	>6.0	1.6~2.4	Iris-virginica
131	>7.0	3.0~4.0	>6.0	1.6~2.4	Iris-virginica
135	>7.0	3.0~4.0	>6.0	1.6~2.4	Iris-virginica
144	6.0~7.0	3.0~4.0	4.0~6.0	>2.4	Iris-virginica
109	>7.0	3.0~4.0	>6.0	>2.4	Iris-virginica

In [172]:
```python
# randomly split the dataset into training data and test data:
rdm = np.random.rand(len(newiris)) < 0.8
train_iris = newiris[rdm]
test_iris = newiris[~rdm]
```

In [173]:
```python
len(train_iris)
```

Out[173]: 114

In [174]:
```python
len(test_iris)
```

Out[174]: 29

In [175]:
```python
# built iris tree dictionary
irisDict = treeDict(train_iris)
```

In [190]:
```
classifyDF (irisDict,test_iris)
```

```
Label:  Iris-versicolor
Predict outcome is:  Iris-versicolor


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-versicolor
Predict outcome is:  Iris-virginica


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-versicolor
Predict outcome is:  Iris-virginica


Label:  Iris-versicolor
Predict outcome is:  Iris-versicolor


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-versicolor
Predict outcome is:  Iris-versicolor


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-versicolor
Predict outcome is:  Iris-versicolor


Label:  Iris-setosa
```

```
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-setosa
Predict outcome is:  Iris-setosa


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-virginica
Predict outcome is:  Iris-virginica


Label:  Iris-versicolor
Predict outcome is:  Iris-versicolor


Label:  Iris-versicolor
Predict outcome is:  Iris-virginica


Error rate: 10.344827586206897
```

In [ ]:

```
Discussion:
    1: The algorithmn used here could easily cause building a overfitting tree. For large dataset,
       the tree plotting looks like spaghetti using this code.
    2: This model did not try to deal with missing values
    3: For unseen data prediction, error might occur when using classify method.
    4: The tree is not stable, it varies by the training data. The test error rate could be very high
    6: Numeric valued training data need to split into proper points. Further study is needed for
       choosing the best point
    5: Pruning method needs to further study also.
```