CS 273P Homework 4

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Problem 1 : Decision Trees

1 a) Entropy of y = 6/10*log(10/6)+4/10*log(10/4) = 0.44218+0.52877 = 0.97095

1 b) Information Gain (X)= H(Y) - H(Y|X)

X1 = 0.97095 - ((4/10)((3/4) log(4/3)+(1/4)log4) + (6/10)((1/2)log2+(1/2)log2))

= 0.97095 - (0.32451+0.6)

= 0.4644 bits

X2 = 0.97095 - (5/10 (1/5 log 5 + 4/5 log 5/4) + 5/10 (6 log 6 + 0 log 0))

= 0.97095 - (0.36096+0)

= 0.60999

X3 = 0.97095 - (3/10 (2/3 log 3/2 + 1/3 log 3) + 7/10 (4/7 log 7/4 + 3/7 log 7/3))

= 0.97095 = (0.27548 + 0.68965)

= 0.00582

X4 = 0.97095 - (3/10 (1/3 log 3 + 2/3 log 3/2) + 7/10 (5/7 log 7/5 + 2/7 log 7/2))

= 0.97095 - (0.27548 + 0.60418)

= 0.09129

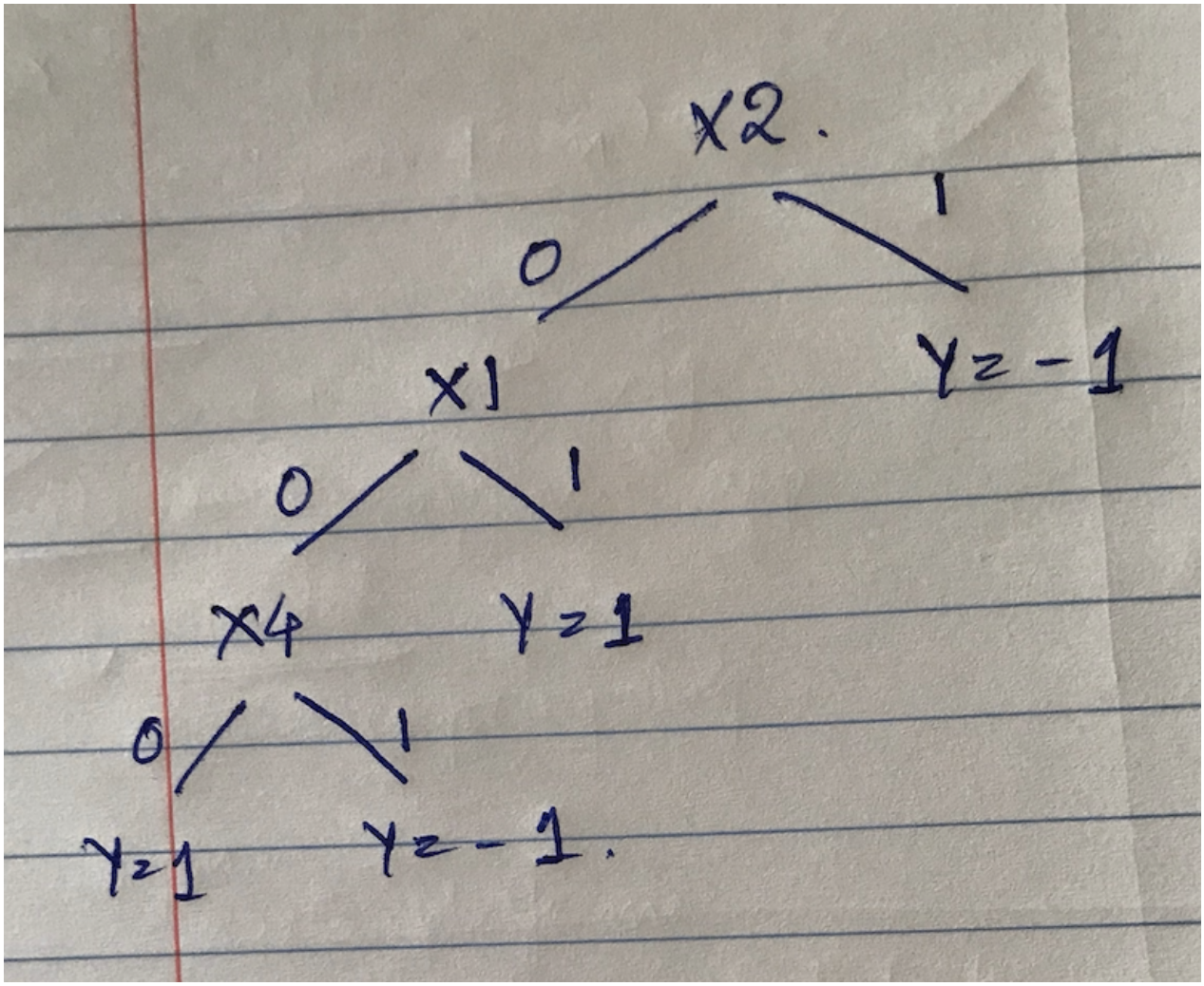
X5 = 0.97095 - (7/10 (4/7 log 7/4 + 3/7 log 7/3) + 3/10 (2/3 log 3/2 + 1/3 log 3))

= 0.97095 - (0.68965 + 0.27548)

= 0.00582

Splitting should happen on feature X2 first.

1 c)



In [1]:

```
1 import numpy as np
2 import matplotlib.pyplot as plt
3 import mltools as ml
4 np.random.seed(0)
```

Problem 2 : Decision Trees on Kaggle

2a

In [2]:
```
dataX=np.genfromtxt("X_train.txt",delimiter=None)
dataY=np.genfromtxt("Y_train.txt",delimiter=None)
#Taking 0-10000 as Training data
#Xtr=dataX[0:10000,0:3]
Xtr=dataX[0:10000,]
Ytr=dataY[0:10000,]
#Taking 10001-20000 as Validation data
Xte=dataX[10000:20000,]
Yte=dataY[10000:20000,]
```

#Size of training data= Rows=10000 (1-10000) , Columns=14

#Size of test data = Rows= 10000 (10001-20000) , Columns =14

2b

In [3]:
```
#Learn a decision tree classifier on the data
learnerTr = ml.dtree.treeClassify(Xtr,Ytr, maxDepth=50)
mseTr=learnerTr.err(Xtr,Ytr)
mseTe=learnerTr.err(Xte,Yte)
print("Max depth = 50")
print("Error of training data = "+str(mseTr))
print("Error of test data = "+str(mseTe))
```

```
Max depth = 50
Error of training data = 0.0047
Error of test data = 0.3816
```

2c

In [4]:
```
# With max depth parameter from 0 - 15
mseTRL=[]
mseTEL=[]
for i in range(0,16):
    learner2TR=ml.dtree.treeClassify(Xtr,Ytr,maxDepth=i)
    mseTR2=learner2TR.err(Xtr,Ytr)
    mseTE2=learner2TR.err(Xte,Yte)
    mseTRL.append(mseTR2)
    mseTEL.append(mseTE2)
    print("Max Depth: "+str(i)+" , Training error: "+str(mseTR2)+" , Tes
_,axis=plt.subplots()
plt.title("maxDepth error rates [ Training error: red , Test error: gree
axis.plot(mseTRL,c='red')
axis.plot(mseTEL,c='green')
plt.show()


```

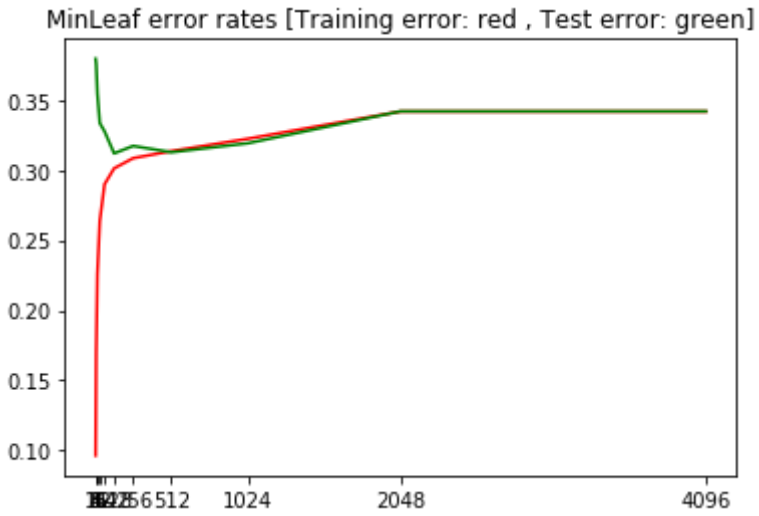
```
Max Depth: 0 , Training error: 0.3418 , Test error: 0.3419
Max Depth: 1 , Training error: 0.3418 , Test error: 0.3419
Max Depth: 2 , Training error: 0.3223 , Test error: 0.3191
Max Depth: 3 , Training error: 0.3133 , Test error: 0.3126
Max Depth: 4 , Training error: 0.3105 , Test error: 0.3152
Max Depth: 5 , Training error: 0.3008 , Test error: 0.3102
Max Depth: 6 , Training error: 0.2949 , Test error: 0.3103
Max Depth: 7 , Training error: 0.2872 , Test error: 0.3118
Max Depth: 8 , Training error: 0.277 , Test error: 0.313
Max Depth: 9 , Training error: 0.2632 , Test error: 0.3186
Max Depth: 10 , Training error: 0.2455 , Test error: 0.3243
Max Depth: 11 , Training error: 0.2309 , Test error: 0.3258
Max Depth: 12 , Training error: 0.2088 , Test error: 0.3344
Max Depth: 13 , Training error: 0.1923 , Test error: 0.3431
Max Depth: 14 , Training error: 0.1648 , Test error: 0.3439
Max Depth: 15 , Training error: 0.1454 , Test error: 0.3575
```

Complexity increases as depth increases. The most ideal depth is 6 as we get minimum test error at this depth. Before this depth the learner underfits, whereas starts overfitting right after this depth.

2d

In [5]:
```
#Minleaf 2^2 to 2^12
mseTRL=[]
mseTEL=[]
for j in range(2,13):
    learnerTR=ml.dtree.treeClassify(Xtr,Ytr,maxDepth=50,minLeaf=2**j)
    mseTR2=learnerTR.err(Xtr,Ytr)
    mseTE2=learnerTR.err(Xte,Yte)
    mseTRL.append(mseTR2)
    mseTEL.append(mseTE2)
    print("MinLeaf: "+str(2**j)+" , Training error: "+str(mseTR2)+" , Te
_,axis=plt.subplots()
plt.title("MinLeaf error rates [Training error: red , Test error: green]
axis.plot([4,8,16,32,64,128,256,512,1024,2048,4096],mseTRL,c='red')
axis.plot([4,8,16,32,64,128,256,512,1024,2048,4096],mseTEL,c='green')
axis.set_xticks([4,8,16,32,64,128,256,512,1024,2048,4096])
plt.show()
```

```
MinLeaf: 4 , Training error: 0.0964 , Test error: 0.3794
MinLeaf: 8 , Training error: 0.1692 , Test error: 0.3755
MinLeaf: 16 , Training error: 0.2256 , Test error: 0.3546
MinLeaf: 32 , Training error: 0.2637 , Test error: 0.3335
MinLeaf: 64 , Training error: 0.2899 , Test error: 0.3276
MinLeaf: 128 , Training error: 0.3012 , Test error: 0.3119
MinLeaf: 256 , Training error: 0.3085 , Test error: 0.3172
MinLeaf: 512 , Training error: 0.3135 , Test error: 0.3127
MinLeaf: 1024 , Training error: 0.3223 , Test error: 0.3191
MinLeaf: 2048 , Training error: 0.3418 , Test error: 0.3419
MinLeaf: 4096 , Training error: 0.3418 , Test error: 0.3419
```

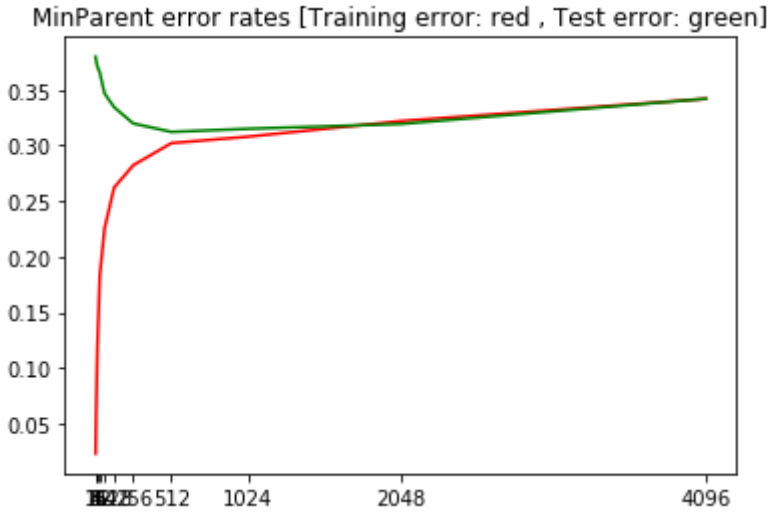


Complexity decreases as minLeaf grows because the training error continues to increase with increasing value of minLeaf. Ideal value of minLeaf is 128, where the test error has minimum value. minLeaf lesser than 128 underfits the model, whereas a value greater than 128 overfits it.

2 e

In [6]:
```
# minParent ranging from 2^2 to 2^12
mseTRL=[]
mseTEL=[]
for j in range(2,13):
    learnerTR=ml.dtree.treeClassify(Xtr,Ytr,maxDepth=50,minParent=2**j)
    mseTR2=learnerTR.err(Xtr,Ytr)
    mseTE2=learnerTR.err(Xte,Yte)
    mseTRL.append(mseTR2)
    mseTEL.append(mseTE2)
    print("MinParent: "+str(2**j)+" , Training error: "+str(mseTR2)+" ,
_,axis=plt.subplots()
plt.title("MinParent error rates [Training error: red , Test error: gree
axis.plot([4,8,16,32,64,128,256,512,1024,2048,4096],mseTRL,c='red')
axis.plot([4,8,16,32,64,128,256,512,1024,2048,4096],mseTEL,c='green')
axis.set_xticks([4,8,16,32,64,128,256,512,1024,2048,4096])
plt.show()
```

```
MinParent: 4 , Training error: 0.0233 , Test error: 0.3796
MinParent: 8 , Training error: 0.0624 , Test error: 0.3758
MinParent: 16 , Training error: 0.1179 , Test error: 0.3709
MinParent: 32 , Training error: 0.183 , Test error: 0.3654
MinParent: 64 , Training error: 0.2255 , Test error: 0.3467
MinParent: 128 , Training error: 0.2621 , Test error: 0.3343
MinParent: 256 , Training error: 0.2821 , Test error: 0.3197
MinParent: 512 , Training error: 0.302 , Test error: 0.3121
MinParent: 1024 , Training error: 0.3078 , Test error: 0.3149
MinParent: 2048 , Training error: 0.3218 , Test error: 0.3192
MinParent: 4096 , Training error: 0.3418 , Test error: 0.3419
```

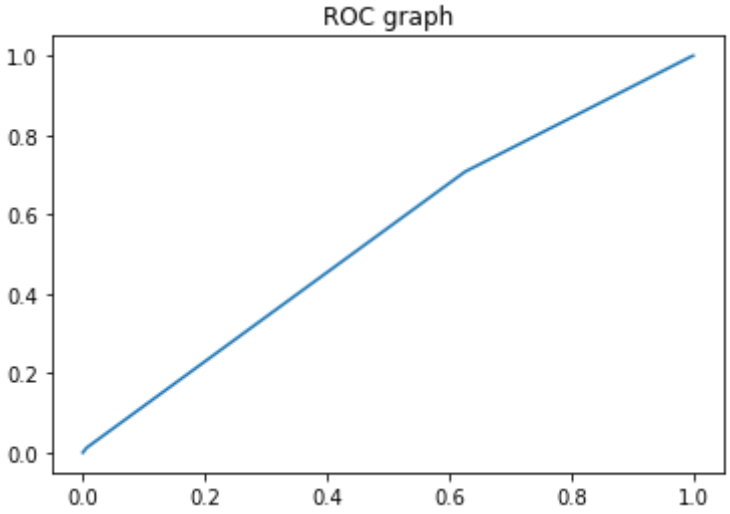


Ideal value of minParent is 512.

2 f

In [7]:
```
# ROC curve and AUC ( area under curve) for maxDepth= 50
learnerTR=ml.dtree.treeClassify(Xtr,Ytr,maxDepth=50)
ROC=learnerTR.roc(Xte,Yte)
plt.plot(ROC[0],ROC[1])
plt.title("ROC graph")
plt.show()
AUC=learnerTR.auc(Xte,Yte)
print("AUC for maxDepth 50 is "+str(AUC))

```




```
AUC for maxDepth 50 is 0.5812224819257972
```

2 g

In [8]:
```
# Predictions keeping values of maxDepth=6 , minLeaf=128 and minParent=
nXte=np.genfromtxt("X_test.txt",delimiter=None)
learnerTR=ml.dtree.treeClassify(Xtr,Ytr,maxDepth=6,minLeaf=128,minParent
Ypred=learnerTR.predictSoft(nXte)
np.savetxt('Gupta_6943.txt',
np.vstack( (np.arange(len(Ypred)) , Ypred[:,1]) ).T,
'%d, %.2f',header='ID,Prob1',comments='',delimiter=',');
```

Problem 3: Random Forests

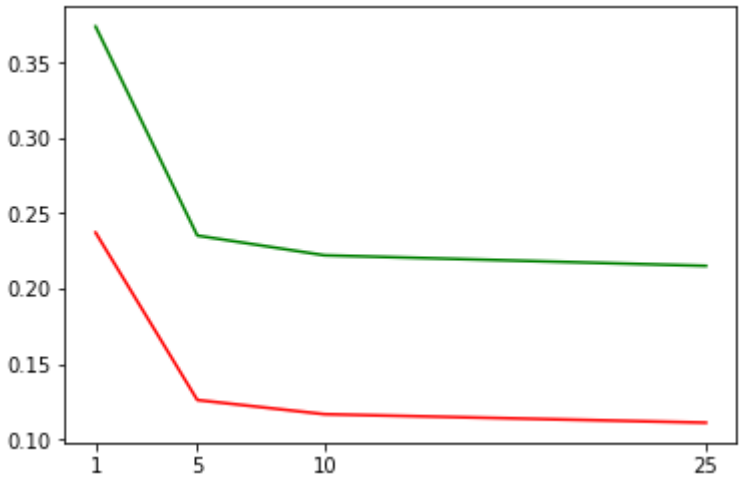
3a

In [9]:

```
ensemble=[0]*25
Ytrhat=np.zeros((np.size(Ytr),25))
Ytehat=np.zeros((np.size(Yte),25))
for i in range(25):
    Xb,Yb=ml.bootstrapData(Xtr,Ytr)
    ensemble[i]=ml.dtree.treeClassify(Xb,Yb,maxDepth=15,minLeaf=4,nFeatu
    Ytrhat[:,i]=ensemble[i].predict(Xtr)
    Ytehat[:,i]=ensemble[i].predict(Xte)

#mseTR and mseTE for learners [1,5,10,25]
mseTR=[]
mseTE=[]
for index,value in enumerate([1,5,10,25]):
    mseTR.append(np.mean((Ytr-np.mean(Ytrhat[:,0:value],1))**2))
    mseTE.append(np.mean((Yte-np.mean(Ytehat[:,0:value],1))**2))
    print(str(value)+" Ensemble members: mseTR= "+str(mseTR[index])+" ,
_,axis=plt.subplots()
axis.plot([1,5,10,25],mseTR,c='red')
axis.plot([1,5,10,25],mseTE,c='green')
axis.set_xticks([1,5,10,25])
plt.show()
```

```
1 Ensemble members: mseTR= 0.2372 , mseTE= 0.3739
5 Ensemble members: mseTR= 0.126092 , mseTE= 0.23521600000000004
10 Ensemble members: mseTR= 0.11668600000000001 , mseTE= 0.22211999999999
998
25 Ensemble members: mseTR= 0.11106112 , mseTE= 0.21510464
```



3 b

In [10]:

```
#Uploading results on Kaggle
ensemble2=[0]*25
Xte=np.genfromtxt("X_test.txt",delimiter=None)
Ypred2=np.zeros((np.size(Xte,0),1))
for i in range(25):
    Xb,Yb=ml.bootstrapData(Xtr,Ytr)
    ensemble2[i]=ml.dtree.treeClassify(Xb,Yb,maxDepth=8,minLeaf=256,nFea
    Ypred2=Ypred2+ensemble[i].predictSoft(Xte)
Ypred2=Ypred2/25
print("AUC after 25 learners: "+str(ensemble2[24].auc(Xb,Yb)))
np.savetxt('Gupta_6943.txt',
np.vstack( (np.arange(len(Ypred2)) , Ypred2[:,1]) ).T,
'%d, %.2f',header='ID,Prob1',comments='',delimiter=',');


```

```
AUC after 25 learners: 0.6948394504598249
```