Decision trees -- CART

Kulikov Alex, gr. 397

In [1]:
```
import numpy
import pandas
import scipy
import sklearn
import pprint
import seaborn

%pylab inline
%load_ext autoreload
%autoreload 2

pandas.options.display.max_colwidth = 0

pp = pprint.PrettyPrinter(indent=4)

from IPython.core.display import HTML
HTML("<style>.container { width:90% !important; }</style>")
```

```
Populating the interactive namespace from numpy and matplotlib
```

Out[1]:

Time to look at the data

In [2]:
```
df = pandas.read_csv("kaggle_data/adult.data")
```

In [3]:
```
df.head()
```

Out[3]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country	label
0	39	State-gov	77516	Bachelors	13	Never-married	Adm-clerical	Not-in-family	White	Male	2174	0	40	United-States	0
1	50	Self-emp-not-inc	83311	Bachelors	13	Married-civ-spouse	Exec-managerial	Husband	White	Male	0	0	13	United-States	0
2	38	Private	215646	HS-grad	9	Divorced	Handlers-cleaners	Not-in-family	White	Male	0	0	40	United-States	0
3	53	Private	234721	11th	7	Married-civ-spouse	Handlers-cleaners	Husband	Black	Male	0	0	40	United-States	0
4	28	Private	338409	Bachelors	13	Married-civ-spouse	Prof-specialty	Wife	Black	Female	0	0	40	Cuba	0

In [4]:
```
print "Head:"
print df.head()
print "Shape:"
print shape(df)
```

```
Head:
   age          workclass  fnlwgt   education  education-num  \
0  39    State-gov         77516    Bachelors  13
1  50    Self-emp-not-inc  83311    Bachelors  13
2  38    Private           215646   HS-grad    9
3  53    Private           234721   11th       7
4  28    Private           338409   Bachelors  13

        marital-status          occupation    relationship    race      sex  \
0   Never-married        Adm-clerical        Not-in-family   White   Male
1   Married-civ-spouse   Exec-managerial     Husband         White   Male
2   Divorced             Handlers-cleaners   Not-in-family   White   Male
3   Married-civ-spouse   Handlers-cleaners   Husband         Black   Male
4   Married-civ-spouse   Prof-specialty      Wife            Black   Female

   capital-gain  capital-loss  hours-per-week  native-country  label
0  2174          0             40               United-States  0
1  0             0             13               United-States  0
2  0             0             40               United-States  0
3  0             0             40               United-States  0
4  0             0             40               Cuba           0
Shape:
(32561, 15)
```

In [5]:
```
df.groupby("label").count()
```

Out[5]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country
label														
0	24720	24720	24720	24720	24720	24720	24720	24720	24720	24720	24720	24720	24720	24720
1	7841	7841	7841	7841	7841	7841	7841	7841	7841	7841	7841	7841	7841	7841

In [6]:
```
for column in df.columns:
    print(column + str(shape(df.groupby(column))))
```

```
age(73, 2)
workclass(9, 2)
fnlwgt(21648, 2)
education(16, 2)
education-num(16, 2)
marital-status(7, 2)
occupation(15, 2)
relationship(6, 2)
race(5, 2)
sex(2, 2)
capital-gain(119, 2)
capital-loss(92, 2)
hours-per-week(94, 2)
native-country(42, 2)
label(2, 2)
```

In [7]:
```
df.groupby("native-country").count()
```

Out[7]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	label
native-country														
?	583	583	583	583	583	583	583	583	583	583	583	583	583	583
Cambodia	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Canada	121	121	121	121	121	121	121	121	121	121	121	121	121	121
China	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Columbia	59	59	59	59	59	59	59	59	59	59	59	59	59	59
Cuba	95	95	95	95	95	95	95	95	95	95	95	95	95	95
Dominican-Republic	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Ecuador	28	28	28	28	28	28	28	28	28	28	28	28	28	28
El-Salvador	106	106	106	106	106	106	106	106	106	106	106	106	106	106
England	90	90	90	90	90	90	90	90	90	90	90	90	90	90
France	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Germany	137	137	137	137	137	137	137	137	137	137	137	137	137	137
Greece	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Guatemala	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Haiti	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Holand-Netherlands	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Honduras	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Hong	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Hungary	13	13	13	13	13	13	13	13	13	13	13	13	13	13
India	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Iran	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Ireland	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Italy	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Jamaica	81	81	81	81	81	81	81	81	81	81	81	81	81	81
Japan	62	62	62	62	62	62	62	62	62	62	62	62	62	62

Laos	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Mexico	643	643	643	643	643	643	643	643	643	643	643	643	643	643
Nicaragua	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Outlying-US(Guam-USVI-etc)	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Peru	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Philippines	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Poland	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Portugal	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Puerto-Rico	114	114	114	114	114	114	114	114	114	114	114	114	114	114
Scotland	12	12	12	12	12	12	12	12	12	12	12	12	12	12
South	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Taiwan	51	51	51	51	51	51	51	51	51	51	51	51	51	51
Thailand	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Trinadad&Tobago	19	19	19	19	19	19	19	19	19	19	19	19	19	19
United-States	29170	29170	29170	29170	29170	29170	29170	29170	29170	29170	29170	29170	29170	29170
Vietnam	67	67	67	67	67	67	67	67	67	67	67	67	67	67
Yugoslavia	16	16	16	16	16	16	16	16	16	16	16	16	16	16

In [8]:
```
df.groupby("workclass").count()
```

Out[8]:

	age	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country	label
workclass														
?	1836	1836	1836	1836	1836	1836	1836	1836	1836	1836	1836	1836	1836	1836
Federal-gov	960	960	960	960	960	960	960	960	960	960	960	960	960	960
Local-gov	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093
Never-worked	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Private	22696	22696	22696	22696	22696	22696	22696	22696	22696	22696	22696	22696	22696	22696
Self-emp-inc	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116
Self-emp-not-inc	2541	2541	2541	2541	2541	2541	2541	2541	2541	2541	2541	2541	2541	2541
State-gov	1298	1298	1298	1298	1298	1298	1298	1298	1298	1298	1298	1298	1298	1298
Without-pay	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Let's encode'em

In [9]:
```
from sklearn import preprocessing

def number_encode_features(df):
    result = df.copy()
    encoders = {}
    for column in result.columns:
        if result.dtypes[column] == np.object:
            encoders[column] = preprocessing.LabelEncoder()
            result[column] = encoders[column].fit_transform(result[column])
    return result, encoders

encoded_data, encoders = number_encode_features(df)
encoded_data.head()
```

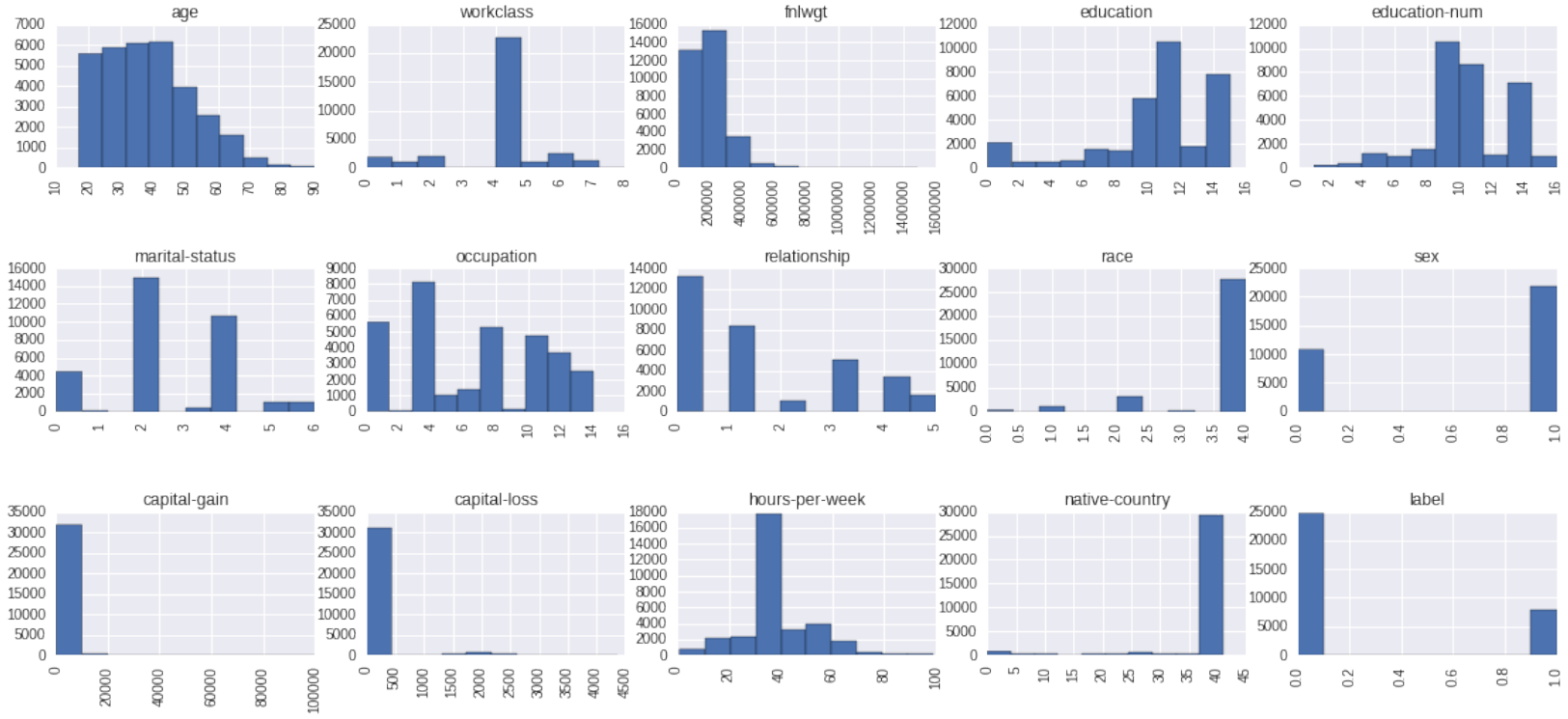
Out[9]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country	label
0	39	7	77516	9	13	4	1	1	4	1	2174	0	40	39	0
1	50	6	83311	9	13	2	4	0	4	1	0	0	13	39	0
2	38	4	215646	11	9	0	6	1	4	1	0	0	40	39	0
3	53	4	234721	1	7	2	6	0	2	1	0	0	40	39	0
4	28	4	338409	9	13	2	10	5	2	0	0	0	40	5	0

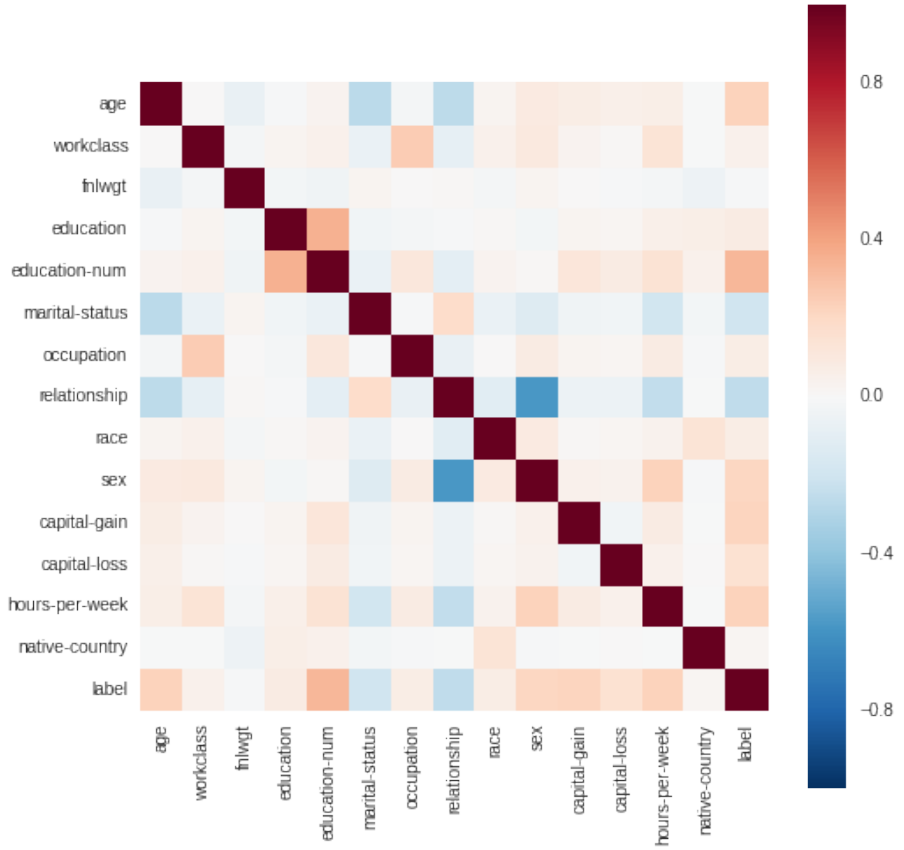
In [10]:
```
pp.pprint(encoders)
```

```
{   'education': LabelEncoder(),
    'marital-status': LabelEncoder(),
    'native-country': LabelEncoder(),
    'occupation': LabelEncoder(),
    'race': LabelEncoder(),
    'relationship': LabelEncoder(),
    'sex': LabelEncoder(),
    'workclass': LabelEncoder()}
```

In [11]:
```
fig = plt.figure(figsize=(19,8))
cols = 5
rows = ceil(float(encoded_data.shape[1]) / cols)
for i, column in enumerate(encoded_data.columns):
    ax = fig.add_subplot(rows, cols, i + 1)
    ax.set_title(column)
    encoded_data[column].hist(axes=ax)
    plt.xticks(rotation="vertical")
plt.subplots_adjust(hspace=0.7, wspace=0.2)
```



In [12]:
```
plt.subplots(figsize=(8,8))
encoded_data, encoders = number_encode_features(df)
seaborn.heatmap(encoded_data.corr(), square=True)
plt.show()
```



In [13]:
```
X_train, y_train = encoded_data[encoded_data.columns[:-1]].values, encoded_data[encoded_data.columns[-1]].values
```

Let's look at the sklearn tree classifier

In [14]:
```
from sklearn import tree

clf = tree.DecisionTreeClassifier(criterion="gini",max_depth=3)
%time clf = clf.fit(X_train[:1000], y_train[:1000])
# %time clf = clf.fit(X_train, y_train)
tree.export_graphviz(clf,out_file="treeSklearn.dot")
```

```
CPU times: user 3.33 ms, sys: 0 ns, total: 3.33 ms
Wall time: 4.89 ms
```

In [15]:
```
from graphviz import Source

dot_source = open("treeSklearn.dot").read()

dot = Source(dot_source)

dot
```

Out[15]: X[7] <= 0.5 gini = 0.3564 samples = 1000 value = [768, 232] X[4] <= 10.5 gini = 0.4943 samples = 376 value = [208, 168] True X[10] <= 7073.5 gini = 0.1841 samples = 624 value = [560, 64] False X[10] <= 5095.5 gini = 0.4186 samples = 238 value = [167, 71] X[2] <= 62410.0 gini = 0.4177 samples = 138 value = [41, 97] gini = 0.3919 samples = 228 value = [167, 61] gini = 0.0 samples = 10 value = [0, 10] gini = 0.32 samples = 10 value = [8, 2] gini = 0.3827 samples = 128 value = [33, 95] X[7] <= 4.5 gini = 0.1631 samples = 614 value = [559, 55] X[1] <= 0.5 gini = 0.18 samples = 10 value = [1, 9] gini = 0.1087 samples = 555 value = [523, 32] gini = 0.4757 samples = 59 value = [36, 23] gini = 0.0 samples = 1 value = [1, 0] gini = 0.0 samples = 9 value = [0, 9]

Decision tree (CART)

You could use this doc to implement (and hopefully understand) CART:
ftp://public.dhe.ibm.com/software/analytics/spss/support/Stats/Docs/Statistics/Algorithms/13.0/TREE-CART.pdf

Gini

In [16]:
```
import CART

ORDINAL_COLUMNS = {3 : "education"}

CONTINUOUS_COLUMNS = {
    0 : "age",
    2 : "fnlwgt",
    4 : "education-num",
    10 : "capital-gain",
    11 : "capital-loss",
    12 : "hours/week"}

CATEGORICAL_COLUMNS = {
    1 : "workclass",
    5 : "marriage",
    7 : "relationship",
    8 : "race",
    9 : "sex"}

CATEGORICAL_COLUMNS_SLOW = {
    6 : "occupation",
    13 : "country"}

cart = CART.CART(1, 3, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS_SLOW)
%time cart = cart.fit(X_train[:1000], y_train[:1000])
```

```
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
7 not split because of max depth
8 not split because of max depth
9 not split because of max depth
10 not split because of max depth
11 not split because of max depth
12 not split because of max depth
13 not split because of max depth
14 not split because of max depth
CPU times: user 13.3 s, sys: 16.7 ms, total: 13.3 s
Wall time: 13.3 s
```

In [17]:
```
from graphviz import Source

cart.dot_print_tree("CARTgini3.dot")

dot_source = open("CARTgini3.dot").read()

dot = Source(dot_source)

dot
```

Out[17]: ID = 0 X[5 (marriage)] : (2,) gini = 0.356 samples = 1000 ID = 1 X[4 (education-num)] : 10 gini = 0.493 samples = 443 ID = 2 X[10 (capital-gain)] : 6849 gini = 0.124 samples = 557 ID = 3 X[10 (capital-gain)] : 5013 gini = 0.419 samples = 281 ID = 4 X[10 (capital-gain)] : 5013 gini = 0.431 samples = 162 ID = 5 X[4 (education-num)] : 12 gini = 0.106 samples = 550 ID = 6 X[0 (age)] : 17 gini = 0.245 samples = 7 ID = 7 samples = 269 ID = 8 samples = 12 ID = 9 samples = 140 ID = 10 samples = 22 ID = 11 samples = 440 ID = 12 samples = 110 ID = 13 samples = 1 ID = 14 samples = 6

In [18]:
```
bad = 0
window = 200

for node_index in range(1000, 1000 + window):
    y_pred, node_pred = cart.predict(numpy.array([X_train[node_index]]))

    if y_train[node_index] != y_pred:
        bad += 1

print("Misclassified " + str(bad) + " out of " + str(window) + ", that gives us about " + str(float((window - bad))/
window * 100) + "% of success")
```

```
Misclassified 40 out of 200, that gives us about 80.0% of success
```

Twoing

In [19]:
```
import CART

ORDINAL_COLUMNS = {3 : "education"}

CONTINUOUS_COLUMNS = {
    0 : "age",
    2 : "fnlwgt",
    4 : "education-num",
    10 : "capital-gain",
    11 : "capital-loss",
    12 : "hours/week"}

CATEGORICAL_COLUMNS = {
    1 : "workclass",
    5 : "marriage",
    7 : "relationship",
    8 : "race",
    9 : "sex"}

CATEGORICAL_COLUMNS_SLOW = {
    6 : "occupation",
    13 : "country"}

cart = CART.CART(1, 3, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS_SLOW, criterion
="twoing")
%time cart = cart.fit(X_train[:1000], y_train[:1000])
```

```
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
7 not split because of max depth
8 not split because of max depth
9 not split because of max depth
10 not split because of max depth
11 not split because of max depth
12 not split because of max depth
13 not split because of max depth
14 not split because of max depth
CPU times: user 9.76 s, sys: 20 ms, total: 9.78 s
Wall time: 9.75 s
```

In [20]:
```
from graphviz import Source

cart.dot_print_tree("CARTtwoing3.dot")

dot_source = open("CARTtwoing3.dot").read()

dot = Source(dot_source)

dot
```

Out[20]: ID = 0 X[2 (fnlwgt)] : 90758 gini = 0.000 samples = 1000 ID = 1 X[2 (fnlwgt)] : 31757 gini = 0.000 samples = 146 ID = 2 X[2 (fnlwgt)] : 304873 gini = 0.000 samples = 854 ID = 3 X[5 (marriage)] : (2,) gini = 0.000 samples = 21 ID = 4 X[0 (age)] : 57 gini = 0.000 samples = 125 ID = 5 X[2 (fnlwgt)] : 254440 gini = 0.000 samples = 729 ID = 6 X[7 (relationship)] : (0,) gini = 0.000 samples = 125 ID = 7 samples = 10 ID = 8 samples = 11 ID = 9 samples = 107 ID = 10 samples = 18 ID = 11 samples = 622 ID = 12 samples = 107 ID = 13 samples = 33 ID = 14 samples = 92

In [21]:
```
bad = 0
window = 200

for node_index in range(1000, 1000 + window):
    y_pred, node_pred = cart.predict(numpy.array([X_train[node_index]]))

    if y_train[node_index] != y_pred:
        bad += 1

print("Misclassified " + str(bad) + " out of " + str(window) + ", that gives us about " + str(float((window - bad))/
window * 100) + "% of success")
```

```
Misclassified 54 out of 200, that gives us about 73.0% of success
```

Ordered Twoing

In [35]:
```
import CART

ORDINAL_COLUMNS = {3 : "education"}

CONTINUOUS_COLUMNS = {
    0 : "age",
    2 : "fnlwgt",
    4 : "education-num",
    10 : "capital-gain",
    11 : "capital-loss",
    12 : "hours/week"}

CATEGORICAL_COLUMNS = {
    1 : "workclass",
    5 : "marriage",
    7 : "relationship",
    8 : "race",
    9 : "sex"}

CATEGORICAL_COLUMNS_SLOW = {
    6 : "occupation",
    13 : "country"}

cart = CART.CART(1, 3, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS_SLOW, criterion
="ordered_twoing")
%time cart = cart.fit(X_train[:1000], y_train[:1000])
```

```
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
7 not split because of max depth
8 not split because of max depth
9 not split because of max depth
10 not split because of max depth
11 not split because of max depth
12 not split because of max depth
13 not split because of max depth
14 not split because of max depth
CPU times: user 7.77 s, sys: 46.7 ms, total: 7.81 s
Wall time: 7.71 s
```

In [36]:
```
from graphviz import Source

cart.dot_print_tree("CARTorderedtwoing3.dot")

dot_source = open("CARTorderedtwoing3.dot").read()

dot = Source(dot_source)

dot
```

Out[36]: ID = 0 X[4 (education-num)] : 12 gini = 0.000 samples = 1000 ID = 1 X[12 (hours/week)] : 46 gini = 0.000 samples = 756 ID = 2 X[10 (capital-gain)] : 2407 gini = 0.000 samples = 244 ID = 3 X[1 (workclass)] : (0, 4, 7) gini = 0.000 samples = 640 ID = 4 X[1 (workclass)] : (0, 5, 7) gini = 0.000 samples = 116 ID = 5 X[0 (age)] : 47 gini = 0.000 samples = 214 ID = 6 X[10 (capital-gain)] : 7688 gini = 0.000 samples = 30 ID = 7 samples = 539 ID = 8 samples = 101 ID = 9 samples = 15 ID = 10 samples = 101 ID = 11 samples = 170 ID = 12 samples = 44 ID = 13 samples = 15 ID = 14 samples = 15

In [37]:
```
bad = 0
window = 200

for node_index in range(1000, 1000 + window):
    y_pred, node_pred = cart.predict(numpy.array([X_train[node_index]]))

    if y_train[node_index] != y_pred:
        bad += 1

print("Misclassified " + str(bad) + " out of " + str(window) + ", that gives us about " + str(float((window - bad))/
window * 100) + "% of success")
```

```
Misclassified 47 out of 200, that gives us about 76.5% of success
```

Not very useful criterion here, cause we have only 2 classes

Optional part: Pruning

More information you could get here: http://www.dcc.fc.up.pt/~ltorgo/PhD/th4.pdf

In [22]:
```
import CART

ORDINAL_COLUMNS = {3 : "education"}

CONTINUOUS_COLUMNS = {
    0 : "age",
    2 : "fnlwgt",
    4 : "education-num",
    10 : "capital-gain",
    11 : "capital-loss",
    12 : "hours/week"}

CATEGORICAL_COLUMNS = {
    1 : "workclass",
    5 : "marriage",
    7 : "relationship",
    8 : "race",
    9 : "sex"}

CATEGORICAL_COLUMNS_SLOW = {
    6 : "occupation",
    13 : "country"}

cart = CART.CART(1, 5, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS_SLOW)
%time cart = cart.fit(X_train[:1000], y_train[:1000])
```

```
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
8 not split because of 1 class
Current node: 9
10 not split because of 1 class
Current node: 11
Current node: 12
13 not split because of 1 class
14 not split because of 1 class
Current node: 15
Current node: 16
Current node: 19
20 not split because of 1 class
Current node: 23
Current node: 24
Current node: 25
Current node: 26
31 not split because of max depth
32 not split because of max depth
33 not split because of max depth
34 not split because of max depth
39 not split because of max depth
40 not split because of max depth
47 not split because of max depth
48 not split because of max depth
49 not split because of max depth
50 not split because of max depth
51 not split because of max depth
52 not split because of max depth
53 not split because of max depth
54 not split because of max depth
CPU times: user 17 s, sys: 26.7 ms, total: 17 s
Wall time: 17 s
```

In [23]:
```
from graphviz import Source

cart.dot_print_tree("CARTgini5NOprune.dot")

dot_source = open("CARTgini5NOprune.dot").read()

dot = Source(dot_source)

dot
```

Out[23]: ID = 0 X[5 (marriage)] : (2,) gini = 0.356 samples = 1000 ID = 1 X[4 (education-num)] : 10 gini = 0.493 samples = 443 ID = 2 X[10 (capital-gain)] : 6849 gini = 0.124 samples = 557 ID = 3 X[10 (capital-gain)] : 5013 gini = 0.419 samples = 281 ID = 4 X[10 (capital-gain)] : 5013 gini = 0.431 samples = 162 ID = 5 X[4 (education-num)] : 12 gini = 0.106 samples = 550 ID = 6 X[0 (age)] : 17 gini = 0.245 samples = 7 ID = 7 X[1 (workclass)] : (1, 5) gini = 0.392 samples = 269 ID = 8 samples = 12 ID = 9 X[4 (education-num)] : 14 gini = 0.463 samples = 140 ID = 10 samples = 22 ID = 11 X[0 (age)] : 43 gini = 0.040 samples = 440 ID = 12 X[0 (age)] : 34 gini = 0.320 samples = 110 ID = 13 samples = 1 ID = 14 samples = 6 ID = 15 X[0 (age)] : 33 gini = 0.444 samples = 21 ID = 16 X[0 (age)] : 32 gini = 0.358 samples = 248 ID = 19 X[0 (age)] : 28 gini = 0.482 samples = 126 ID = 20 samples = 14 ID = 23 X[1 (workclass)] : (1,) gini = 0.012 samples = 337 ID = 24 X[12 (hours/week)] : 40 gini = 0.127 samples = 103 ID = 25 X[3 (education)] : 12 gini = 0.073 samples = 53 ID = 26 X[12 (hours/week)] : 42 gini = 0.456 samples = 57 ID = 31 samples = 3 ID = 32 samples = 18 ID = 33 samples = 54 ID = 34 samples = 194 ID = 39 samples = 10 ID = 40 samples = 116 ID = 47 samples = 5 ID = 48 samples = 332 ID = 49 samples = 85 ID = 50 samples = 18 ID = 51 samples = 52 ID = 52 samples = 1 ID = 53 samples = 30 ID = 54 samples = 27

In [24]:
```
cart.prune(1, 0.2)
```

In [25]:
```
from graphviz import Source

cart.dot_print_tree("CARTgini5prune.dot")

dot_source = open("CARTgini5prune.dot").read()

dot = Source(dot_source)

dot
```

Out[25]: ID = 0 X[5 (marriage)] : (2,) gini = 0.356 samples = 1000 ID = 1 X[4 (education-num)] : 10 gini = 0.493 samples = 443 ID = 2 X[10 (capital-gain)] : 6849 gini = 0.124 samples = 557 ID = 3 X[10 (capital-gain)] : 5013 gini = 0.419 samples = 281 ID = 4 samples = 162 ID = 5 X[4 (education-num)] : 12 gini = 0.106 samples = 550 ID = 6 X[0 (age)] : 17 gini = 0.245 samples = 7 ID = 7 samples = 269 ID = 8 samples = 12 ID = 11 X[0 (age)] : 43 gini = 0.040 samples = 440 ID = 12 X[0 (age)] : 34 gini = 0.320 samples = 110 ID = 13 samples = 1 ID = 14 samples = 6 ID = 23 X[1 (workclass)] : (1,) gini = 0.012 samples = 337 ID = 24 X[12 (hours/week)] : 40 gini = 0.127 samples = 103 ID = 25 samples = 53 ID = 26 X[12 (hours/week)] : 42 gini = 0.456 samples = 57 ID = 47 samples = 5 ID = 48 samples = 332 ID = 49 samples = 85 ID = 50 samples = 18 ID = 53 samples = 30 ID = 54 samples = 27

Pruned!

Tree comparison visualisation

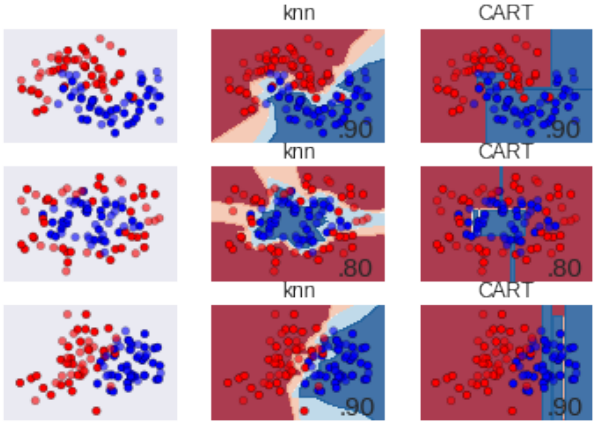
In [50]:
```
# 1) Сгенерируйте 3 двумерных двухклассовых выборки
# 2) Обучите на нах классификаторы: Ваше деврево, kNN
# 3) С постоянным шагом по каждой координате проведите классфикацию точек плоскости
# 4) Какой классфикатор работает лучше, в чем преимущества и недостатки Решаюших деревьев и KNN для этих выборок?

from sklearn.datasets import make_moons, make_circles, make_classification
from sklearn.neighbors import KNeighborsClassifier
import CART

from matplotlib.colors import ListedColormap
from sklearn.cross_validation import train_test_split
from sklearn.preprocessing import StandardScaler

X, y = make_classification(n_features=2, n_redundant=0, n_informative=2,
                           random_state=1, n_clusters_per_class=1)
rng = np.random.RandomState(2)
X += 2 * rng.uniform(size=X.shape)
linearly_separable = (X, y)

datasets = [make_moons(noise=0.3, random_state=0),
            make_circles(noise=0.2, factor=0.5, random_state=1),
            linearly_separable]

names = ["MyCART", "knn"]
knn = KNeighborsClassifier(3)

step = 0.01
i = 1

for ds in datasets:
    X, y = ds
    X = StandardScaler().fit_transform(X)
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=.4)

    x_min, x_max = X[:, 0].min() - .5, X[:, 0].max() + .5
    y_min, y_max = X[:, 1].min() - .5, X[:, 1].max() + .5
    xx, yy = np.meshgrid(np.arange(x_min, x_max, step),
                         np.arange(y_min, y_max, step))

    # just plot the dataset first
    cm = plt.cm.RdBu
    cm_bright = ListedColormap(['#FF0000', '#0000FF'])
    ax = plt.subplot(len(datasets), 3, i)
    # Plot the training points
    ax.scatter(X_train[:, 0], X_train[:, 1], c=y_train, cmap=cm_bright)
    # and testing points
    ax.scatter(X_test[:, 0], X_test[:, 1], c=y_test, cmap=cm_bright, alpha=0.6)
    ax.set_xlim(xx.min(), xx.max())
    ax.set_ylim(yy.min(), yy.max())
    ax.set_xticks(())
```

```
    ax.set_yticks(())
    i += 1

    ax = plt.subplot(len(datasets), 3, i)
    knn.fit(X_train, y_train)
    score = knn.score(X_test, y_test)

    # Plot the decision boundary. For that, we will assign a color to each
    # point in the mesh [x_min, m_max]x[y_min, y_max].
    if hasattr(knn, "decision_function"):
        Z = knn.decision_function(np.c_[xx.ravel(), yy.ravel()])
    else:
        Z = knn.predict_proba(np.c_[xx.ravel(), yy.ravel()])[:, 1]

    # Put the result into a color plot
    Z = Z.reshape(xx.shape)

    ax.contourf(xx, yy, Z, cmap=cm, alpha=.8)

    # Plot also the training points
    ax.scatter(X_train[:, 0], X_train[:, 1], c=y_train, cmap=cm_bright)
    # and testing points
    ax.scatter(X_test[:, 0], X_test[:, 1], c=y_test, cmap=cm_bright,
               alpha=0.6)

    ax.set_xlim(xx.min(), xx.max())
    ax.set_ylim(yy.min(), yy.max())
    ax.set_xticks(())
    ax.set_yticks(())
    ax.set_title("knn")
    ax.text(xx.max() - .3, yy.min() + .3, ('%.2f' % score).lstrip('0'),
            size=15, horizontalalignment='right')
    i += 1


    ax = plt.subplot(len(datasets), 3, i)


    ORDINAL_COLUMNS = {}

    CONTINUOUS_COLUMNS = {
        0 : "x",
        1 : "y"}

    CATEGORICAL_COLUMNS = {}

    CATEGORICAL_COLUMNS_SLOW = {}

    cart_datasets = CART.CART(1, 5, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS_SL
OW, criterion="gini")
```

```
%time cart_datasets = cart_datasets.fit(ds[0], ds[1])

min_x = min(ds[0][0])
max_x = max(ds[0][0])
min_y = min(ds[0][1])
max_y = max(ds[0][1])

plane = numpy.zeros((xx.shape))

x_index = 0
y_index = 0

plane, tmp = cart_datasets.predict(np.c_[xx.ravel(), yy.ravel()])

plane = plane.reshape(xx.shape)


# Put the result into a color plot
ax.contourf(xx, yy, plane, cmap=cm, alpha = .8)

# Plot also the training points
ax.scatter(X_train[:, 0], X_train[:, 1], c=y_train, cmap=cm_bright)
# and testing points
ax.scatter(X_test[:, 0], X_test[:, 1], c=y_test, cmap=cm_bright,
           alpha=0.6)

ax.set_xlim(xx.min(), xx.max())
ax.set_ylim(yy.min(), yy.max())
ax.set_xticks(())
ax.set_yticks(())
ax.set_title("CART")
ax.text(xx.max() - .3, yy.min() + .3, ('%.2f' % score).lstrip('0'),
        size=15, horizontalalignment='right')
i += 1
```

```
Current node: 0
Current node: 1
Current node: 2
3 not split because of 1 class
Current node: 4
Current node: 5
6 not split because of 1 class
9 not split because of 1 class
Current node: 10
Current node: 11
12 not split because of 1 class
21 not split because of 1 class
Current node: 22
Current node: 23
24 not split because of 1 class
45 not split because of max depth
46 not split because of max depth
47 not split because of max depth
48 not split because of max depth
CPU times: user 53.3 ms, sys: 0 ns, total: 53.3 ms
Wall time: 54.1 ms
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
6 not split because of 1 class
7 not split because of 1 class
Current node: 8
Current node: 9
Current node: 10
11 not split because of 1 class
12 not split because of 1 class
17 not split because of 1 class
18 not split because of 1 class
19 not split because of 1 class
Current node: 20
Current node: 21
Current node: 22
41 not split because of max depth
42 not split because of max depth
43 not split because of max depth
44 not split because of max depth
45 not split because of max depth
46 not split because of max depth
CPU times: user 76.7 ms, sys: 0 ns, total: 76.7 ms
Wall time: 76.8 ms
Current node: 0
Current node: 1
```

```
Current node: 2
3 not split because of 1 class
Current node: 4
Current node: 5
6 not split because of 1 class
Current node: 9
10 not split because of 1 class
Current node: 11
12 not split because of 1 class
Current node: 19
20 not split because of 1 class
Current node: 23
24 not split because of 1 class
39 not split because of max depth
40 not split because of max depth
47 not split because of max depth
48 not split because of max depth
CPU times: user 36.7 ms, sys: 0 ns, total: 36.7 ms
Wall time: 36.2 ms
```



Overall result is quite good

Even the moons were divided properly

Still, scikit-knn is better

Как ни странно, для 3 датасета дерево оказалось так себе. Видимо, это из-за диагональности границы между классами.

Для лун у CART не хватает глубины 3, чтобы корректно распознать внутренность луны

Tree bagging

The training algorithm for random forests applies the general technique of bootstrap aggregating, or bagging, to tree learners. Given a training set $X = x_1, \ldots, x_n$ with responses $Y = y_1, \ldots, y_n$, bagging repeatedly (B times) selects a random sample with replacement of the training set and fits trees to these samples. After training, predictions for unseen samples x' can be made by averaging the predictions from all the individual regression trees on x':

$$\hat{f} = \frac{1}{B}\sum_{b=1}^{B}\hat{f}_b(x')$$

or by taking the majority vote in the case of decision trees.

This bootstrapping procedure leads to better model performance because it decreases the variance of the model, without increasing the bias. This means that while the predictions of a single tree are highly sensitive to noise in its training set, the average of many trees is not, as long as the trees are not correlated. Simply training many trees on a single training set would give strongly correlated trees (or even the same tree many times, if the training algorithm is deterministic); bootstrap sampling is a way of de-correlating the trees by showing them different training sets.

In [38]:
```
def shuffle_in_unison_inplace(a, b):
    assert len(a) == len(b)
    p = numpy.random.permutation(len(a))
    return a[p], b[p]
```

In [39]:
```
def bagging(X, y, size):
    X, y = shuffle_in_unison_inplace(X, y)
    sample_X, sample_y = X[:size], y[:size]
    return sample_X, sample_y
```

In [114]:
```
import CART

ORDINAL_COLUMNS = {3 : "education"}

CONTINUOUS_COLUMNS = {
    0 : "age",
    2 : "fnlwgt",
    4 : "education-num",
    10 : "capital-gain",
    11 : "capital-loss",
    12 : "hours/week"}

CATEGORICAL_COLUMNS = {
    1 : "workclass",
    5 : "marriage",
    7 : "relationship",
    8 : "race",
    9 : "sex"}

CATEGORICAL_COLUMNS_SLOW = {
    6 : "occupation",
    13 : "country"}

class Forest(sklearn.base.BaseEstimator, sklearn.base.ClassifierMixin):
    def __init__(self, num_trees):
        self.num_trees = num_trees
        self.trees = []

    def fit(self, X_train, y_train):
        '''
        Create trees here, using bagging.
        '''

        for index in range(self.num_trees):
            one_tree = CART.CART(1, 7, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS
_SLOW)
            X_train_sample, y_train_sample = bagging(X_train, y_train, 1000)
            %time one_tree = one_tree.fit(X_train_sample, y_train_sample)
            self.trees.append(one_tree)

        return self

    def predict(self, X_test):
        '''
        Predict the label here using your grown trees.
        '''

        y_pred = numpy.zeros(X_test.shape[0])

        for index in range(self.num_trees):
```

```
#             print(X_test.shape)
            one_y_pred, one_node_pred = self.trees[index].predict(numpy.array(X_test))
#             print(one_y_pred.shape)
#             print(one_y_pred)
            y_pred += one_y_pred

        for result in range(y_pred.__len__()):
            y_pred[result] = (float(y_pred[result]/self.num_trees))

        return y_pred
```

In [100]:
```
forest = Forest(10)
forest = forest.fit(X_train, y_train)
```

```
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
6 not split because of 1 class
Current node: 7
8 not split because of 1 class
Current node: 9
Current node: 10
Current node: 11
Current node: 12
Current node: 15
Current node: 16
19 not split because of 1 class
Current node: 20
Current node: 21
Current node: 22
Current node: 23
Current node: 24
25 not split because of 1 class
26 not split because of 1 class
Current node: 31
32 not split because of 1 class
Current node: 33
Current node: 34
Current node: 41
Current node: 42
Current node: 43
44 not split because of 1 class
Current node: 45
46 not split because of 1 class
Current node: 47
Current node: 48
Current node: 49
Current node: 50
63 not split because of 1 class
Current node: 64
Current node: 67
Current node: 68
69 not split because of 1 class
Current node: 70
Current node: 83
Current node: 84
Current node: 85
86 not split because of 1 class
87 not split because of 1 class
88 not split because of 1 class
91 not split because of 1 class
```

```
Current node: 92
Current node: 95
Current node: 96
97 not split because of 1 class
98 not split because of 1 class
99 not split because of 1 class
Current node: 100
Current node: 101
102 not split because of 1 class
129 not split because of max depth
130 not split because of max depth
135 not split because of max depth
136 not split because of max depth
137 not split because of max depth
138 not split because of max depth
141 not split because of max depth
142 not split because of max depth
167 not split because of max depth
168 not split because of max depth
169 not split because of max depth
170 not split because of max depth
171 not split because of max depth
172 not split because of max depth
185 not split because of max depth
186 not split because of max depth
191 not split because of max depth
192 not split because of max depth
193 not split because of max depth
194 not split because of max depth
201 not split because of max depth
202 not split because of max depth
203 not split because of max depth
204 not split because of max depth
CPU times: user 19.8 s, sys: 56.7 ms, total: 19.9 s
Wall time: 19.8 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
Current node: 8
9 not split because of 1 class
Current node: 10
Current node: 11
12 not split because of 1 class
Current node: 13
Current node: 14
```

```
Current node: 15
Current node: 16
Current node: 17
Current node: 18
Current node: 21
22 not split because of 1 class
Current node: 23
Current node: 24
27 not split because of 1 class
Current node: 28
Current node: 29
30 not split because of 1 class
Current node: 31
Current node: 32
33 not split because of 1 class
34 not split because of 1 class
35 not split because of 1 class
Current node: 36
Current node: 37
Current node: 38
43 not split because of 1 class
44 not split because of 1 class
Current node: 47
Current node: 48
Current node: 49
Current node: 50
57 not split because of 1 class
58 not split because of 1 class
Current node: 59
60 not split because of 1 class
63 not split because of 1 class
Current node: 64
Current node: 65
Current node: 66
Current node: 73
Current node: 74
Current node: 75
76 not split because of 1 class
Current node: 77
78 not split because of 1 class
95 not split because of 1 class
Current node: 96
Current node: 97
Current node: 98
Current node: 99
Current node: 100
Current node: 101
Current node: 102
Current node: 119
Current node: 120
```

```
129 not split because of max depth
130 not split because of max depth
131 not split because of max depth
132 not split because of max depth
133 not split because of max depth
134 not split because of max depth
147 not split because of max depth
148 not split because of max depth
149 not split because of max depth
150 not split because of max depth
151 not split because of max depth
152 not split because of max depth
155 not split because of max depth
156 not split because of max depth
193 not split because of max depth
194 not split because of max depth
195 not split because of max depth
196 not split because of max depth
197 not split because of max depth
198 not split because of max depth
199 not split because of max depth
200 not split because of max depth
201 not split because of max depth
202 not split because of max depth
203 not split because of max depth
204 not split because of max depth
205 not split because of max depth
206 not split because of max depth
239 not split because of max depth
240 not split because of max depth
241 not split because of max depth
242 not split because of max depth
CPU times: user 18.6 s, sys: 20 ms, total: 18.6 s
Wall time: 18.6 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
Current node: 8
Current node: 9
Current node: 10
Current node: 11
Current node: 12
13 not split because of 1 class
14 not split because of 1 class
Current node: 15
```

```
Current node: 16
17 not split because of 1 class
18 not split because of 1 class
Current node: 19
Current node: 20
Current node: 21
Current node: 22
Current node: 23
Current node: 24
Current node: 25
26 not split because of 1 class
Current node: 31
Current node: 32
Current node: 33
34 not split because of 1 class
Current node: 39
Current node: 40
41 not split because of 1 class
Current node: 42
43 not split because of 1 class
44 not split because of 1 class
Current node: 45
Current node: 46
Current node: 47
Current node: 48
Current node: 49
50 not split because of 1 class
Current node: 51
Current node: 52
Current node: 63
64 not split because of 1 class
Current node: 65
Current node: 66
Current node: 67
Current node: 68
Current node: 79
Current node: 80
81 not split because of 1 class
82 not split because of 1 class
Current node: 85
Current node: 86
Current node: 91
Current node: 92
93 not split because of 1 class
Current node: 94
95 not split because of 1 class
96 not split because of 1 class
Current node: 97
Current node: 98
99 not split because of 1 class
```

```
100 not split because of 1 class
103 not split because of 1 class
Current node: 104
Current node: 105
Current node: 106
127 not split because of max depth
128 not split because of max depth
131 not split because of max depth
132 not split because of max depth
133 not split because of max depth
134 not split because of max depth
135 not split because of max depth
136 not split because of max depth
137 not split because of max depth
138 not split because of max depth
159 not split because of max depth
160 not split because of max depth
161 not split because of max depth
162 not split because of max depth
171 not split because of max depth
172 not split because of max depth
173 not split because of max depth
174 not split because of max depth
183 not split because of max depth
184 not split because of max depth
185 not split because of max depth
186 not split because of max depth
189 not split because of max depth
190 not split because of max depth
195 not split because of max depth
196 not split because of max depth
197 not split because of max depth
198 not split because of max depth
209 not split because of max depth
210 not split because of max depth
211 not split because of max depth
212 not split because of max depth
213 not split because of max depth
214 not split because of max depth
CPU times: user 18.7 s, sys: 86.7 ms, total: 18.7 s
Wall time: 18.4 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
Current node: 8
```

```
Current node: 9
10 not split because of 1 class
Current node: 11
12 not split because of 1 class
Current node: 13
Current node: 14
15 not split because of 1 class
Current node: 16
Current node: 17
18 not split because of 1 class
19 not split because of 1 class
20 not split because of 1 class
Current node: 23
Current node: 24
27 not split because of 1 class
28 not split because of 1 class
Current node: 29
Current node: 30
Current node: 33
Current node: 34
35 not split because of 1 class
Current node: 36
Current node: 47
Current node: 48
Current node: 49
Current node: 50
Current node: 59
Current node: 60
61 not split because of 1 class
Current node: 62
Current node: 67
68 not split because of 1 class
Current node: 69
70 not split because of 1 class
Current node: 73
Current node: 74
95 not split because of 1 class
Current node: 96
97 not split because of 1 class
98 not split because of 1 class
Current node: 99
Current node: 100
Current node: 101
Current node: 102
Current node: 119
Current node: 120
121 not split because of 1 class
Current node: 122
Current node: 125
126 not split because of 1 class
```

```
135 not split because of max depth
136 not split because of max depth
139 not split because of max depth
140 not split because of max depth
147 not split because of max depth
148 not split because of max depth
149 not split because of max depth
150 not split because of max depth
193 not split because of max depth
194 not split because of max depth
199 not split because of max depth
200 not split because of max depth
201 not split because of max depth
202 not split because of max depth
203 not split because of max depth
204 not split because of max depth
205 not split because of max depth
206 not split because of max depth
239 not split because of max depth
240 not split because of max depth
241 not split because of max depth
242 not split because of max depth
245 not split because of max depth
246 not split because of max depth
251 not split because of max depth
252 not split because of max depth
CPU times: user 17.8 s, sys: 56.7 ms, total: 17.9 s
Wall time: 17.7 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
6 not split because of 1 class
Current node: 7
8 not split because of 1 class
Current node: 9
Current node: 10
Current node: 11
12 not split because of 1 class
Current node: 15
Current node: 16
Current node: 19
20 not split because of 1 class
Current node: 21
22 not split because of 1 class
Current node: 23
Current node: 24
Current node: 31
```

```
32 not split because of 1 class
Current node: 33
Current node: 34
Current node: 39
40 not split because of 1 class
Current node: 43
Current node: 44
Current node: 47
48 not split because of 1 class
Current node: 49
50 not split because of 1 class
63 not split because of 1 class
64 not split because of 1 class
67 not split because of 1 class
Current node: 68
Current node: 69
Current node: 70
Current node: 79
80 not split because of 1 class
Current node: 87
88 not split because of 1 class
89 not split because of 1 class
90 not split because of 1 class
95 not split because of 1 class
Current node: 96
99 not split because of 1 class
Current node: 100
137 not split because of max depth
138 not split because of max depth
139 not split because of max depth
140 not split because of max depth
141 not split because of max depth
142 not split because of max depth
159 not split because of max depth
160 not split because of max depth
175 not split because of max depth
176 not split because of max depth
193 not split because of max depth
194 not split because of max depth
201 not split because of max depth
202 not split because of max depth
CPU times: user 18.9 s, sys: 30 ms, total: 19 s
Wall time: 19 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
```

```
Current node: 7
Current node: 8
Current node: 9
Current node: 10
Current node: 11
Current node: 12
Current node: 13
14 not split because of 1 class
Current node: 15
Current node: 16
17 not split because of 1 class
Current node: 18
19 not split because of 1 class
Current node: 20
21 not split because of 1 class
22 not split because of 1 class
Current node: 23
Current node: 24
Current node: 25
Current node: 26
27 not split because of 1 class
28 not split because of 1 class
Current node: 31
Current node: 32
33 not split because of 1 class
Current node: 34
37 not split because of 1 class
38 not split because of 1 class
Current node: 41
Current node: 42
Current node: 47
Current node: 48
49 not split because of 1 class
50 not split because of 1 class
51 not split because of 1 class
Current node: 52
Current node: 53
Current node: 54
Current node: 63
64 not split because of 1 class
Current node: 65
Current node: 66
Current node: 69
70 not split because of 1 class
Current node: 83
Current node: 84
Current node: 85
86 not split because of 1 class
Current node: 95
96 not split because of 1 class
```

```
Current node: 97
Current node: 98
Current node: 105
Current node: 106
107 not split because of 1 class
108 not split because of 1 class
Current node: 109
Current node: 110
127 not split because of max depth
128 not split because of max depth
131 not split because of max depth
132 not split because of max depth
133 not split because of max depth
134 not split because of max depth
139 not split because of max depth
140 not split because of max depth
167 not split because of max depth
168 not split because of max depth
169 not split because of max depth
170 not split because of max depth
171 not split because of max depth
172 not split because of max depth
191 not split because of max depth
192 not split because of max depth
195 not split because of max depth
196 not split because of max depth
197 not split because of max depth
198 not split because of max depth
211 not split because of max depth
212 not split because of max depth
213 not split because of max depth
214 not split because of max depth
219 not split because of max depth
220 not split because of max depth
221 not split because of max depth
222 not split because of max depth
CPU times: user 18.6 s, sys: 83.3 ms, total: 18.7 s
Wall time: 18.4 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
8 not split because of 1 class
9 not split because of 1 class
Current node: 10
Current node: 11
```

```
Current node: 12
Current node: 13
14 not split because of 1 class
Current node: 15
Current node: 16
21 not split because of 1 class
Current node: 22
Current node: 23
Current node: 24
25 not split because of 1 class
Current node: 26
27 not split because of 1 class
28 not split because of 1 class
Current node: 31
Current node: 32
Current node: 33
Current node: 34
Current node: 45
46 not split because of 1 class
Current node: 47
Current node: 48
Current node: 49
50 not split because of 1 class
53 not split because of 1 class
54 not split because of 1 class
Current node: 63
64 not split because of 1 class
Current node: 65
Current node: 66
67 not split because of 1 class
68 not split because of 1 class
Current node: 69
Current node: 70
Current node: 91
92 not split because of 1 class
Current node: 95
Current node: 96
Current node: 97
Current node: 98
Current node: 99
100 not split because of 1 class
127 not split because of max depth
128 not split because of max depth
131 not split because of max depth
132 not split because of max depth
133 not split because of max depth
134 not split because of max depth
139 not split because of max depth
140 not split because of max depth
141 not split because of max depth
```

```
142 not split because of max depth
183 not split because of max depth
184 not split because of max depth
191 not split because of max depth
192 not split because of max depth
193 not split because of max depth
194 not split because of max depth
195 not split because of max depth
196 not split because of max depth
197 not split because of max depth
198 not split because of max depth
199 not split because of max depth
200 not split because of max depth
CPU times: user 19.9 s, sys: 36.7 ms, total: 19.9 s
Wall time: 19.8 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
Current node: 8
9 not split because of 1 class
Current node: 10
Current node: 11
12 not split because of 1 class
Current node: 13
Current node: 14
Current node: 15
16 not split because of 1 class
17 not split because of 1 class
Current node: 18
21 not split because of 1 class
Current node: 22
Current node: 23
Current node: 24
27 not split because of 1 class
28 not split because of 1 class
Current node: 29
30 not split because of 1 class
Current node: 31
Current node: 32
37 not split because of 1 class
38 not split because of 1 class
45 not split because of 1 class
46 not split because of 1 class
Current node: 47
48 not split because of 1 class
```

```
Current node: 49
Current node: 50
59 not split because of 1 class
Current node: 60
Current node: 63
Current node: 64
65 not split because of 1 class
Current node: 66
Current node: 95
96 not split because of 1 class
Current node: 99
Current node: 100
Current node: 101
Current node: 102
Current node: 121
Current node: 122
127 not split because of max depth
128 not split because of max depth
129 not split because of max depth
130 not split because of max depth
133 not split because of max depth
134 not split because of max depth
191 not split because of max depth
192 not split because of max depth
199 not split because of max depth
200 not split because of max depth
201 not split because of max depth
202 not split because of max depth
203 not split because of max depth
204 not split because of max depth
205 not split because of max depth
206 not split because of max depth
243 not split because of max depth
244 not split because of max depth
245 not split because of max depth
246 not split because of max depth
CPU times: user 19.9 s, sys: 23.3 ms, total: 19.9 s
Wall time: 19.8 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
6 not split because of 1 class
Current node: 7
Current node: 8
Current node: 9
Current node: 10
Current node: 11
```

```
Current node: 12
Current node: 15
Current node: 16
Current node: 17
18 not split because of 1 class
Current node: 19
20 not split because of 1 class
Current node: 21
Current node: 22
Current node: 23
Current node: 24
25 not split because of 1 class
Current node: 26
Current node: 31
Current node: 32
33 not split because of 1 class
Current node: 34
Current node: 35
Current node: 36
Current node: 39
40 not split because of 1 class
43 not split because of 1 class
Current node: 44
Current node: 45
46 not split because of 1 class
Current node: 47
Current node: 48
Current node: 49
Current node: 50
Current node: 53
54 not split because of 1 class
Current node: 63
Current node: 64
Current node: 65
66 not split because of 1 class
69 not split because of 1 class
70 not split because of 1 class
71 not split because of 1 class
Current node: 72
Current node: 73
Current node: 74
79 not split because of 1 class
Current node: 80
Current node: 89
Current node: 90
91 not split because of 1 class
Current node: 92
95 not split because of 1 class
Current node: 96
Current node: 97
```

```
Current node: 98
99 not split because of 1 class
Current node: 100
Current node: 101
Current node: 102
107 not split because of 1 class
108 not split because of 1 class
127 not split because of max depth
128 not split because of max depth
129 not split because of max depth
130 not split because of max depth
131 not split because of max depth
132 not split because of max depth
145 not split because of max depth
146 not split because of max depth
147 not split because of max depth
148 not split because of max depth
149 not split because of max depth
150 not split because of max depth
161 not split because of max depth
162 not split because of max depth
179 not split because of max depth
180 not split because of max depth
181 not split because of max depth
182 not split because of max depth
185 not split because of max depth
186 not split because of max depth
193 not split because of max depth
194 not split because of max depth
195 not split because of max depth
196 not split because of max depth
197 not split because of max depth
198 not split because of max depth
201 not split because of max depth
202 not split because of max depth
203 not split because of max depth
204 not split because of max depth
205 not split because of max depth
206 not split because of max depth
CPU times: user 17.3 s, sys: 36.7 ms, total: 17.3 s
Wall time: 17.3 s
Current node: 0
Current node: 1
Current node: 2
Current node: 3
4 not split because of 1 class
Current node: 5
Current node: 6
Current node: 7
Current node: 8
```

```
Current node: 11
Current node: 12
13 not split because of 1 class
14 not split because of 1 class
Current node: 15
Current node: 16
17 not split because of 1 class
Current node: 18
Current node: 23
Current node: 24
Current node: 25
Current node: 26
Current node: 31
Current node: 32
33 not split because of 1 class
34 not split because of 1 class
Current node: 37
Current node: 38
Current node: 47
48 not split because of 1 class
Current node: 49
Current node: 50
Current node: 51
52 not split because of 1 class
Current node: 53
Current node: 54
Current node: 63
64 not split because of 1 class
Current node: 65
Current node: 66
75 not split because of 1 class
76 not split because of 1 class
Current node: 77
Current node: 78
Current node: 95
Current node: 96
Current node: 99
Current node: 100
Current node: 101
Current node: 102
103 not split because of 1 class
Current node: 104
Current node: 107
Current node: 108
Current node: 109
Current node: 110
127 not split because of max depth
128 not split because of max depth
131 not split because of max depth
132 not split because of max depth
```

```
133 not split because of max depth
134 not split because of max depth
155 not split because of max depth
156 not split because of max depth
157 not split because of max depth
158 not split because of max depth
191 not split because of max depth
192 not split because of max depth
193 not split because of max depth
194 not split because of max depth
199 not split because of max depth
200 not split because of max depth
201 not split because of max depth
202 not split because of max depth
203 not split because of max depth
204 not split because of max depth
205 not split because of max depth
206 not split because of max depth
209 not split because of max depth
210 not split because of max depth
215 not split because of max depth
216 not split because of max depth
217 not split because of max depth
218 not split because of max depth
219 not split because of max depth
220 not split because of max depth
221 not split because of max depth
222 not split because of max depth
CPU times: user 19.4 s, sys: 36.7 ms, total: 19.4 s
Wall time: 19.4 s
```

In [102]:

```
window = 400

%time y_pred = forest.predict(X_train[:window])

for index in range(window):
    y_pred[index] = int(y_pred[index])

bad = 0

for node_index in range(window):
    if y_train[node_index] != y_pred[node_index]:
        bad += 1

print("Misclassified " + str(bad) + " out of " + str(window) + ", that gives us about " + str(float((window - bad))/
window * 100) + "% of success")
```

```
(400, 14)
(400,)
[ 0.  0.  0.  0.  0.  1.  0.  0.  1.  1.  1.  1.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.
  0.  1.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.  1.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  1.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.
  0.  0.  1.  1.]
(400, 14)
(400,)
[ 0.  0.  0.  0.  0.  1.  0.  0.  1.  1.  1.  1.  0.  0.  1.  1.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.
  0.  0.  0.  1.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  1.  0.
  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.
  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  1.
  0.  1.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.
  0.  1.  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  1.  0.  0.  0.  0.  1.  0.  1.  0.  1.  0.  0.  1.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.]
```

```
(400, 14)
(400,)
[ 1.  0.  0.  0.  1.  1.  0.  0.  1.  1.  0.  0.  0.  0.  1.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.
  0.  0.  0.  1.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  1.  1.
  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  1.
  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  1.
  0.  1.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  1.
  1.  0.  1.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  1.  0.  1.  0.  1.  0.  0.  0.  0.  0.  1.  0.  1.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.
  1.  0.  0.  1.  0.  0.  0.  0.  1.  0.  1.  0.  1.  0.  0.  1.  0.  0.
  0.  1.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  1.]
(400, 14)
(400,)
[ 0.  1.  0.  1.  1.  1.  0.  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  1.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  1.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  1.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  1.]
```

```
(400, 14)
(400,)
[ 0.  0.  0.  0.  1.  1.  0.  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.
  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  1.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  1.]
(400, 14)
(400,)
[ 0.  0.  0.  0.  0.  1.  0.  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  1.  0.  0.  0.  0.  0.  1.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  1.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.]
```

```
(400, 14)
(400,)
[ 0.  1.  0.  0.  1.  1.  0.  0.  1.  1.  0.  1.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  1.
  0.  0.  0.  1.  1.  0.  1.  0.  0.  0.  1.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.  1.  0.  0.  0.  0.
  0.  1.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  1.  1.]
(400, 14)
(400,)
[ 0.  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  1.  0.  0.  0.
  0.  0.  1.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.
  0.  0.  0.  1.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  1.  0.  0.  1.  0.  1.
  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.
  0.  1.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  1.  0.  0.  0.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.
  0.  1.  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.  0.  1.  0.  0.  1.  0.  1.
  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.]
```

```
(400, 14)
(400,)
[ 0.  0.  0.  0.  1.  1.  0.  0.  1.  1.  1.  1.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  1.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.
  0.  0.  0.  0.  1.  1.  1.  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.
  1.  0.  0.  0.  1.  0.  0.  0.  0.  1.  0.  1.  1.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  1.  0.  1.  1.  0.  0.  1.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  1.  0.  0.  0.  1.  0.  1.  0.  0.  1.  0.  1.  0.  1.
  0.  1.  0.  0.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  1.
  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  1.  1.  1.  0.  0.  1.  0.  1.  0.  0.  1.
  1.  0.  0.  0.  1.  1.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  1.  0.
  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  1.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  1.  0.  0.  0.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  1.  1.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  1.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.
  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.]
(400, 14)
(400,)
[ 0.  1.  0.  0.  0.  1.  0.  1.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  1.  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  1.  0.
  0.  0.  0.  0.  0.  1.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  1.
  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  1.  0.  0.
  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  1.
  1.  0.  0.  0.  1.  0.  0.  0.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  1.  1.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  1.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  1.  0.  0.  1.  0.  1.  0.  0.  0.  1.  1.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  1.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.  0.
  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.
  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  1.  1.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  1.  0.  0.
  0.  0.  0.  1.]
```

```
CPU times: user 367 ms, sys: 13.3 ms, total: 380 ms
Wall time: 340 ms
Misclassified 78 out of 400, that gives us about 80.5% of success
```

Code F1 score and Cross Validation Process

You could use sklearn functions instead.

In [115]:
```
# F1
from sklearn.metrics import f1_score

def f1(y_true, y_predict):
    return f1_score(y_true, y_predict)
```

In [116]:
```
# Cross validation

from sklearn.cross_validation import cross_val_score

forest = Forest(10)

def cross_validation(X, y, metric, cv_fold=5):
    return cross_val_score(forest, X, y, cv = cv_fold, n_jobs=-1)
```

In [117]:
```
print(cross_validation(X_train[:1000], y_train[:1000], "gini"))
```

```
CPU times: user 20.7 s, sys: 6.67 ms, total: 20.8 s
Wall time: 22.5 s
CPU times: user 23.1 s, sys: 36.7 ms, total: 23.1 s
Wall time: 25.6 s
CPU times: user 22.5 s, sys: 10 ms, total: 22.6 s
Wall time: 25.8 s
CPU times: user 23.8 s, sys: 10 ms, total: 23.8 s
Wall time: 27.7 s
CPU times: user 20.9 s, sys: 23.3 ms, total: 20.9 s
Wall time: 23.6 s
CPU times: user 22.7 s, sys: 16.7 ms, total: 22.7 s
Wall time: 24.3 s
CPU times: user 22.4 s, sys: 13.3 ms, total: 22.4 s
Wall time: 24.2 s
CPU times: user 23.7 s, sys: 0 ns, total: 23.7 s
Wall time: 25.4 s
CPU times: user 20.8 s, sys: 0 ns, total: 20.8 s
Wall time: 21.9 s
CPU times: user 22.3 s, sys: 6.67 ms, total: 22.3 s
Wall time: 22.7 s
CPU times: user 22.7 s, sys: 3.33 ms, total: 22.7 s
Wall time: 23.7 s
CPU times: user 23.5 s, sys: 3.33 ms, total: 23.5 s
Wall time: 24.4 s
CPU times: user 20.6 s, sys: 3.33 ms, total: 20.6 s
Wall time: 21 s
CPU times: user 22.1 s, sys: 3.33 ms, total: 22.1 s
Wall time: 22.8 s
CPU times: user 22.5 s, sys: 3.33 ms, total: 22.6 s
Wall time: 22.8 s
CPU times: user 23.4 s, sys: 6.67 ms, total: 23.4 s
Wall time: 24.1 s
CPU times: user 20.6 s, sys: 23.3 ms, total: 20.6 s
Wall time: 21.2 s
CPU times: user 22.1 s, sys: 6.67 ms, total: 22.1 s
Wall time: 23.1 s
CPU times: user 22.5 s, sys: 3.33 ms, total: 22.5 s
Wall time: 23 s
CPU times: user 23.5 s, sys: 0 ns, total: 23.5 s
Wall time: 24.1 s
CPU times: user 20.5 s, sys: 3.33 ms, total: 20.5 s
Wall time: 21.4 s
CPU times: user 22 s, sys: 10 ms, total: 22 s
Wall time: 22.8 s
CPU times: user 22.5 s, sys: 13.3 ms, total: 22.5 s
Wall time: 23.6 s
CPU times: user 23.3 s, sys: 6.67 ms, total: 23.3 s
Wall time: 24.2 s
CPU times: user 20.6 s, sys: 16.7 ms, total: 20.6 s
Wall time: 22 s
```

```
CPU times: user 22.1 s, sys: 3.33 ms, total: 22.1 s
Wall time: 22.7 s
CPU times: user 22.5 s, sys: 3.33 ms, total: 22.5 s
Wall time: 23.6 s
CPU times: user 23.4 s, sys: 3.33 ms, total: 23.4 s
Wall time: 24.1 s
CPU times: user 20.7 s, sys: 10 ms, total: 20.7 s
Wall time: 22.1 s
CPU times: user 22.1 s, sys: 10 ms, total: 22.1 s
Wall time: 23.5 s
CPU times: user 22.6 s, sys: 6.67 ms, total: 22.6 s
Wall time: 24 s
CPU times: user 23.2 s, sys: 0 ns, total: 23.2 s
Wall time: 23.4 s
CPU times: user 20.7 s, sys: 13.3 ms, total: 20.7 s
Wall time: 22.7 s
CPU times: user 22.1 s, sys: 0 ns, total: 22.1 s
Wall time: 23.3 s
CPU times: user 22.5 s, sys: 6.67 ms, total: 22.5 s
Wall time: 24 s
CPU times: user 20.7 s, sys: 10 ms, total: 20.7 s
Wall time: 21.8 s
CPU times: user 23.2 s, sys: 3.33 ms, total: 23.2 s
Wall time: 23.6 s
CPU times: user 22.1 s, sys: 10 ms, total: 22.1 s
Wall time: 23.6 s
CPU times: user 22.3 s, sys: 26.7 ms, total: 22.4 s
Wall time: 23.5 s
CPU times: user 19.1 s, sys: 0 ns, total: 19.1 s
Wall time: 20.3 s
CPU times: user 19.6 s, sys: 3.33 ms, total: 19.6 s
Wall time: 19.9 s
CPU times: user 11.3 s, sys: 0 ns, total: 11.3 s
Wall time: 11.3 s
CPU times: user 11.9 s, sys: 0 ns, total: 11.9 s
Wall time: 11.9 s
CPU times: user 11.4 s, sys: 0 ns, total: 11.4 s
Wall time: 11.4 s
CPU times: user 11.3 s, sys: 0 ns, total: 11.3 s
Wall time: 11.3 s
CPU times: user 11.2 s, sys: 0 ns, total: 11.2 s
Wall time: 11.2 s
CPU times: user 11.3 s, sys: 3.33 ms, total: 11.3 s
Wall time: 11.3 s
CPU times: user 11.3 s, sys: 0 ns, total: 11.3 s
Wall time: 11.3 s
CPU times: user 11.3 s, sys: 3.33 ms, total: 11.3 s
Wall time: 11.3 s
CPU times: user 11.4 s, sys: 0 ns, total: 11.4 s
Wall time: 11.4 s
```

```
[ 0.73134328  0.8358209   0.84        0.8241206   0.80904523]
```

Final result

In [119]:
```
test_df = pandas.read_csv("kaggle_data/adult.test")
```

In [120]:
```
test_df.head()
```

Out[120]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country
0	51	Private	335997	HS-grad	9	Married-civ-spouse	Craft-repair	Husband	White	Male	0	1902	40	United-States
1	50	Private	98227	HS-grad	9	Divorced	Craft-repair	Not-in-family	White	Male	0	0	40	United-States
2	48	Local-gov	204629	Doctorate	16	Married-civ-spouse	Prof-specialty	Husband	White	Male	15024	0	45	Canada
3	32	Private	246038	Bachelors	13	Never-married	Prof-specialty	Not-in-family	White	Male	0	0	40	United-States
4	42	Private	67243	1st-4th	2	Married-civ-spouse	Adm-clerical	Husband	White	Male	0	0	55	Portugal

In [121]:
```
print "Head:"
print test_df.head()
print "Shape:"
print shape(test_df)
```

```
Head:
   age   workclass  fnlwgt   education  education-num       marital-status  \
0  51    Private    335997   HS-grad    9               Married-civ-spouse
1  50    Private    98227    HS-grad    9               Divorced
2  48    Local-gov  204629   Doctorate  16              Married-civ-spouse
3  32    Private    246038   Bachelors  13              Never-married
4  42    Private    67243    1st-4th    2               Married-civ-spouse

         occupation    relationship    race    sex  capital-gain  capital-loss  \
0   Craft-repair     Husband         White   Male  0             1902
1   Craft-repair     Not-in-family   White   Male  0             0
2   Prof-specialty   Husband         White   Male  15024         0
3   Prof-specialty   Not-in-family   White   Male  0             0
4   Adm-clerical     Husband         White   Male  0             0

   hours-per-week  native-country
0  40               United-States
1  40               United-States
2  45               Canada
3  40               United-States
4  55               Portugal
Shape:
(6444, 14)
```

In [123]:
```
for column in test_df.columns:
    print(column + str(shape(test_df.groupby(column))))
```

```
age(70, 2)
workclass(8, 2)
fnlwgt(5573, 2)
education(16, 2)
education-num(16, 2)
marital-status(7, 2)
occupation(15, 2)
relationship(6, 2)
race(5, 2)
sex(2, 2)
capital-gain(83, 2)
capital-loss(57, 2)
hours-per-week(86, 2)
native-country(41, 2)
```

In [124]:
```
test_df.groupby("native-country").count()
```

Out[124]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week
native-country													
?	112	112	112	112	112	112	112	112	112	112	112	112	112
Cambodia	3	3	3	3	3	3	3	3	3	3	3	3	3
Canada	30	30	30	30	30	30	30	30	30	30	30	30	30
China	18	18	18	18	18	18	18	18	18	18	18	18	18
Columbia	8	8	8	8	8	8	8	8	8	8	8	8	8
Cuba	15	15	15	15	15	15	15	15	15	15	15	15	15
Dominican-Republic	10	10	10	10	10	10	10	10	10	10	10	10	10
Ecuador	3	3	3	3	3	3	3	3	3	3	3	3	3
El-Salvador	11	11	11	11	11	11	11	11	11	11	11	11	11
England	21	21	21	21	21	21	21	21	21	21	21	21	21
France	4	4	4	4	4	4	4	4	4	4	4	4	4
Germany	27	27	27	27	27	27	27	27	27	27	27	27	27
Greece	11	11	11	11	11	11	11	11	11	11	11	11	11
Guatemala	4	4	4	4	4	4	4	4	4	4	4	4	4
Haiti	13	13	13	13	13	13	13	13	13	13	13	13	13
Honduras	2	2	2	2	2	2	2	2	2	2	2	2	2
Hong	3	3	3	3	3	3	3	3	3	3	3	3	3
Hungary	4	4	4	4	4	4	4	4	4	4	4	4	4
India	29	29	29	29	29	29	29	29	29	29	29	29	29
Iran	8	8	8	8	8	8	8	8	8	8	8	8	8
Ireland	7	7	7	7	7	7	7	7	7	7	7	7	7
Italy	12	12	12	12	12	12	12	12	12	12	12	12	12
Jamaica	6	6	6	6	6	6	6	6	6	6	6	6	6
Japan	8	8	8	8	8	8	8	8	8	8	8	8	8
Laos	1	1	1	1	1	1	1	1	1	1	1	1	1

Mexico	88	88	88	88	88	88	88	88	88	88	88	88	88
Nicaragua	5	5	5	5	5	5	5	5	5	5	5	5	5
Outlying-US(Guam-USVI-etc)	1	1	1	1	1	1	1	1	1	1	1	1	1
Peru	4	4	4	4	4	4	4	4	4	4	4	4	4
Philippines	37	37	37	37	37	37	37	37	37	37	37	37	37
Poland	8	8	8	8	8	8	8	8	8	8	8	8	8
Portugal	9	9	9	9	9	9	9	9	9	9	9	9	9
Puerto-Rico	19	19	19	19	19	19	19	19	19	19	19	19	19
Scotland	3	3	3	3	3	3	3	3	3	3	3	3	3
South	13	13	13	13	13	13	13	13	13	13	13	13	13
Taiwan	8	8	8	8	8	8	8	8	8	8	8	8	8
Thailand	5	5	5	5	5	5	5	5	5	5	5	5	5
Trinadad&Tobago	1	1	1	1	1	1	1	1	1	1	1	1	1
United-States	5865	5865	5865	5865	5865	5865	5865	5865	5865	5865	5865	5865	5865
Vietnam	5	5	5	5	5	5	5	5	5	5	5	5	5
Yugoslavia	3	3	3	3	3	3	3	3	3	3	3	3	3

In [125]:
```
test_df.groupby("workclass").count()
```

Out[125]:

	age	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country
workclass													
?	265	265	265	265	265	265	265	265	265	265	265	265	265
Federal-gov	260	260	260	260	260	260	260	260	260	260	260	260	260
Local-gov	457	457	457	457	457	457	457	457	457	457	457	457	457
Private	4239	4239	4239	4239	4239	4239	4239	4239	4239	4239	4239	4239	4239
Self-emp-inc	382	382	382	382	382	382	382	382	382	382	382	382	382
Self-emp-not-inc	542	542	542	542	542	542	542	542	542	542	542	542	542
State-gov	295	295	295	295	295	295	295	295	295	295	295	295	295
Without-pay	4	4	4	4	4	4	4	4	4	4	4	4	4

Let's encode'em

In [126]:
```
from sklearn import preprocessing

def number_encode_features(test_df):
    result = test_df.copy()
    encoders = {}
    for column in result.columns:
        if result.dtypes[column] == np.object:
            encoders[column] = preprocessing.LabelEncoder()
            result[column] = encoders[column].fit_transform(result[column])
    return result, encoders

encoded_data_test, encoders_test = number_encode_features(test_df)
encoded_data_test.head()
```

Out[126]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	native-country
0	51	3	335997	11	9	2	3	0	4	1	0	1902	40	38
1	50	3	98227	11	9	0	3	1	4	1	0	0	40	38
2	48	2	204629	10	16	2	10	0	4	1	15024	0	45	2
3	32	3	246038	9	13	4	10	1	4	1	0	0	40	38
4	42	3	67243	3	2	2	1	0	4	1	0	0	55	31

In [127]:
```
pp.pprint(encoders_test)
```

```
{   'education': LabelEncoder(),
    'marital-status': LabelEncoder(),
    'native-country': LabelEncoder(),
    'occupation': LabelEncoder(),
    'race': LabelEncoder(),
    'relationship': LabelEncoder(),
    'sex': LabelEncoder(),
    'workclass': LabelEncoder()}
```

In [150]:
```
X_test = encoded_data_test[encoded_data_test.columns[:]].values
```

In [151]:
```
X_test.shape
```

Out[151]:
```
(6444, 14)
```

In [176]:
```
print(X_train.shape)
print(y_train.shape)
```

```
(32561, 14)
(32561,)
```

In [230]:
```
import CART

ORDINAL_COLUMNS = {3 : "education"}

CONTINUOUS_COLUMNS = {
    0 : "age",
    2 : "fnlwgt",
    4 : "education-num",
    10 : "capital-gain",
    11 : "capital-loss",
    12 : "hours/week"}

CATEGORICAL_COLUMNS = {
    1 : "workclass",
    5 : "marriage",
    7 : "relationship",
    8 : "race",
    9 : "sex"}

CATEGORICAL_COLUMNS_SLOW = {
    6 : "occupation",
    13 : "country"}

cart = CART.CART(1, 5, ORDINAL_COLUMNS, CONTINUOUS_COLUMNS, CATEGORICAL_COLUMNS, CATEGORICAL_COLUMNS_SLOW)
%time cart = cart.fit(X_train[:1000], y_train[:1000])
```

```
Current node: 0
Current node: 1
Current node: 2
Current node: 3
Current node: 4
Current node: 5
Current node: 6
Current node: 7
8 not split because of 1 class
Current node: 9
10 not split because of 1 class
Current node: 11
Current node: 12
13 not split because of 1 class
14 not split because of 1 class
Current node: 15
Current node: 16
Current node: 19
20 not split because of 1 class
Current node: 23
Current node: 24
Current node: 25
Current node: 26
31 not split because of max depth
32 not split because of max depth
33 not split because of max depth
34 not split because of max depth
39 not split because of max depth
40 not split because of max depth
47 not split because of max depth
48 not split because of max depth
49 not split because of max depth
50 not split because of max depth
51 not split because of max depth
52 not split because of max depth
53 not split because of max depth
54 not split because of max depth
CPU times: user 16.3 s, sys: 33.3 ms, total: 16.3 s
Wall time: 16.3 s
```

In [231]:
```
%time y_pred, node_pred = cart.predict(numpy.array(X_test))
```

```
0
1000
2000
3000
4000
5000
6000
CPU times: user 493 ms, sys: 73.3 ms, total: 567 ms
Wall time: 488 ms
```

In [232]:
```
test_df["label"] = numpy.zeros(test_df.shape[0])
```

In [233]:
```
print(test_df.shape)
```

```
(6444, 2)
```

In [234]:
```
print(y_pred.shape)
```

```
(6444,)
```

In [235]:
```
print(numpy.count_nonzero(y_pred))
```

```
2670
```

In [236]:
```
test_df["label"] = y_pred
test_df["id"] = test_df.index
```

In [237]:
```
test_df = test_df[['id', 'label']]
test_df.columns = ['Id', 'label']
```

In [238]:
```
test_df.to_csv('solution.csv', index=False)
```

In [239]:
```
!wc -l solution.csv
```

```
6445 solution.csv
```

Lol, 1/32 of train set gives us about 0.72666 on our kaggle contest (7th place)

Bref, it works.