Importing Libraries

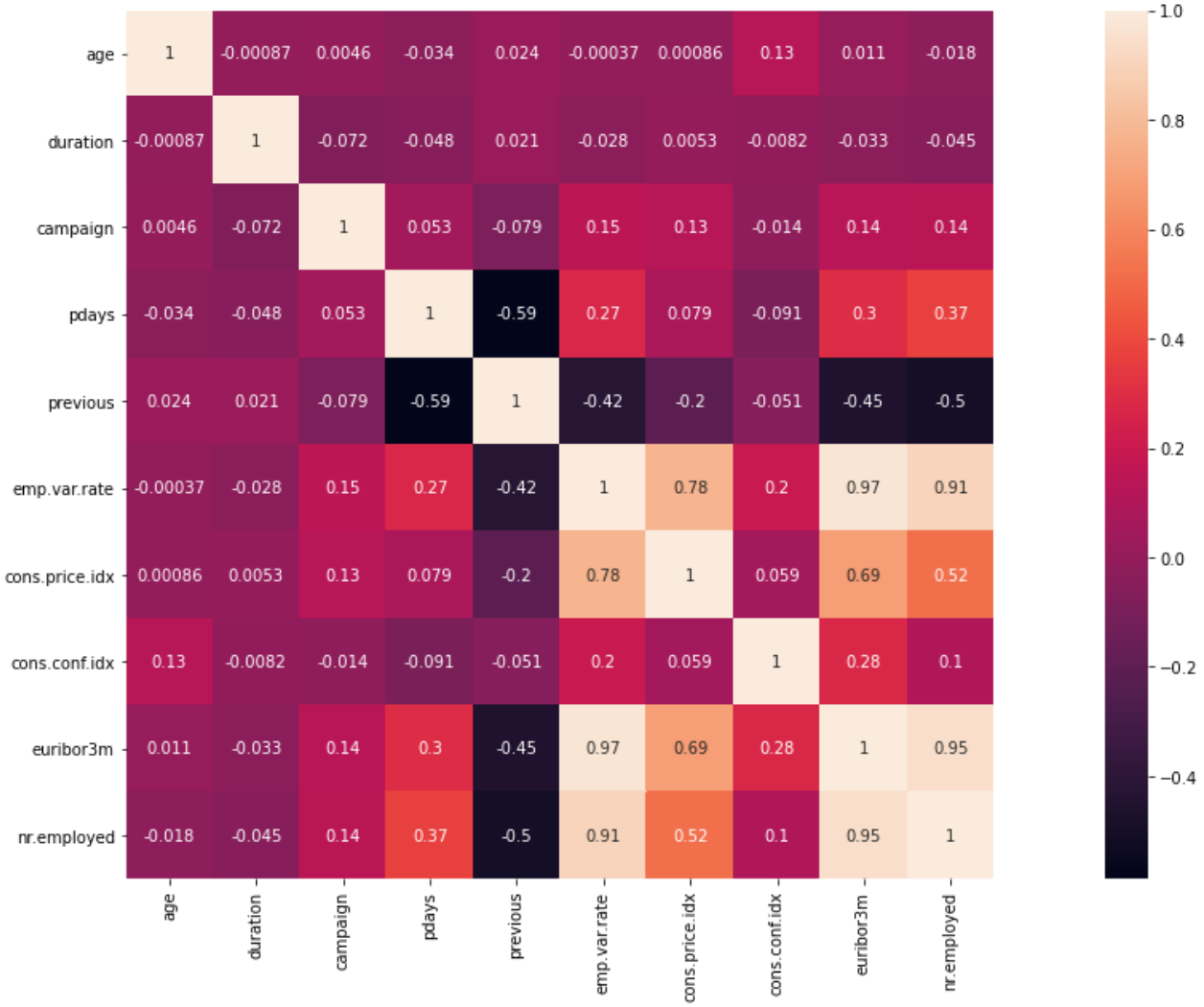
In [1]:
```
import numpy as np
import pandas as pd
from sklearn.preprocessing import LabelEncoder
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.naive_bayes import GaussianNB
from sklearn.model_selection import GridSearchCV
from sklearn.model_selection import train_test_split
from sklearn import metrics
from sklearn.metrics import confusion_matrix, plot_confusion_matrix
import seaborn as sns
from sklearn.metrics import precision_score
from sklearn.metrics import recall_score
from sklearn.metrics import f1_score
from sklearn.decomposition import FactorAnalysis
from sklearn.utils import resample

import matplotlib.pyplot as plt
```

In [2]:
```
df=pd.read_csv("bank-additional-full.csv",sep=';')

#Dropping some features
df.drop('day_of_week', axis=1, inplace=True)
df.drop('contact', axis=1, inplace=True)
df.drop('month', axis=1, inplace=True)
df.head(5)
```

Out[2]:

	age	job	marital	education	default	housing	loan	duration	campaign	pdays	previous
0	56	housemaid	married	basic.4y	no	no	no	261	1	999	0
1	57	services	married	high.school	unknown	no	no	149	1	999	0
2	37	services	married	high.school	no	yes	no	226	1	999	0
3	40	admin.	married	basic.6y	no	no	no	151	1	999	0
4	56	services	married	high.school	no	no	yes	307	1	999	0

In [3]:
```
#Correlation of numeric features
cor=df.corr(method="pearson")
plt.figure(figsize=(25,10))
sns.heatmap(cor,vmax=1, square=True,annot=True)
plt.show()
```



Creating a new feature for higly correlated(numerical) features

In [4]:
```
fact=FactorAnalysis(n_components=1)
df['new_factor']=fact.fit_transform(df[['emp.var.rate', 'cons.price.idx','euribor3m','n
df.drop(['emp.var.rate', 'cons.price.idx','euribor3m','nr.employed'], axis=1, inplace=T
df.head(5)
```

```
C:\Users\Akshat\anaconda3\lib\site-packages\sklearn\decomposition\_factor_analysis.py:24
0: ConvergenceWarning: FactorAnalysis did not converge. You might want to increase the n
umber of iterations.
  warnings.warn('FactorAnalysis did not converge.' +
```

Out[4]:

	age	job	marital	education	default	housing	loan	duration	campaign	pdays	previous
0	56	housemaid	married	basic.4y	no	no	no	261	1	999	0
1	57	services	married	high.school	unknown	no	no	149	1	999	0
2	37	services	married	high.school	no	yes	no	226	1	999	0
3	40	admin.	married	basic.6y	no	no	no	151	1	999	0
4	56	services	married	high.school	no	no	yes	307	1	999	0

In [5]:
```
#Dropping unknow values form dataset
df.drop(df[df['job'] == 'unknown' ].index , inplace=True)
```

```
df.drop(df[df['marital'] == 'unknown' ].index , inplace=True)
df.drop(df[df['education'] == 'unknown' ].index , inplace=True)
df.drop(df[df['default'] == 'unknown' ].index , inplace=True)
df.drop(df[df['housing'] == 'unknown' ].index , inplace=True)
df.drop(df[df['loan'] == 'unknown' ].index , inplace=True)
```

In [6]:

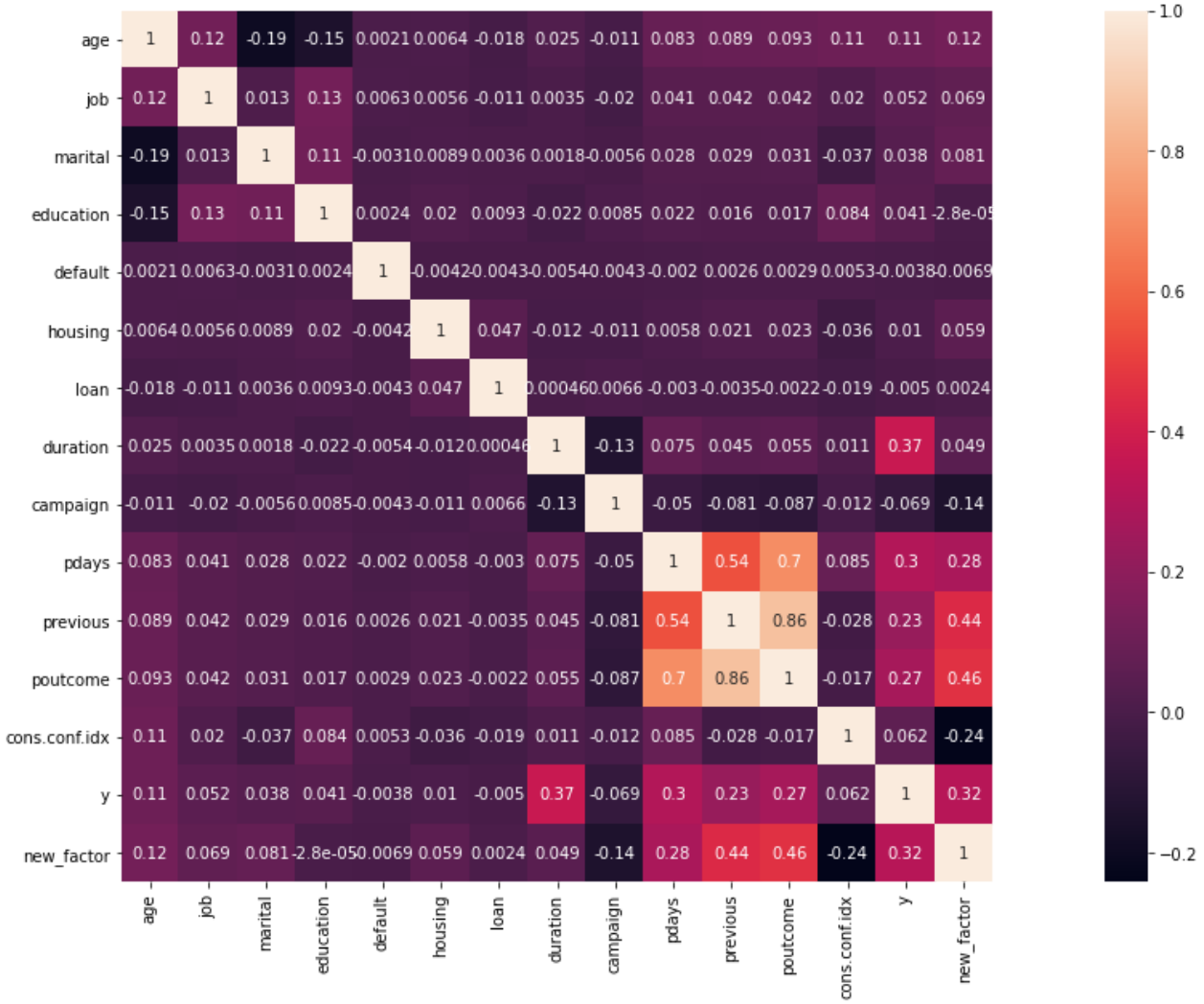
```
#Assigning numerical values for categorical features
df['poutcome']=  df['poutcome'].map({'nonexistent':1, 'failure':2, 'success':3})
df['housing'] = df['housing'].map({'no':1, 'yes':2})
df['loan'] = df['loan'].map({'no':1, 'yes':2})
df['default'] = df['default'].map({'no':1, 'yes':2})
df['job'] = df['job'].map({'housemaid':1, 'services':2, 'admin.':3, 'blue-collar':4, 't
       'retired':6, 'management':7, 'unemployed':8, 'self-employed':9,
       'entrepreneur':10, 'student':11})
df['y'] = df['y'].map({'no':0, 'yes':1})
df["marital"] = df["marital"].astype('category')
df["marital"] = df["marital"].cat.codes
df["education"] = df["education"].astype('category')
df["education"] = df["education"].cat.codes

#changing numeric (age,pdays,duration) to categorical
d = {range(0, 25): 3, range(25, 42): 1, range(42, 58): 2,range(58, 90): 4}
df['age'] = df['age'].apply(lambda x: next((v for k, v in d.items() if x in k), 0))
d = {range(1, 10): 1, range(10, 20): 2, range(20, 1000): 0}
df['pdays'] = df['pdays'].apply(lambda x: next((v for k, v in d.items() if x in k), 0))
d = {range(1, 60): 1, range(60, 200): 2, range(200, 600): 3, range(600, 1000): 4,range(
df['duration'] = df['duration'].apply(lambda x: next((v for k, v in d.items() if x in k
df.head(5)
```

Out[6]:

	age	job	marital	education	default	housing	loan	duration	campaign	pdays	previous	poutco
0	2	1	1	0	1	1	1	3	1	0	0	
2	1	2	1	3	1	2	1	3	1	0	0	
3	1	3	1	1	1	1	1	2	1	0	0	
4	2	2	1	3	1	1	2	3	1	0	0	
6	4	3	1	5	1	1	1	2	1	0	0	

In [8]:

```
#Correlation of catergorical features
cor=df.corr(method="pearson")
plt.figure(figsize=(25,10))
sns.heatmap(cor,vmax=1, square=True,annot=True)
plt.show()
```



Creating a new feature for higly correlated (categorical) features

In [9]:
```
fact=FactorAnalysis(n_components=1)
df['newp_factor']=fact.fit_transform(df[['pdays', 'previous','poutcome']])
df.drop(['pdays', 'previous','poutcome'], axis=1, inplace=True)
df.head(5)
```

```
C:\Users\Akshat\anaconda3\lib\site-packages\sklearn\decomposition\_factor_analysis.py:240: ConvergenceWarning: FactorAnalysis did not converge. You might want to increase the number of iterations.
  warnings.warn('FactorAnalysis did not converge.' +
```

Out[9]:

	age	job	marital	education	default	housing	loan	duration	campaign	cons.conf.idx	y	new_fac
0	2	1	1	0	1	1	1	3	1	-36.4	0	-0.709
2	1	2	1	3	1	2	1	3	1	-36.4	0	-0.709
3	1	3	1	1	1	1	1	2	1	-36.4	0	-0.709
4	2	2	1	3	1	1	2	3	1	-36.4	0	-0.709
6	4	3	1	5	1	1	1	2	1	-36.4	0	-0.709

Upsampling

In [10]:
```
def upsample(df):
    df_M = df[df.y == 0]
    df_m = df[df.y == 1]
    df_m_upsample = resample(df_m,
                             replace = True,
                             n_samples=df_M.shape[0],
                             random_state=1)
    df_up = pd.concat([df_M,df_m_upsample],axis=0)
    y = df_up.y
    X = df_up.drop('y',axis=1)
    return X,y
X,y=upsample(df)
```

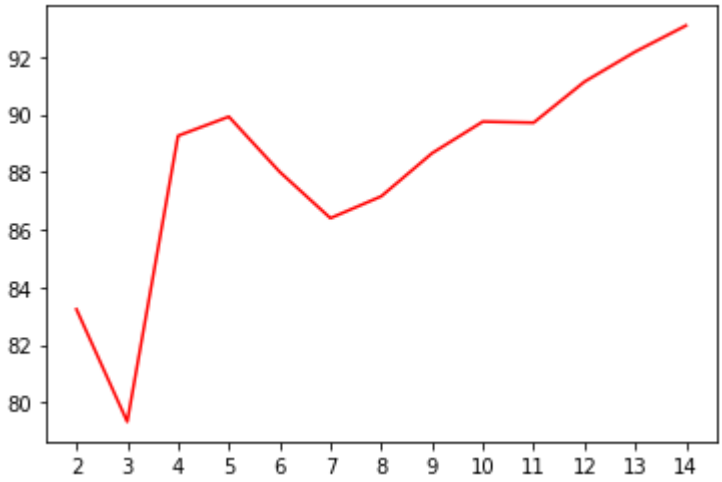
In [11]:
```
#Split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=1
```

Decision Tree

In [12]:
```
#Checking for best max_depth
rec=[]
prec=[]
acc=[]
f1 =[]
for i in range(2,15):
    regressor=DecisionTreeClassifier(criterion="entropy",max_depth=i)
    regressor.fit(X_train,y_train)
    y_pred = regressor.predict(X_test)
    rec.append(metrics.recall_score(y_test, y_pred)*100)
    prec.append(metrics.precision_score(y_test, y_pred)*100)
    acc.append(metrics.accuracy_score(y_test, y_pred)*100)
    f1.append(metrics.f1_score(y_test, y_pred)*100)
plt.plot(rec,'r')
#plt.plot(prec,'b')
#plt.plot(acc,'g')
#plt.plot(f1,'y')
plt.xticks(list(range(len(rec))), list(range(2,15)))
```

Out[12]:
```
([<matplotlib.axis.XTick at 0x1bd487b2790>,
  <matplotlib.axis.XTick at 0x1bd487b2760>,
  <matplotlib.axis.XTick at 0x1bd487af2e0>,
  <matplotlib.axis.XTick at 0x1bd485eb490>,
  <matplotlib.axis.XTick at 0x1bd485eb9a0>,
  <matplotlib.axis.XTick at 0x1bd485ebb50>,
  <matplotlib.axis.XTick at 0x1bd485f10a0>,
  <matplotlib.axis.XTick at 0x1bd485f15b0>,
  <matplotlib.axis.XTick at 0x1bd485f1ac0>,
  <matplotlib.axis.XTick at 0x1bd485f1fd0>,
  <matplotlib.axis.XTick at 0x1bd485f8520>,
  <matplotlib.axis.XTick at 0x1bd485f8a30>,
  <matplotlib.axis.XTick at 0x1bd485f8f40>],
 [Text(0, 0, '2'),
  Text(1, 0, '3'),
  Text(2, 0, '4'),
  Text(3, 0, '5'),
  Text(4, 0, '6'),
  Text(5, 0, '7'),
  Text(6, 0, '8'),
  Text(7, 0, '9'),
  Text(8, 0, '10'),
```

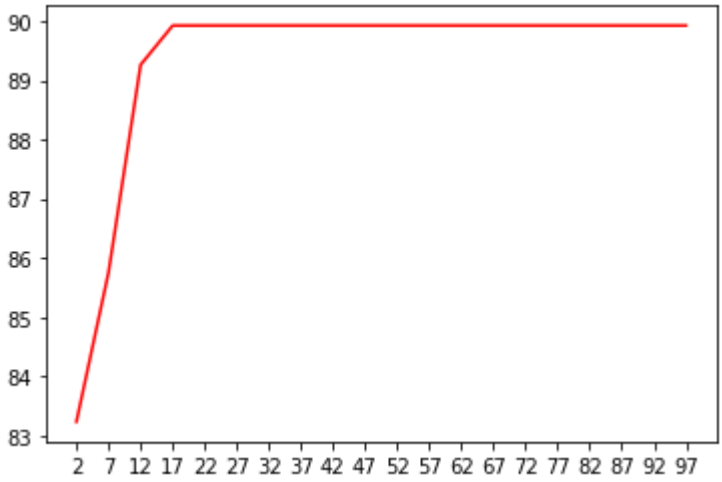
```
 Text(9, 0, '11'),
 Text(10, 0, '12'),
 Text(11, 0, '13'),
 Text(12, 0, '14')])
```



In [14]:
```
#Checking for best max_leaf_node
rec=[]
prec=[]
acc=[]
for i in range(2,100,5):
    regressor=DecisionTreeClassifier(criterion="entropy",max_depth = 5, max_leaf_nodes=
    regressor.fit(X_train,y_train)
    y_pred = regressor.predict(X_test)
    rec.append(metrics.recall_score(y_test, y_pred)*100)
    prec.append(metrics.precision_score(y_test, y_pred)*100)
    acc.append(metrics.accuracy_score(y_test, y_pred)*100)

plt.plot(rec,'r')
#plt.plot(prec,'b')
#plt.plot(acc,'g')
plt.xticks(list(range(len(rec))), list(range(2,100,5)))
```

Out[14]:
```
([<matplotlib.axis.XTick at 0x1bd486a0d00>,
  <matplotlib.axis.XTick at 0x1bd486a0cd0>,
  <matplotlib.axis.XTick at 0x1bd486a0520>,
  <matplotlib.axis.XTick at 0x1bd486c6760>,
  <matplotlib.axis.XTick at 0x1bd486c6c70>,
  <matplotlib.axis.XTick at 0x1bd486cd1c0>,
  <matplotlib.axis.XTick at 0x1bd486cd6d0>,
  <matplotlib.axis.XTick at 0x1bd486cdbe0>,
  <matplotlib.axis.XTick at 0x1bd486d5130>,
  <matplotlib.axis.XTick at 0x1bd486d5640>,
  <matplotlib.axis.XTick at 0x1bd486d5b50>,
  <matplotlib.axis.XTick at 0x1bd486d90a0>,
  <matplotlib.axis.XTick at 0x1bd486d51c0>,
  <matplotlib.axis.XTick at 0x1bd486cd250>,
  <matplotlib.axis.XTick at 0x1bd486d9250>,
  <matplotlib.axis.XTick at 0x1bd486d9760>,
  <matplotlib.axis.XTick at 0x1bd486d9c70>,
  <matplotlib.axis.XTick at 0x1bd486e01c0>,
  <matplotlib.axis.XTick at 0x1bd486e06d0>,
  <matplotlib.axis.XTick at 0x1bd486e0be0>],
 [Text(0, 0, '2'),
  Text(1, 0, '7'),
  Text(2, 0, '12'),
  Text(3, 0, '17'),
  Text(4, 0, '22'),
```

```
 Text(5, 0, '27'),
 Text(6, 0, '32'),
 Text(7, 0, '37'),
 Text(8, 0, '42'),
 Text(9, 0, '47'),
 Text(10, 0, '52'),
 Text(11, 0, '57'),
 Text(12, 0, '62'),
 Text(13, 0, '67'),
 Text(14, 0, '72'),
 Text(15, 0, '77'),
 Text(16, 0, '82'),
 Text(17, 0, '87'),
 Text(18, 0, '92'),
 Text(19, 0, '97')])
```



From above graphs fix max_leaf_nodes = 20 and max_depth = 5 (also considering the case of overfitting)

In [15]:
```
#Training decisiontree
DT=DecisionTreeClassifier(criterion="entropy",max_depth=5, max_leaf_nodes=20)
DT.fit(X_train,y_train)
```

Out[15]:
```
DecisionTreeClassifier(criterion='entropy', max_depth=5, max_leaf_nodes=20)
```

In [16]:
```
#Predtion for test set and some metrics result
y_pred = DT.predict(X_test)
print("Accuracy:",metrics.accuracy_score(y_test, y_pred)*100,'%')
print("Precision:",metrics.precision_score(y_test, y_pred)*100,'%')
print("Recall:",metrics.recall_score(y_test, y_pred)*100,'%')
print("F1:",metrics.f1_score(y_test, y_pred)*100,'%')
```

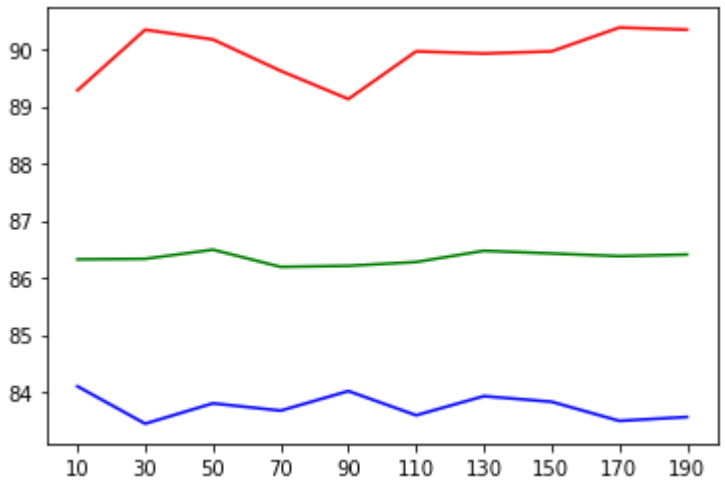
```
Accuracy: 85.27037176117162 %
Precision: 82.07123098201936 %
Recall: 89.92233377533624 %
F1: 85.81759016541625 %
```

Random Forest

In [17]:
```
#Checking for best number of trees
rec=[]
prec=[]
acc=[]
for i in range(10,200,20):
```

```
    clf=RandomForestClassifier(n_estimators=i,n_jobs=-1, max_depth=8)
    clf.fit(X_train,y_train.values.ravel())
    y_pred=clf.predict(X_test)
    rec.append(metrics.recall_score(y_test, y_pred)*100)
    prec.append(metrics.precision_score(y_test, y_pred)*100)
    acc.append(metrics.accuracy_score(y_test, y_pred)*100)

plt.plot(rec,'r')
plt.plot(prec,'b')
plt.plot(acc,'g')
plt.xticks(list(range(len(rec))), list(range(10,200,20)))
```

Out[17]:
```
([<matplotlib.axis.XTick at 0x1bd48732c70>,
  <matplotlib.axis.XTick at 0x1bd48732c10>,
  <matplotlib.axis.XTick at 0x1bd48746f40>,
  <matplotlib.axis.XTick at 0x1bd4991b340>,
  <matplotlib.axis.XTick at 0x1bd4991b850>,
  <matplotlib.axis.XTick at 0x1bd4991bd60>,
  <matplotlib.axis.XTick at 0x1bd499212b0>,
  <matplotlib.axis.XTick at 0x1bd499217c0>,
  <matplotlib.axis.XTick at 0x1bd4991b520>,
  <matplotlib.axis.XTick at 0x1bd48747460>],
 [Text(0, 0, '10'),
  Text(1, 0, '30'),
  Text(2, 0, '50'),
  Text(3, 0, '70'),
  Text(4, 0, '90'),
  Text(5, 0, '110'),
  Text(6, 0, '130'),
  Text(7, 0, '150'),
  Text(8, 0, '170'),
  Text(9, 0, '190')])
```



From the above graph fix n_estimators=100

In [18]:
```
#Training random forest
RF=RandomForestClassifier(n_estimators=100,n_jobs=-1, max_depth=8)
RF.fit(X_train,y_train.values.ravel())
```

Out[18]:
```
RandomForestClassifier(max_depth=8, n_jobs=-1)
```

In [19]:
```
#Predtion for test set and some metrics result
y_pred=RF.predict(X_test)
print("Accuracy:",metrics.accuracy_score(y_test, y_pred)*100,'%')
print("Precision:",metrics.precision_score(y_test, y_pred)*100,'%')
```

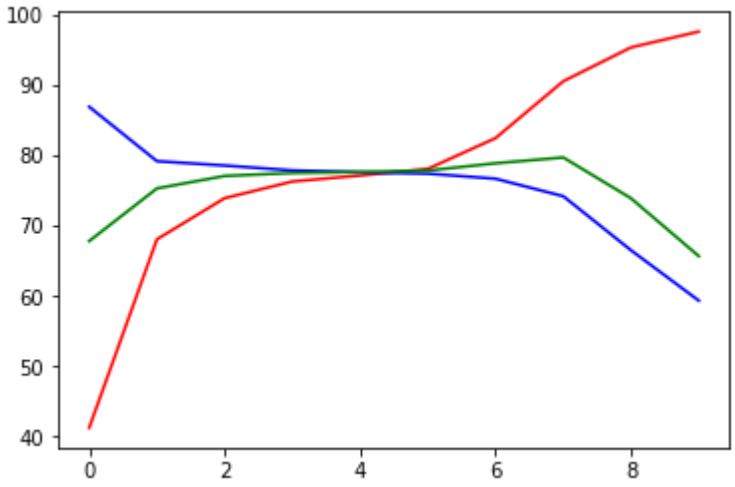
```
print("Recall:",metrics.recall_score(y_test, y_pred)*100,'%')
print("F1:",metrics.f1_score(y_test, y_pred)*100,'%')
```

```
Accuracy: 86.62223056702967 %
Precision: 84.1061946902655 %
Recall: 90.01704868346278 %
F1: 86.96129563546528 %
```

Naive Bayes

In [20]:
```
rec=[]
prec=[]
acc=[]
L = np.logspace(0,-9,num=100)
for j in range(0,len(L),10):
    i = L[j]
    model=GaussianNB(var_smoothing=i)
    model.fit(X_train,y_train.values.ravel())
    y_pred=model.predict(X_test)
    rec.append(metrics.recall_score(y_test, y_pred)*100)
    prec.append(metrics.precision_score(y_test, y_pred)*100)
    acc.append(metrics.accuracy_score(y_test, y_pred)*100)

plt.plot(rec,'r')
plt.plot(prec,'b')
plt.plot(acc,'g')
```

Out[20]:
```
[<matplotlib.lines.Line2D at 0x1bd4997c3a0>]
```



In [21]:
```
nb = GaussianNB()
params = {'priors':[None],
          'var_smoothing':np.logspace(0,-9,num=100)}

gs_NB = GridSearchCV(estimator=nb,
                     param_grid = params,
                     verbose = 1,
                     cv = 10,
                     n_jobs=-1)
gs_NB.fit(X_train,y_train.values.ravel())
```

```
Fitting 10 folds for each of 100 candidates, totalling 1000 fits
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done  42 tasks      | elapsed:   15.0s
```

```
[Parallel(n_jobs=-1)]: Done 192 tasks      | elapsed:   23.7s
[Parallel(n_jobs=-1)]: Done 442 tasks      | elapsed:   44.4s
[Parallel(n_jobs=-1)]: Done 792 tasks      | elapsed:  1.2min
[Parallel(n_jobs=-1)]: Done 1000 out of 1000 | elapsed:  1.4min finished
```

Out[21]:
```
GridSearchCV(cv=10, estimator=GaussianNB(), n_jobs=-1,
             param_grid={'priors': [None],
                         'var_smoothing': array([1.00000000e+00, 8.11130831e-01, 6.57933
225e-01, 5.33669923e-01,
       4.32876128e-01, 3.51119173e-01, 2.84803587e-01, 2.31012970e-01,
       1.87381742e-01, 1.51991108e-01, 1.23284674e-01, 1.00000000e-01,
       8.11130831e-02, 6.57933225e-02, 5.33669923e-02, 4.32876128e-02,
       3.51119...
       1.23284674e-07, 1.00000000e-07, 8.11130831e-08, 6.57933225e-08,
       5.33669923e-08, 4.32876128e-08, 3.51119173e-08, 2.84803587e-08,
       2.31012970e-08, 1.87381742e-08, 1.51991108e-08, 1.23284674e-08,
       1.00000000e-08, 8.11130831e-09, 6.57933225e-09, 5.33669923e-09,
       4.32876128e-09, 3.51119173e-09, 2.84803587e-09, 2.31012970e-09,
       1.87381742e-09, 1.51991108e-09, 1.23284674e-09, 1.00000000e-09])},
             verbose=1)
```

In [22]:
```
gs_NB.best_estimator_
```

Out[22]:
```
GaussianNB(var_smoothing=6.579332246575682e-07)
```

In [23]:
```
#Training naive bayes
NB = GaussianNB(var_smoothing=6.579332246575682e-07)
NB.fit(X_train,y_train.values.ravel())
```

Out[23]:
```
GaussianNB(var_smoothing=6.579332246575682e-07)
```

In [24]:
```
#predtion for test set and some metrics result
y_pred=NB.predict(X_test)
print("Accuracy:",metrics.accuracy_score(y_test, y_pred)*100,'%')
print("Precision:",metrics.precision_score(y_test, y_pred)*100,'%')
print("Recall:",metrics.recall_score(y_test, y_pred)*100,'%')
print("F1:",metrics.f1_score(y_test, y_pred)*100,'%')
```

```
Accuracy: 79.94742771310553 %
Precision: 75.13193667039822 %
Recall: 88.99412767569615 %
F1: 81.47762747138398 %
```

In [ ]:
```
```