In [ ]:
```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
```

In [ ]:
```
train_data = pd.read_csv("../data/train_u6lujuX_CVtuZ9i.csv")
train_data.head()
```

Out[ ]:

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	Applicant_Incom
0	LP001002	Male	No	0	Graduate	No	584
1	LP001003	Male	Yes	1	Graduate	No	458
2	LP001005	Male	Yes	0	Graduate	Yes	300
3	LP001006	Male	Yes	0	Not Graduate	No	258
4	LP001008	Male	No	0	Graduate	No	600

In [ ]:
```
print(train_data.shape)
```

```
(614, 13)
```

In [ ]:
```
train_data.describe()
```

Out[ ]:

	Applicant_Income	Coapplicant_Income	Loan_Amount	Loan_Amount_Term	Credit
count	614.000000	614.000000	592.000000	600.00000	56
mean	5403.459283	1621.245798	146.412162	342.00000	
std	6109.041673	2926.248369	85.587325	65.12041	
min	150.000000	0.000000	9.000000	12.00000	
25%	2877.500000	0.000000	100.000000	360.00000	
50%	3812.500000	1188.500000	128.000000	360.00000	
75%	5795.000000	2297.250000	168.000000	360.00000	
max	81000.000000	41667.000000	700.000000	480.00000	

In [ ]:
```
# variable types
train_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 614 entries, 0 to 613
Data columns (total 13 columns):
 #   Column               Non-Null Count  Dtype  
---  ------               --------------  -----  
 0   Loan_ID              614 non-null    object 
 1   Gender               601 non-null    object 
 2   Married              611 non-null    object 
 3   Dependents           599 non-null    object 
 4   Education            614 non-null    object 
 5   Self_Employed        582 non-null    object 
 6   Applicant_Income     614 non-null    int64  
 7   Coapplicant_Income   614 non-null    float64
 8   Loan_Amount          592 non-null    float64
 9   Loan_Amount_Term     600 non-null    float64
 10  Credit_History       564 non-null    float64
 11  Property_Area        614 non-null    object 
 12  Loan_Status          614 non-null    object 
dtypes: float64(4), int64(1), object(8)
memory usage: 62.5+ KB
```

In [ ]:
```
# count missing values per col
def missing_values(df):
    a = num_null_values = df.isnull().sum()
    return a
```

In [ ]:
```
missing_values(train_data)
```

Out[ ]:
```
Loan_ID                0
Gender                13
Married                3
Dependents            15
Education              0
Self_Employed         32
Applicant_Income       0
Coapplicant_Income     0
Loan_Amount           22
Loan_Amount_Term      14
Credit_History        50
Property_Area          0
Loan_Status            0
dtype: int64
```

In [ ]:
```
# drop cols, mutate df in place
# Dependents col includes 3+ value, which makes processing complicated -
train_data.drop(["Loan_ID","Dependents"], axis=1, inplace=True)
```

In [ ]:
```
train_data
```

Out[ ]:

	Gender	Married	Education	Self_Employed	Applicant_Income	Coapplicant_Income
0	Male	No	Graduate	No	5849	0.0
1	Male	Yes	Graduate	No	4583	1508.0
2	Male	Yes	Graduate	Yes	3000	0.0
3	Male	Yes	Not Graduate	No	2583	2358.0
4	Male	No	Graduate	No	6000	0.0
...	...	...	...	...	...	..
609	Female	No	Graduate	No	2900	0.0
610	Male	Yes	Graduate	No	4106	0.0
611	Male	Yes	Graduate	No	8072	240.0
612	Male	Yes	Graduate	No	7583	0.0
613	Female	No	Graduate	Yes	4583	0.0

614 rows × 11 columns

In [ ]:
```
### Dealing with null values [ categorical ] ###

cols = train_data[["Gender", "Married", "Self_Employed"]]
for i in cols:
    # fill missing values with mode of column, e.g. replace missing gende
    train_data[i].fillna(train_data[i].mode().iloc[0], inplace=True)
```

In [ ]:
```
# no more missing values for categorical features
train_data.isnull().sum()
```

Out[ ]:
```
Gender                 0
Married                0
Education              0
Self_Employed          0
Applicant_Income       0
Coapplicant_Income     0
Loan_Amount           22
Loan_Amount_Term      14
Credit_History        50
Property_Area          0
Loan_Status            0
dtype: int64
```

In [ ]:
```
## Dealing with Numerical Values missing_data ##
n_cols = train_data[["Loan_Amount", "Loan_Amount_Term", "Credit_History"]
for i in n_cols:
    # fill missing numerical values with mean of feature
    train_data[i].fillna(train_data[i].mean(axis=0), inplace=True)
```

In [ ]:
```
### Visualization ###
def bar_chart(col):
    Approved = train_data[train_data["Loan_Status"]=="Y"][col].value_coun
    Disapproved = train_data[train_data["Loan_Status"]=="N"][col].value_c

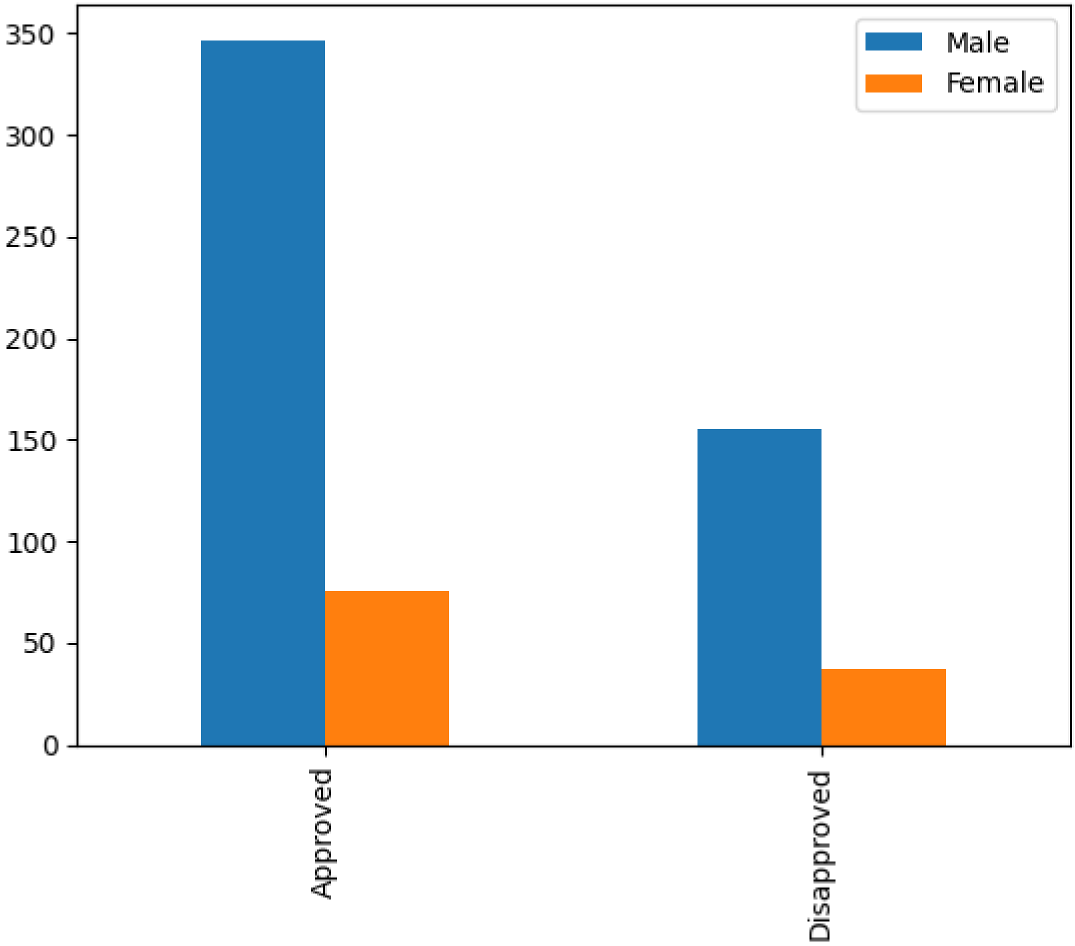
    print(Approved)
```

```
    print(Disapproved)

    df1 = pd.DataFrame([Approved, Disapproved])
    df1.index = ["Approved", "Disapproved"]
    df1.plot(kind="bar")
```

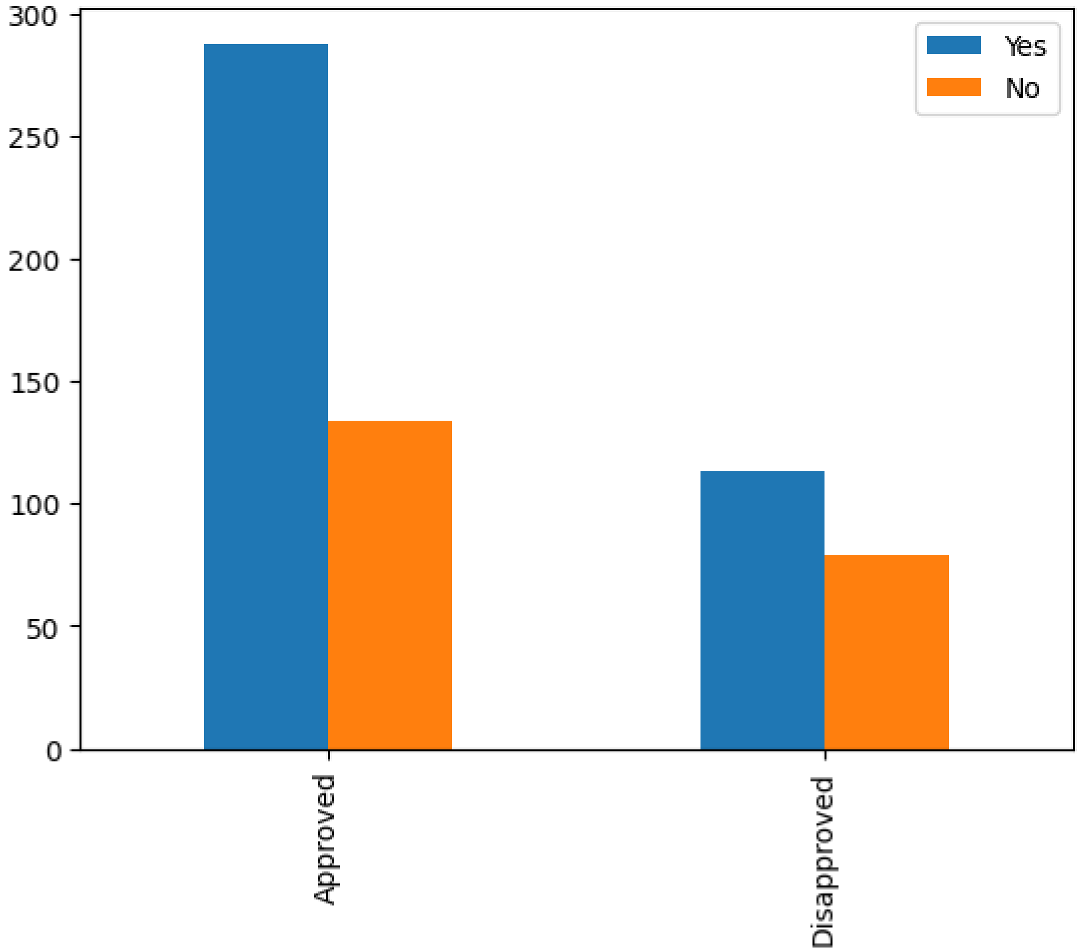
In [ ]:
```
bar_chart("Gender")
```

```
Male      347
Female     75
Name: Gender, dtype: int64
Male      155
Female     37
Name: Gender, dtype: int64
```



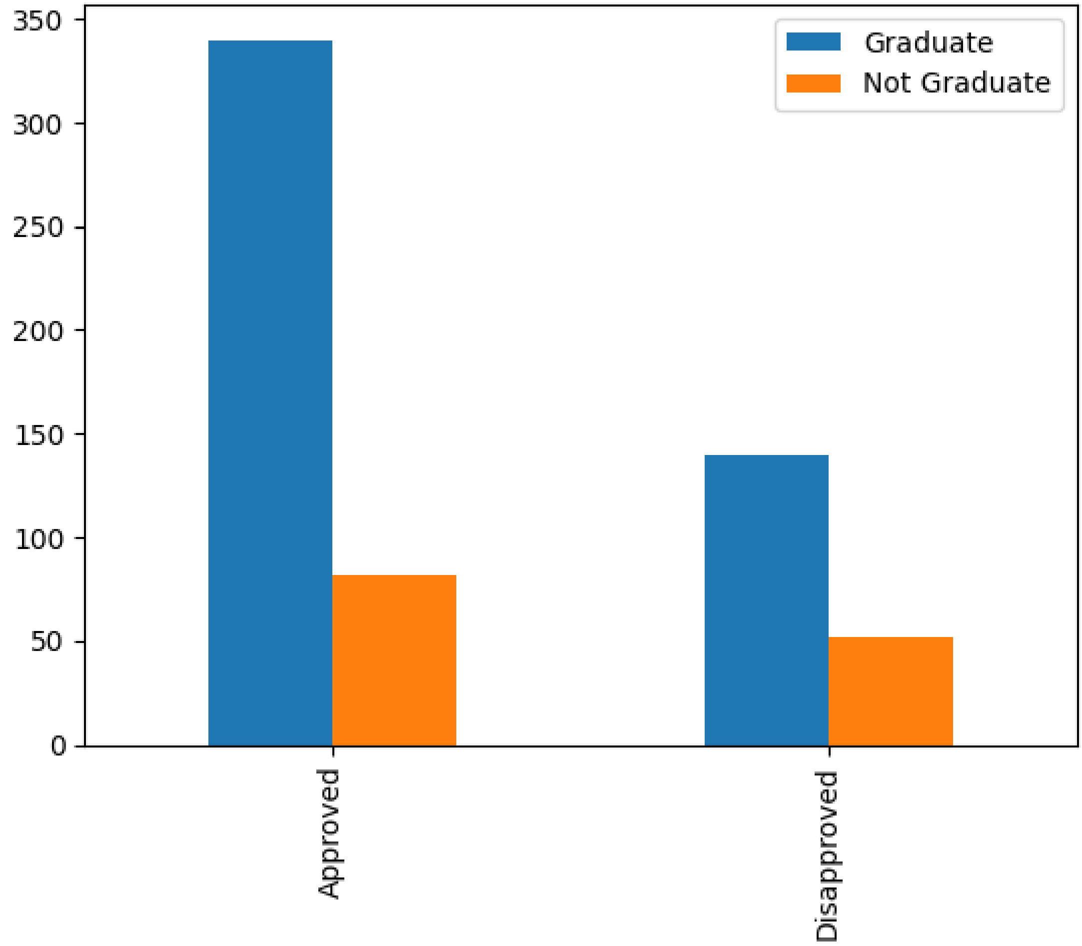
In [ ]:
```
bar_chart("Married")
```

```
Yes    288
No     134
Name: Married, dtype: int64
Yes    113
No      79
Name: Married, dtype: int64
```



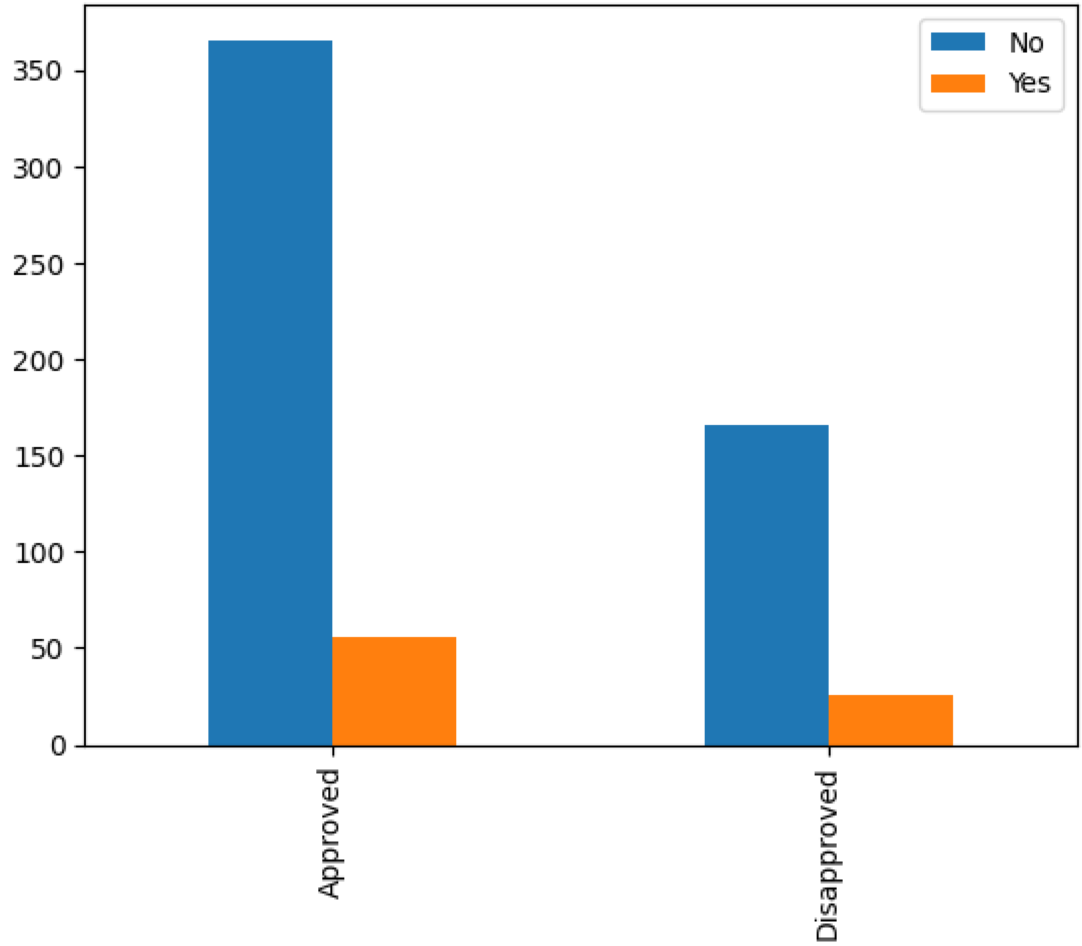
In [ ]:
```
bar_chart("Education")
```

```
Graduate        340
Not Graduate     82
Name: Education, dtype: int64
Graduate        140
Not Graduate     52
Name: Education, dtype: int64
```



In [ ]:
```
bar_chart("Self_Employed")
```

```
No     366
Yes     56
Name: Self_Employed, dtype: int64
No     166
Yes     26
Name: Self_Employed, dtype: int64
```



In [ ]:
```
from sklearn.preprocessing import OrdinalEncoder


ord_enc = OrdinalEncoder()
# encode categories into numbers so machine can understand
train_data[["Gender",'Married','Education','Self_Employed','Property_Area
train_data.head()
```

Out[ ]:

	Gender	Married	Education	Self_Employed	Applicant_Income	Coapplicant_Income
0	1.0	0.0	0.0	0.0	5849	0.0
1	1.0	1.0	0.0	0.0	4583	1508.0
2	1.0	1.0	0.0	1.0	3000	0.0
3	1.0	1.0	1.0	0.0	2583	2358.0
4	1.0	0.0	0.0	0.0	6000	0.0

In [ ]:
```
train_data[["Gender",'Married','Education','Self_Employed','Property_Area
```

In [ ]:
```
train_data
```

Out[ ]:

	Gender	Married	Education	Self_Employed	Applicant_Income	Coapplicant_Income
0	1	0	0	0	5849	0.0
1	1	1	0	0	4583	1508.0
2	1	1	0	1	3000	0.0
3	1	1	1	0	2583	2358.0
4	1	0	0	0	6000	0.0
...	...	...	...	...	...	..
609	0	0	0	0	2900	0.0
610	1	1	0	0	4106	0.0
611	1	1	0	0	8072	240.0
612	1	1	0	0	7583	0.0
613	0	0	0	1	4583	0.0

614 rows × 11 columns

In [ ]:

```
from sklearn.model_selection import train_test_split
# remove target variable from feature set
X = train_data.drop("Loan_Status", axis=1)
# store target variable in y
y = train_data["Loan_Status"]


X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
print(X_train.shape)
print(y_train.shape)
print(X_test.shape)
print(y_test.shape)
```

```
(491, 10)
(491,)
(123, 10)
(123,)
```

In [ ]:

```
from sklearn.naive_bayes import GaussianNB
# data follows normal distribution

gfc = GaussianNB()
# learn what kind of features result in which kind of loan statuses
gfc.fit(X_train, y_train)
# run against X_test
pred1 = gfc.predict(X_test)
```

In [ ]:

```
from sklearn.metrics import precision_score, recall_score, accuracy_score

# why use precision and recall? when dataset is imbalanced
def loss(y_true, y_pred):
    # how many correct TP / TP+FP
    pre = precision_score(y_true, y_pred)
    # how many correct TP / TP+FN
    rec = recall_score(y_true, y_pred)
    acc = accuracy_score(y_true, y_pred)
```

```
    print('precision', pre)
    print('recall', rec)
    print('accuracy', acc)
```

In [ ]:
```
loss(y_test, pred1)
```

```
precision 0.7920792079207921
recall 0.9523809523809523
accuracy 0.7967479674796748
```

In [ ]:
```
from sklearn.svm import SVC
from sklearn.model_selection import GridSearchCV

# defining parameter range
param_grid = {
  'C': [0.1, 1, 10, 100, 1000],
  'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
  'kernel': ['rbf']
}
grid = GridSearchCV(SVC(), param_grid, refit=True, verbose=3)
grid.fit(X_train, y_train)
```

```
Fitting 5 folds for each of 25 candidates, totalling 125 fits
[CV 1/5] END ........C=0.1, gamma=1, kernel=rbf;, score=0.687 total time
=   0.0s
[CV 2/5] END ........C=0.1, gamma=1, kernel=rbf;, score=0.684 total time
=   0.0s
[CV 3/5] END ........C=0.1, gamma=1, kernel=rbf;, score=0.684 total time
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[CV 4/5] END ........C=0.1, gamma=1, kernel=rbf;, score=0.694 total time
=   0.0s
[CV 5/5] END ........C=0.1, gamma=1, kernel=rbf;, score=0.694 total time
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[CV 1/5] END ......C=0.1, gamma=0.1, kernel=rbf;, score=0.687 total time
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[CV 2/5] END ......C=0.1, gamma=0.1, kernel=rbf;, score=0.684 total time
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[CV 3/5] END ......C=0.1, gamma=0.1, kernel=rbf;, score=0.684 total time
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[CV 4/5] END ......C=0.1, gamma=0.1, kernel=rbf;, score=0.694 total time
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[CV 5/5] END ......C=0.1, gamma=0.1, kernel=rbf;, score=0.694 total time
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[CV 1/5] END .....C=0.1, gamma=0.01, kernel=rbf;, score=0.687 total time
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[CV 2/5] END .....C=0.1, gamma=0.01, kernel=rbf;, score=0.684 total time
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[CV 3/5] END .....C=0.1, gamma=0.01, kernel=rbf;, score=0.684 total time
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[CV 4/5] END .....C=0.1, gamma=0.01, kernel=rbf;, score=0.694 total time
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[CV 2/5] END ....C=0.1, gamma=0.001, kernel=rbf;, score=0.684 total time
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[CV 3/5] END ....C=0.1, gamma=0.001, kernel=rbf;, score=0.684 total time
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[CV 4/5] END ....C=0.1, gamma=0.001, kernel=rbf;, score=0.694 total time
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[CV 5/5] END ....C=0.1, gamma=0.001, kernel=rbf;, score=0.694 total time
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[CV 1/5] END ...C=0.1, gamma=0.0001, kernel=rbf;, score=0.687 total time
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[CV 2/5] END ...C=0.1, gamma=0.0001, kernel=rbf;, score=0.684 total time
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[CV 3/5] END ...C=0.1, gamma=0.0001, kernel=rbf;, score=0.684 total time
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[CV 4/5] END ...C=0.1, gamma=0.0001, kernel=rbf;, score=0.694 total time
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[CV 5/5] END ...C=0.1, gamma=0.0001, kernel=rbf;, score=0.694 total time
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[CV 1/5] END ..........C=1, gamma=1, kernel=rbf;, score=0.687 total time
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[CV 2/5] END ..........C=1, gamma=1, kernel=rbf;, score=0.684 total time
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[CV 3/5] END ..........C=1, gamma=1, kernel=rbf;, score=0.684 total time
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[CV 4/5] END ..........C=1, gamma=1, kernel=rbf;, score=0.694 total time
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[CV 5/5] END ..........C=1, gamma=1, kernel=rbf;, score=0.694 total time
```

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[CV 1/5] END ........C=1, gamma=0.1, kernel=rbf;, score=0.697 total time
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[CV 3/5] END ........C=1, gamma=0.1, kernel=rbf;, score=0.684 total time
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[CV 4/5] END ........C=1, gamma=0.1, kernel=rbf;, score=0.694 total time
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[CV 5/5] END ........C=1, gamma=0.1, kernel=rbf;, score=0.704 total time
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[CV 1/5] END .......C=1, gamma=0.01, kernel=rbf;, score=0.697 total time
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[CV 1/5] END .....C=1, gamma=0.0001, kernel=rbf;, score=0.646 total time
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[CV 2/5] END .....C=1, gamma=0.0001, kernel=rbf;, score=0.653 total time
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[CV 1/5] END ....C=10, gamma=0.0001, kernel=rbf;, score=0.616 total time
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[CV 3/5] END ....C=10, gamma=0.0001, kernel=rbf;, score=0.622 total time
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[CV 4/5] END ....C=10, gamma=0.0001, kernel=rbf;, score=0.622 total time
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[CV 1/5] END ......C=100, gamma=0.1, kernel=rbf;, score=0.697 total time
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[CV 3/5] END ......C=100, gamma=0.1, kernel=rbf;, score=0.684 total time
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[CV 5/5] END ......C=100, gamma=0.1, kernel=rbf;, score=0.704 total time
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[CV 1/5] END .....C=100, gamma=0.01, kernel=rbf;, score=0.697 total time
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[CV 5/5] END ....C=100, gamma=0.001, kernel=rbf;, score=0.714 total time
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[CV 1/5] END ...C=100, gamma=0.0001, kernel=rbf;, score=0.606 total time
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[CV 2/5] END ...C=100, gamma=0.0001, kernel=rbf;, score=0.592 total time
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[CV 3/5] END ...C=100, gamma=0.0001, kernel=rbf;, score=0.582 total time
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[CV 4/5] END ...C=100, gamma=0.0001, kernel=rbf;, score=0.622 total time
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[CV 5/5] END ...C=100, gamma=0.0001, kernel=rbf;, score=0.673 total time
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[CV 3/5] END .......C=1000, gamma=1, kernel=rbf;, score=0.684 total time
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[CV 4/5] END .....C=1000, gamma=0.1, kernel=rbf;, score=0.694 total time
= 0.0s
[CV 5/5] END .....C=1000, gamma=0.1, kernel=rbf;, score=0.704 total time
= 0.0s
[CV 1/5] END ....C=1000, gamma=0.01, kernel=rbf;, score=0.697 total time
= 0.0s
[CV 2/5] END ....C=1000, gamma=0.01, kernel=rbf;, score=0.684 total time
= 0.0s
[CV 3/5] END ....C=1000, gamma=0.01, kernel=rbf;, score=0.684 total time
= 0.0s
[CV 4/5] END ....C=1000, gamma=0.01, kernel=rbf;, score=0.673 total time
= 0.0s
[CV 5/5] END ....C=1000, gamma=0.01, kernel=rbf;, score=0.704 total time
= 0.0s
[CV 1/5] END ...C=1000, gamma=0.001, kernel=rbf;, score=0.677 total time
= 0.0s
[CV 2/5] END ...C=1000, gamma=0.001, kernel=rbf;, score=0.653 total time
= 0.0s
[CV 3/5] END ...C=1000, gamma=0.001, kernel=rbf;, score=0.694 total time
= 0.0s
[CV 4/5] END ...C=1000, gamma=0.001, kernel=rbf;, score=0.673 total time
= 0.0s
[CV 5/5] END ...C=1000, gamma=0.001, kernel=rbf;, score=0.714 total time
```

```
=   0.0s
[CV 1/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.606 total time
=   0.0s
[CV 2/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.582 total time
=   0.0s
[CV 3/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.592 total time
=   0.0s
[CV 4/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.622 total time
=   0.0s
[CV 5/5] END ..C=1000, gamma=0.0001, kernel=rbf;, score=0.673 total time
=   0.0s
```

Out[ ]: ▸ **GridSearchCV**

▸ **estimator: SVC**

▸ SVC

In [ ]:
```
grid.best_params_
```

Out[ ]: {'C': 1, 'gamma': 0.1, 'kernel': 'rbf'}

In [ ]:
```
svc = SVC(C= 0.1, gamma= 1, kernel= 'rbf')
svc.fit(X_train, y_train)
pred2 = svc.predict(X_test)
loss(y_test,pred2)
```

```
precision 0.6829268292682927
recall 1.0
accuracy 0.6829268292682927
```

In [ ]:
```
from xgboost import XGBClassifier

xgb = XGBClassifier(learning_rate=0.1,
 n_estimators=1000,
 max_depth=3,
 min_child_weight=1,
 gamma=0,
 subsample=0.8,
 colsample_bytree=0.8,
 objective= 'binary:logistic',
 nthread=4,
 scale_pos_weight=1,
 seed=27)
xgb.fit(X_train, y_train)
pred3 = xgb.predict(X_test)
loss(y_test, pred3)
```

```
precision 0.8152173913043478
recall 0.8928571428571429
accuracy 0.7886178861788617
```

In [ ]:
```
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import RandomizedSearchCV

def randomized_search(params, runs=20, clf=DecisionTreeClassifier(random_
    rand_clf = RandomizedSearchCV(clf, params, n_iter=runs, cv=5, n_jobs=
    rand_clf.fit(X_train, y_train)
    best_model = rand_clf.best_estimator_
```

```
    # Extract best score
    best_score = rand_clf.best_score_

    # Print best score
    print("Training score: {:.3f}".format(best_score))

    # Predict test set labels
    y_pred = best_model.predict(X_test)

    # Compute accuracy
    accuracy = accuracy_score(y_test, y_pred)

    # Print accuracy
    print('Test score: {:.3f}'.format(accuracy))

    return best_model
```

In [ ]:

```
randomized_search(params={'criterion':['entropy', 'gini'],
                              'splitter':['random', 'best'],
                          'min_weight_fraction_leaf':[0.0, 0.0025, 0.005,
                          'min_samples_split':[2, 3, 4, 5, 6, 8, 10],
                          'min_samples_leaf':[1, 0.01, 0.02, 0.03, 0.04],
                          'min_impurity_decrease':[0.0, 0.0005, 0.005, 0.
                          'max_leaf_nodes':[10, 15, 20, 25, 30, 35, 40, 4
                          'max_features':[0.95, 0.90, 0.85, 0.80, 0.75, 0
                          'max_depth':[None, 2,4,6,8],
                          'min_weight_fraction_leaf':[0.0, 0.0025, 0.005,
                         })
```

```
Training score: 0.811
Test score: 0.805
```

Out[ ]:

```
DecisionTreeClassifier

DecisionTreeClassifier(criterion='entropy', max_depth=2, max_feat
ures=0.95,
                       min_samples_leaf=0.04, min_samples_split=
6,
                       random_state=2)
```

In [ ]:

```
ds = DecisionTreeClassifier(max_depth=8, max_features=0.9, max_leaf_nodes
                       min_impurity_decrease=0.05, min_samples_leaf=0.02,
                       min_samples_split=10, min_weight_fraction_leaf=0.0
                       random_state=2, splitter='random')
ds.fit(X_train, y_train)
pred4 =ds.predict(X_test)
loss(y_test, pred4)
```

```
precision 0.7830188679245284
recall 0.9880952380952381
accuracy 0.8048780487804879
```

In [ ]:

```
from sklearn.ensemble import RandomForestClassifier

randomized_search(params={
                         'min_samples_leaf':[1,2,4,6,8,10,20,30],
                          'min_impurity_decrease':[0.0, 0.01, 0.05, 0.10,
                          'max_features':[0.8, 0.7, 0.6, 0.5, 0.4],
```

```
                                    'max_depth':[None,2,4,6,8,10,20],
                                   }, clf=RandomForestClassifier(random_state=2))
```

```
Training score: 0.813
Test score: 0.805
```

Out[ ]:

```
▾ RandomForestClassifier
RandomForestClassifier(max_depth=10, max_features=0.4, min_samples_leaf=6,
                       random_state=2)
```

In [ ]:

```
import joblib
joblib.dump(ds, "model.pkl")
model = joblib.load('model.pkl' )
model.predict(X_test.iloc[[0,1],:])
```

Out[ ]:

```
array([1, 1])
```

In [ ]: