

MACHINE LEARNING TECHNIQUES

GROUP 04

AANCHAL SRIVASTAVA - B001

ANMOL SETHI - B008

PRAGYA SAJWAN - B033

SHIVANI JOGI - B040

SWARNA DUBEY -B043

YASH BANSAL -B050

Logistic Regression for Churn Prediction Dataset

Sourcing the data

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

Data set

```
churn=pd.read_csv('churn_prediction1.csv')
```

churn

	customer_id	vintage	age	gender	dependents	occupation	\
0	1	3135	66	Male	0.0	self_employed	
1	2	310	35	Male	0.0	self_employed	
2	4	2356	31	Male	0.0	salaried	
3	5	478	90	NaN	NaN	self_employed	
4	6	2531	42	Male	2.0	self_employed	
...	
1295	1380	766	10	Female	0.0	student	
1296	1381	1314	49	Female	0.0	self_employed	
1297	1382	2993	59	Male	4.0	salaried	
1298	1383	1766	13	Male	0.0	student	
1299	1384	7306	77	Female	0.0	self_employed	

	city	customer_nw_category	branch_code	\
0	Chicago	2	755	
1	NaN	2	3214	
2	Chicago	2	41	

3	Revere	2	582
4	Arlington	3	388
...
1295	Los Angeles	2	2497
1296	NaN	3	1349
1297	Philadelphia	3	411
1298	Philadelphia	1	542
1299	Philadelphia	1	240

	days_since_last_transaction	...	previous_month_end_balance	\
0	224.0	...	1458.71	
1	60.0	...	8704.66	
2	NaN	...	5815.29	
3	147.0	...	2291.91	
4	58.0	...	1401.72	
...	
1295	27.0	...	119.03	
1296	97.0	...	15383.49	
1297	0.0	...	4116.26	
1298	339.0	...	4545.45	
1299	62.0	...	15014.05	

	average_monthly_balance_prevQ	average_monthly_balance_prevQ2	\
0	1458.71	1449.07	
1	7799.26	12419.41	
2	4910.17	2815.94	
3	2084.54	1006.54	
4	1643.31	1871.12	
...	
1295	2419.19	118.29	
1296	16546.57	7883.34	
1297	3775.87	3463.84	
1298	4512.45	4272.54	
1299	13910.17	23436.02	

	current_month_credit	previous_month_credit	current_month_debit
\			
0	0.20	0.20	0.20
1	0.56	0.56	5486.27
2	0.61	0.61	6046.73
3	0.47	0.47	0.47
4	0.33	714.61	588.62
...

1295	7630.32	0.21	963.42
1296	0.54	0.54	1725.80
1297	1321.96	773.34	142.89
1298	0.23	0.23	0.23
1299	0.34	0.34	180.13

	previous_month_debit	current_month_balance
previous_month_balance \		
0	0.20	1458.71
1458.71		
1	100.56	6496.78
8787.61		
2	259.23	5006.28
5070.14		
3	2143.33	2291.91
1669.79		
4	1538.06	1157.15
1677.16		
...
...		
1295	0.21	7019.52
119.03		
1296	2502.37	14993.75
16766.38		
1297	407.17	3991.89
3690.78		
1298	0.23	4582.40
4513.19		
1299	73.78	14890.06
14461.60		

	churn
0	0
1	0
2	0
3	1
4	1
...	...
1295	1
1296	0
1297	0
1298	0
1299	0

[1300 rows x 21 columns]

churn.info()

<class 'pandas.core.frame.DataFrame'>

RangeIndex: 1300 entries, 0 to 1299

Data columns (total 21 columns):

#	Column	Non-Null Count	Dtype
0	customer_id	1300 non-null	int64
1	vintage	1300 non-null	int64
2	age	1300 non-null	int64
3	gender	1275 non-null	object
4	dependents	1189 non-null	float64
5	occupation	1293 non-null	object
6	city	1258 non-null	object
7	customer_nw_category	1300 non-null	int64
8	branch_code	1300 non-null	int64
9	days_since_last_transaction	1149 non-null	float64
10	current_balance	1300 non-null	float64
11	previous_month_end_balance	1300 non-null	float64
12	average_monthly_balance_prevQ	1300 non-null	float64
13	average_monthly_balance_prevQ2	1300 non-null	float64
14	current_month_credit	1300 non-null	float64
15	previous_month_credit	1300 non-null	float64
16	current_month_debit	1300 non-null	float64
17	previous_month_debit	1300 non-null	float64
18	current_month_balance	1300 non-null	float64
19	previous_month_balance	1300 non-null	float64
20	churn	1300 non-null	int64

dtypes: float64(12), int64(6), object(3)

memory usage: 213.4+ KB

churn.isnull().sum()

customer_id	0
vintage	0
age	0
gender	25
dependents	111
occupation	7
city	42
customer_nw_category	0
branch_code	0
days_since_last_transaction	151
current_balance	0
previous_month_end_balance	0
average_monthly_balance_prevQ	0
average_monthly_balance_prevQ2	0
current_month_credit	0

```

previous_month_credit      0
current_month_debit        0
previous_month_debit        0
current_month_balance       0
previous_month_balance      0
churn                      0
dtype: int64

```

```
churn.dropna(inplace=True)
```

```
churn.isnull().sum()
```

```

customer_id      0
vintage          0
age             0
gender           0
dependents       0
occupation       0
city            0
customer_nw_category  0
branch_code      0
days_since_last_transaction  0
current_balance  0
previous_month_end_balance  0
average_monthly_balance_prevQ  0
average_monthly_balance_prevQ2  0
current_month_credit  0
previous_month_credit  0
current_month_debit  0
previous_month_debit  0
current_month_balance  0
previous_month_balance  0
churn             0
dtype: int64

```

Preprocessing of the data

Target

```
y = churn['churn']
```

```
type(churn)
```

```
pandas.core.frame.DataFrame
```

```
y.unique()
```

```
array([0, 1], dtype=int64)
```

Only two classes- binary classification.

```
# Features
```

```
X=churn.drop(['churn'],axis=1)
```

```
X.shape
```

```
(1001, 20)
```

```
X.columns
```

```
Index(['customer_id', 'vintage', 'age', 'gender', 'dependents',  
      'occupation',  
      'city', 'customer_nw_category', 'branch_code',  
      'days_since_last_transaction', 'current_balance',  
      'previous_month_end_balance', 'average_monthly_balance_prevQ',  
      'average_monthly_balance_prevQ2', 'current_month_credit',  
      'previous_month_credit', 'current_month_debit',  
      'previous_month_debit',  
      'current_month_balance', 'previous_month_balance'],  
      dtype='object')
```

```
category_cols=['customer_id', 'vintage', 'age', 'gender',  
              'dependents', 'occupation',  
              'city', 'customer_nw_category', 'branch_code',  
              'days_since_last_transaction', 'current_balance',  
              'previous_month_end_balance', 'average_monthly_balance_prevQ',  
              'average_monthly_balance_prevQ2', 'current_month_credit',  
              'previous_month_credit', 'current_month_debit',  
              'previous_month_debit',  
              'current_month_balance', 'previous_month_balance']
```

```
len(category_cols)
```

```
20
```

```
# Converting categorical features to numeric
```

```
X_1 = churn.drop(['churn'],axis=1)
```

```
X_1.shape
```

```
(1001, 20)
```

```
# Adding constant
```

```
import statsmodels.api as sm  
X_1=sm.add_constant(X_1)  
X_1.shape
```

```
(1001, 21)
```

```
X_1.iloc[0:10,0:20]
```

	const	customer_id	vintage	age	gender	dependents
0	1.0	1	3135	66	Male	0.0
4	1.0	6	2531	42	Male	2.0
5	1.0	7	263	42	Female	0.0
6	1.0	8	5922	72	Male	0.0
7	1.0	9	1145	46	Male	0.0
8	1.0	10	2132	31	Male	0.0
9	1.0	11	3379	40	Male	3.0
10	1.0	12	661	68	Male	0.0
11	1.0	13	7108	32	Male	0.0
12	1.0	14	2438	73	Male	0.0

	city	customer_nw_category	branch_code
0	Chicago	2	755
4	Arlington	3	388
5	Cambridge	2	1666
6	Revere	1	1
7	Arvada	2	317
8	Cambridge	2	4110
9	Columbus	2	38
10	Detroit	3	709
11	Morristown	1	89
12	New York City	3	409

	days_since_last_transaction	current_balance
0	224.0	1458.71
4	58.0	927.72
5	60.0	15202.20
6	98.0	7006.93
7	172.0	10096.58
8	19.0	1355.86

1355.86		
9	0.0	4957.95
4244.38		
10	5.0	1928.76
1571.47		
11	20.0	6886.40
8372.64		
12	47.0	554.38
5728.66		

	average_monthly_balance_prevQ	average_monthly_balance_prevQ2	\
0	1458.71	1449.07	
4	1643.31	1871.12	
5	15211.29	13798.82	
6	7859.74	11232.37	
7	6511.82	16314.17	
8	1702.44	1126.13	
9	2168.53	1864.33	
10	1722.60	747.66	
11	9149.45	21007.52	
12	1794.39	137.25	

	current_month_credit	previous_month_credit	
current_month_debit	\		
0	0.20	0.20	0.20
4	0.33	714.61	588.62
5	0.36	0.36	857.50
6	0.64	0.64	1299.64
7	0.27	0.27	443.13
8	714.51	121.09	714.51
9	6912.29	4206.13	1887.30
10	443.40	0.54	0.54
11	7564.53	4550.24	9907.91
12	0.33	500.33	5098.90

	previous_month_debit	current_month_balance
0	0.20	1458.71
4	1538.06	1157.15
5	286.07	15719.44

6	439.26	7076.06
7	5688.44	8563.84
8	359.44	1183.45
9	1348.85	1823.16
10	208.79	1606.54
11	5161.96	8532.97
12	508.53	2541.22

```
X_1.iloc[0:10,20:40]
```

	previous_month_balance
0	1458.71
4	1677.16
5	15349.75
6	7755.98
7	5317.04
8	1857.42
9	2416.69
10	1800.15
11	8072.33
12	2612.60

```
#X_1=X_1.drop(['gender'],axis=1)
X_1=X_1.drop(['city'],axis=1)
X_1=X_1.drop(['occupation'],axis=1)
```

Splitting to train and test

```
from sklearn.model_selection import train_test_split
```

```
X_train_1,X_test_1,y_train_1,y_test_1=train_test_split(
    X_1,y,test_size=0.2,random_state=10)
```

```
X_train_1.shape,X_test_1.shape,y_train_1.shape,y_test_1.shape
((800, 18), (201, 18), (800,), (201,))
```

```
type(X_train_1)
```

```
pandas.core.frame.DataFrame
```

Building the model

```
logR_1=sm.Logit(y_train_1,X_train_1)
```

```
# Fit the model
```

```
logR_1=logR_1.fit()
```

```
Optimization terminated successfully.
      Current function value: 0.424048
      Iterations 8
```

Diagnosing the model

```
logR_1.summary2()
```

```
<class 'statsmodels.iolib.summary2.Summary'>
"""
```

Results: Logit

```
=====
Model:                                Logit                                Pseudo R-squared:
0.153
Dependent Variable:                    churn                                AIC:
714.4770
Date:                                2022-12-10 22:49                        BIC:
798.8000
No. Observations:                      800                                Log-Likelihood:      -
339.24
Df Model:                             17                                LL-Null:             -
400.32
Df Residuals:                         782                                LLR p-value:
5.9544e-18
Converged:                             1.0000                                Scale:
1.0000
No. Iterations:                       8.0000
```

```
-----
-----
                                Coef.  Std.Err.    z    P>|z|    [0.025
0.975]
-----
-----
const                            -0.4061    0.5385  -0.7541  0.4508  -1.4616
0.6494
customer_id                      -0.0002    0.0002  -0.6863  0.4925  -0.0006
0.0003
vintage                          -0.0001    0.0001  -1.8297  0.0673  -0.0003
0.0000
age                              -0.0011    0.0062  -0.1845  0.8536  -0.0134
0.0111
dependents                       -0.0133    0.1051  -0.1261  0.8997  -0.2192
0.1927
customer_nw_category             -0.0845    0.1551  -0.5445  0.5861  -0.3885
0.2196
branch_code                      0.0001    0.0001   0.4646  0.6422  -0.0002
0.0003
days_since_last_transaction     -0.0018    0.0014  -1.3503  0.1769  -0.0045
0.0008
current_balance                  -0.0004    0.0001  -5.2830  0.0000  -0.0005
-0.0002
previous_month_end_balance       0.0000    0.0000   0.9432  0.3456  -0.0000
0.0001
```

average_monthly_balance_prevQ	0.0002	0.0001	2.6857	0.0072	0.0001
0.0004					
average_monthly_balance_prevQ2	0.0000	0.0000	0.3723	0.7097	-0.0000
0.0001					
current_month_credit	-0.0000	0.0000	-0.9000	0.3681	-0.0000
0.0000					
previous_month_credit	0.0000	0.0000	1.8072	0.0707	-0.0000
0.0001					
current_month_debit	0.0000	0.0000	0.0862	0.9313	-0.0000
0.0000					
previous_month_debit	-0.0000	0.0000	-0.3263	0.7442	-0.0001
0.0000					
current_month_balance	0.0000	0.0001	0.4992	0.6176	-0.0001
0.0002					
previous_month_balance	-0.0000	0.0001	-0.6405	0.5218	-0.0002
0.0001					

=====

=====

"""

Features with $p < 0.05$

imp_features_1= ['average_monthly_balance_prevQ', 'current_balance']

Update the feature set

X_2=X_1[imp_features_1]

X_2

	average_monthly_balance_prevQ	current_balance
0	1458.71	1458.71
4	1643.31	927.72
5	15211.29	15202.20
6	7859.74	7006.93
7	6511.82	10096.58
...
1294	11546.06	14734.45
1295	2419.19	6785.93
1297	3775.87	5209.62
1298	4512.45	4616.88
1299	13910.17	14834.26

[1001 rows x 2 columns]

Continue with revise feature set

```
X_train_2,X_test_2,y_train_2,y_test_2=train_test_split(
    X_2,y,test_size=0.2,random_state=10)
```

```
X_train_2.shape,X_test_2.shape,y_train_2.shape,y_test_2.shape
((800, 2), (201, 2), (800,), (201,))
```

Building the model

```
logR_2= sm.Logit(y_train_2,X_train_2)
logR_2=logR_2.fit()
logR_2.summary2()
```

```
Optimization terminated successfully.
      Current function value: 0.479419
      Iterations 7
```

```
<class 'statsmodels.iolib.summary2.Summary'>
"""
```

Results: Logit

```
=====
=====
Model:                      Logit                      Pseudo R-squared:
0.042
Dependent Variable:         churn                      AIC:
771.0709
Date:                       2022-12-10 22:52           BIC:
780.4401
No. Observations:           800                      Log-Likelihood:      -
383.54
Df Model:                   1                        LL-Null:              -
400.32
Df Residuals:               798                      LLR p-value:
6.8640e-09
Converged:                  1.0000                    Scale:
1.0000
No. Iterations:             7.0000

-----
-----
                                Coef.  Std.Err.    z      P>|z|    [0.025
0.975]
-----
-----
average_monthly_balance_prevQ  0.0002    0.0000    5.0051  0.0000    0.0001
0.0002
current_balance                -0.0005    0.0000 -10.0018  0.0000   -0.0006
-0.0004
=====
=====
```

```
"""
```

```
# Variance Inflation Factor > 4
```

```
from statsmodels.stats.outliers_influence import  
variance_inflation_factor
```

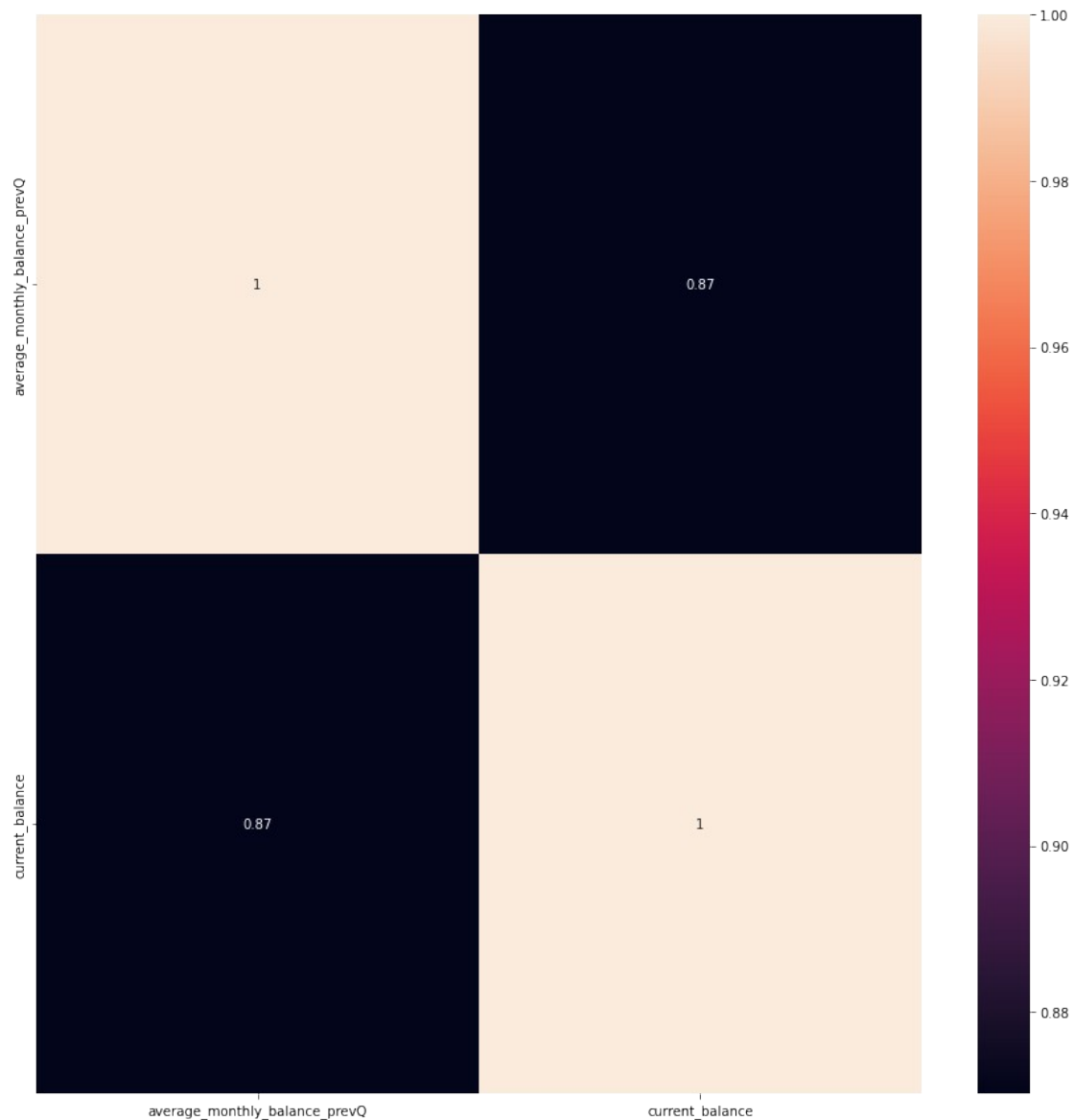
```
def var_inf_factor(data):  
    vif=pd.DataFrame()  
    vif['Feature']=data.columns  
    vif['VIF_Value']=[variance_inflation_factor(data.values,i)  
                     for i in range(data.shape[1])]  
    print(vif)
```

```
# Calling the fn
```

```
var_inf_factor(X_2)
```

	Feature	VIF_Value
0	average_monthly_balance_prevQ	4.989556
1	current_balance	4.989556

```
plt.figure(figsize=(15,15))  
sns.heatmap(X_2.corr(),annot=True);
```



Singnificant features

```
imp_features_2=['average_monthly_balance_prevQ', 'current_balance']
```

```
X_3=X_2[imp_features_2]
```

```
X_3
```

	average_monthly_balance_prevQ	current_balance
0	1458.71	1458.71
4	1643.31	927.72
5	15211.29	15202.20
6	7859.74	7006.93
7	6511.82	10096.58
...
1294	11546.06	14734.45

1295	2419.19	6785.93
1297	3775.87	5209.62
1298	4512.45	4616.88
1299	13910.17	14834.26

[1001 rows x 2 columns]

Continue with revised feature set

```
X_train_3,X_test_3,y_train_3,y_test_3=train_test_split(
    X_3,y,test_size=0.2,random_state=10)
```

```
X_train_3.shape,X_test_3.shape,y_train_3.shape,y_test_3.shape
```

```
((800, 2), (201, 2), (800,), (201,))
```

Building the model

```
logR_3=sm.Logit(y_train_3,X_train_3)
logR_3=logR_3.fit()
logR_3.summary2()
```

```
Optimization terminated successfully.
      Current function value: 0.479419
      Iterations 7
```

```
<class 'statsmodels.iolib.summary2.Summary'>
"""
```

Results: Logit

```
=====
=====
Model:                Logit                Pseudo R-squared:
0.042
Dependent Variable:   churn                AIC:
771.0709
Date:                2022-12-10 22:53        BIC:
780.4401
No. Observations:    800                Log-Likelihood:    -
383.54
Df Model:            1                LL-Null:            -
400.32
Df Residuals:        798                LLR p-value:
6.8640e-09
Converged:           1.0000                Scale:
1.0000
No. Iterations:      7.0000
```

```
-----
-----
                        Coef.  Std.Err.    z    P>|z|    [0.025
0.975]
```

```
-----
-----
```

```
average_monthly_balance_prevQ  0.0002    0.0000    5.0051 0.0000    0.0001
0.0002
current_balance                -0.0005    0.0000 -10.0018 0.0000 -0.0006
-0.0004
```

```
=====
=====
```

```
"""
```

Model building is complete

```
logR_3.params
```

```
average_monthly_balance_prevQ    0.000172
current_balance                  -0.000484
dtype: float64
```

The final LR model:

$Z = \text{Duration of Credit (month)} * -0.031934 +$
 $\text{Age (years)} * 0.044396$

$f(Z) = e^Z / (1 + e^Z)$

Prediction using the model

```
y_pred=logR_3.predict(X_test_3)
y_pred
```

```
1099    0.016492
1123    0.127642
1264    0.001696
224     0.337550
1228    0.362362
```

```
...
247     0.239615
510     0.379636
1144    0.400206
1024    0.069019
243     0.004455
```

```
Length: 201, dtype: float64
```

```
y_test_3
```

```
1099    0
1123    0
1264    0
224     1
1228    0
```

```
...
247     0
```



```
510      0
1144      0
1024      0
243       0
Name: churn, Length: 201, dtype: int64
```

```
# A DF
```

```
pred_df=pd.DataFrame({'Actual Class':y_test_3,
                      'Predicted Prob.':y_pred})
```

```
pred_df
```

	Actual Class	Predicted Prob.
1099	0	0.016492
1123	0	0.127642
1264	0	0.001696
224	1	0.337550
1228	0	0.362362
...
247	0	0.239615
510	0	0.379636
1144	0	0.400206
1024	0	0.069019
243	0	0.004455

```
[201 rows x 2 columns]
```

```
# Adding a col to the DF
```

```
pred_df['Predicted Class']=pred_df['Predicted Prob.'].map(
    lambda x: 1 if x >0.5 else 0 )
```

```
pred_df
```

	Actual Class	Predicted Prob.	Predicted Class
1099	0	0.016492	0
1123	0	0.127642	0
1264	0	0.001696	0
224	1	0.337550	0
1228	0	0.362362	0
...
247	0	0.239615	0
510	0	0.379636	0
1144	0	0.400206	0
1024	0	0.069019	0
243	0	0.004455	0

```
[201 rows x 3 columns]
```

Performance Measures

Confusion Matrix

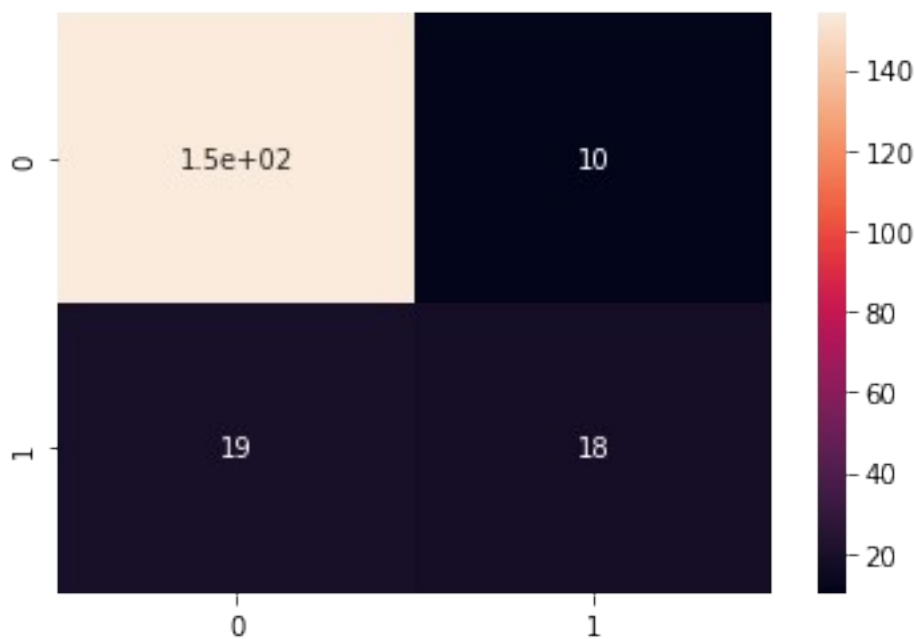
```
from sklearn.metrics import confusion_matrix

cm=confusion_matrix(pred_df['Actual Class'],
                    pred_df['Predicted Class'])

print('The Confusion Matrix:\n ',cm)
sns.heatmap(cm,annot=True);
```

The Confusion Matrix:

```
[[154  10]
 [ 19  18]]
```



TP=154
FN=19
FP= 10
TN=18

Classification Report

```
from sklearn.metrics import classification_report

report=classification_report(pred_df['Actual Class'],
                             pred_df['Predicted Class'])
print(' The classification report:\n',report)

The classification report:
      precision    recall  f1-score   support


```

0	0.89	0.94	0.91	164
1	0.64	0.49	0.55	37
accuracy			0.86	201
macro avg	0.77	0.71	0.73	201
weighted avg	0.84	0.86	0.85	201

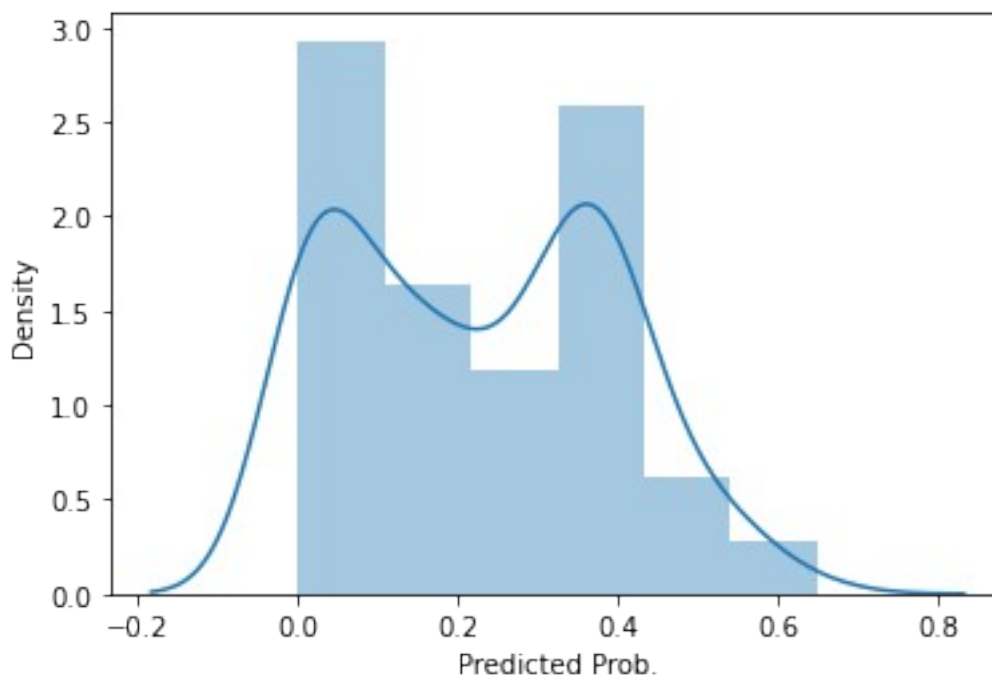
Plotting the distribution of predicted probs

Distribution of pred prob corresponding class=0

```
sns.distplot(pred_df[pred_df['Actual Class']==0]['Predicted Prob.']);
```

C:\Users\hp\anaconda3\lib\site-packages\seaborn\distributions.py:2619: FutureWarning: `distplot` is a deprecated function and will be removed in a future version. Please adapt your code to use either `displot` (a figure-level function with similar flexibility) or `histplot` (an axes-level function for histograms).

```
warnings.warn(msg, FutureWarning)
```

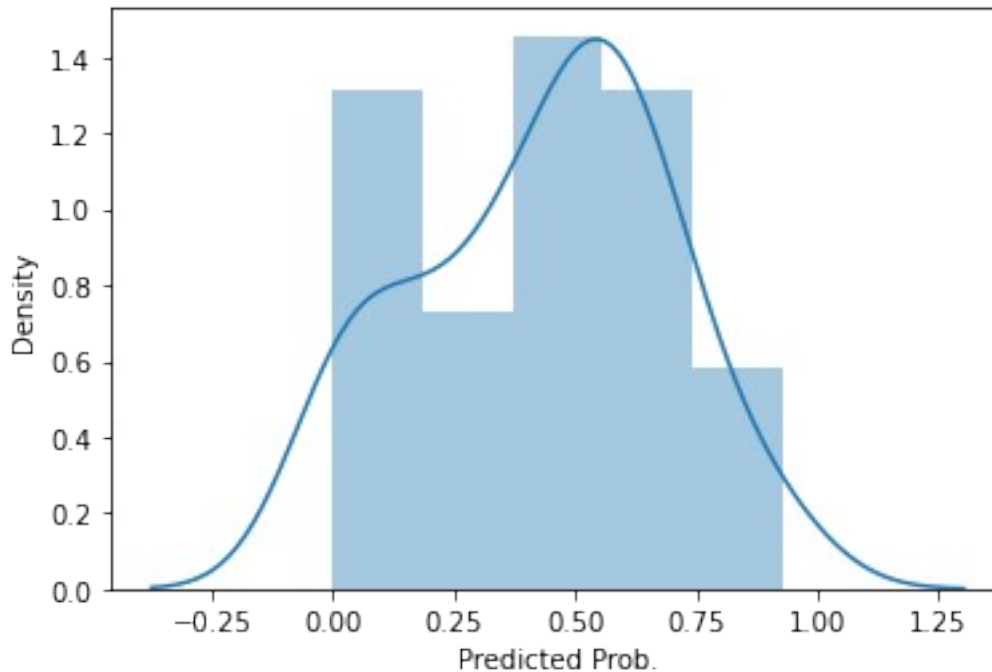


Distribution of pred prob corresponding class=1

```
sns.distplot(pred_df[pred_df['Actual Class']==1]['Predicted Prob.']);
```

C:\Users\hp\anaconda3\lib\site-packages\seaborn\distributions.py:2619: FutureWarning: `distplot` is a deprecated function and will be removed in a future version. Please adapt your code to use either `displot` (a figure-level function with similar flexibility) or `histplot` (an

```
axes-level function for histograms).
warnings.warn(msg, FutureWarning)
```



```
# Distribution of pred prob corresponding class=0,1
```

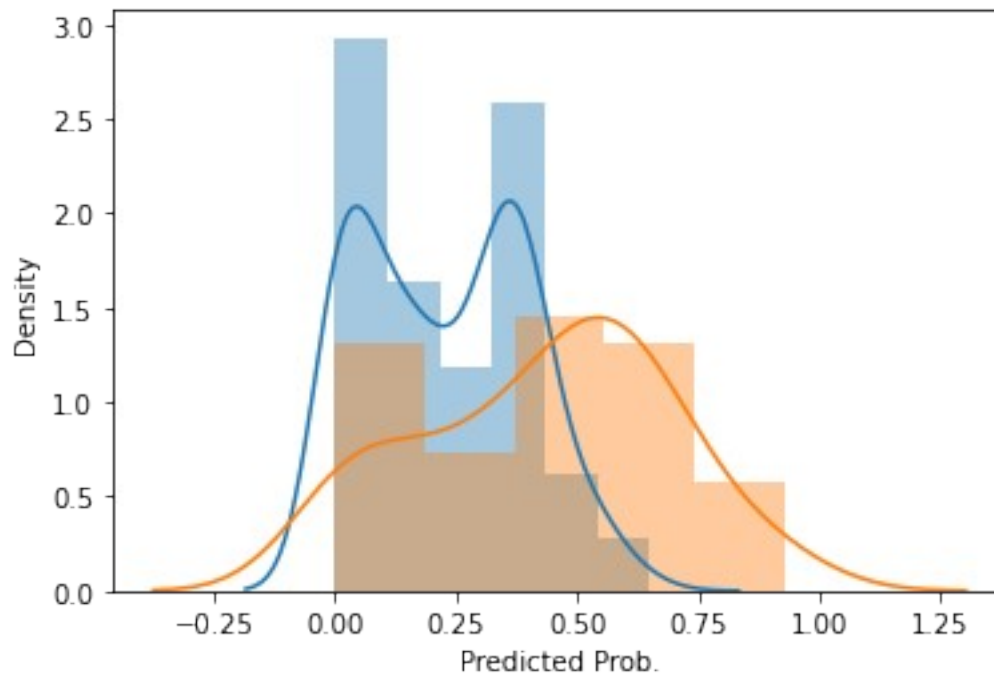
```
sns.distplot(pred_df[pred_df['Actual Class']==0]['Predicted Prob.'])
sns.distplot(pred_df[pred_df['Actual Class']==1]['Predicted Prob.']);
```

```
C:\Users\hp\anaconda3\lib\site-packages\seaborn\distributions.py:2619:
FutureWarning: `distplot` is a deprecated function and will be removed
in a future version. Please adapt your code to use either `displot` (a
figure-level function with similar flexibility) or `histplot` (an
axes-level function for histograms).
```

```
warnings.warn(msg, FutureWarning)
```

```
C:\Users\hp\anaconda3\lib\site-packages\seaborn\distributions.py:2619:
FutureWarning: `distplot` is a deprecated function and will be removed
in a future version. Please adapt your code to use either `displot` (a
figure-level function with similar flexibility) or `histplot` (an
axes-level function for histograms).
```

```
warnings.warn(msg, FutureWarning)
```



ROC Curve

Receiver Operating Characteristics Curve

Plotted by taking:

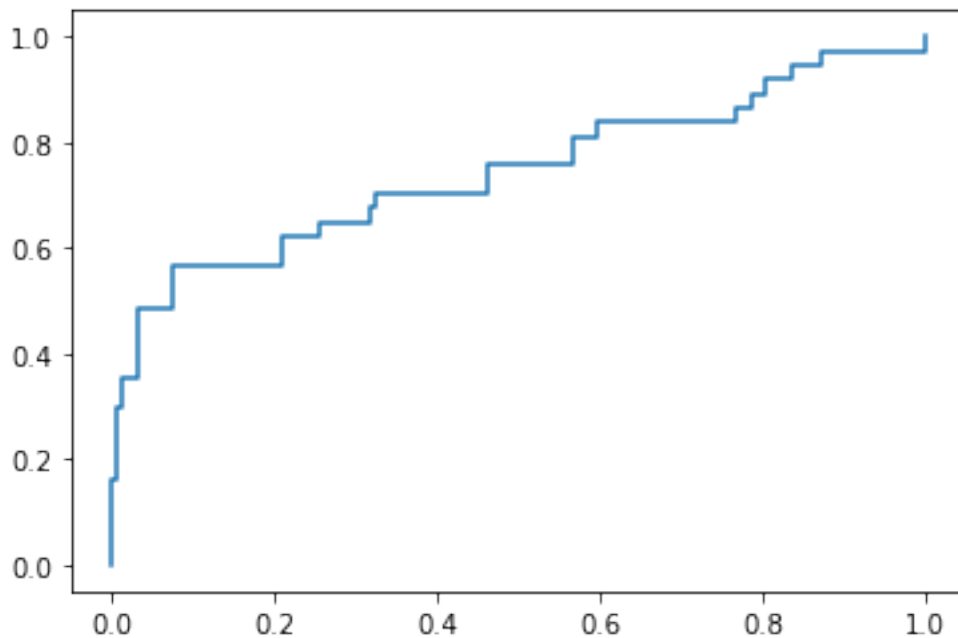
FPR (Sensitivity) ==> X- axis

TPR(1- Specificity) ==> Y -axis

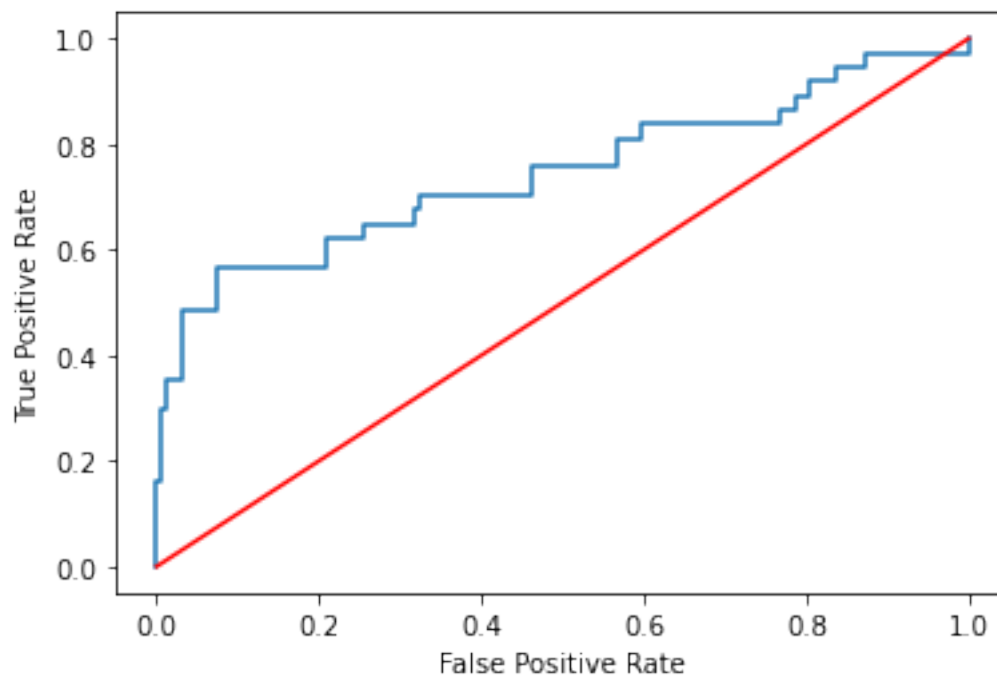
```
from sklearn.metrics import roc_curve
```

```
fpr,tpr,threshold=roc_curve(pred_df['Actual Class'],
                             pred_df['Predicted Prob.'])
```

```
plt.plot(fpr,tpr);
```



```
plt.plot(fpr,tpr)
plt.plot([0,1],[0,1],c='r')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.show();
```



ROC-AUC- Score

```
from sklearn.metrics import roc_auc_score
```

```
score=roc_auc_score(pred_df['Actual Class'],
                    pred_df['Predicted Class'])
```

```
print(' The ROC-AUC-Score:',score)
```

The ROC-AUC-Score: 0.7127554383651944

Finding the optimum classification cut-off

Many measures:

Youden's index: $\text{Max} \{ \text{Sensitivity} + \text{Specificity} - 1 \}$

: $\text{Max} \{ \text{Sensitivity} - (1 - \text{Specificity}) \}$

: $\text{Max} \{ \text{FPR} - \text{TPR} \}$, actual diff

Create a new DF

```
fpr_tpr= pd.DataFrame({'FPR': fpr,
                      'TPR': tpr,
                      'Threshold': threshold})
```

fpr_tpr

	FPR	TPR	Threshold
0	0.000000	0.000000	1.927602e+00
1	0.000000	0.027027	9.276018e-01
2	0.000000	0.162162	6.999725e-01
3	0.006098	0.162162	6.493904e-01
4	0.006098	0.297297	5.853380e-01
5	0.012195	0.297297	5.785498e-01
6	0.012195	0.351351	5.727403e-01
7	0.030488	0.351351	5.593429e-01
8	0.030488	0.486486	5.174376e-01
9	0.073171	0.486486	4.831217e-01
10	0.073171	0.567568	4.585487e-01
11	0.207317	0.567568	3.864647e-01
12	0.207317	0.621622	3.852665e-01
13	0.256098	0.621622	3.697918e-01
14	0.256098	0.648649	3.674144e-01
15	0.317073	0.648649	3.405885e-01
16	0.317073	0.675676	3.392057e-01
17	0.323171	0.675676	3.385553e-01
18	0.323171	0.702703	3.375496e-01
19	0.463415	0.702703	2.571651e-01
20	0.463415	0.756757	2.469419e-01
21	0.567073	0.756757	1.848688e-01
22	0.567073	0.810811	1.771843e-01
23	0.597561	0.810811	1.575910e-01
24	0.597561	0.837838	1.550376e-01

```

25  0.768293  0.837838  5.896333e-02
26  0.768293  0.864865  4.777422e-02
27  0.786585  0.864865  3.983319e-02
28  0.786585  0.891892  3.760126e-02
29  0.804878  0.891892  3.535798e-02
30  0.804878  0.918919  3.220052e-02
31  0.835366  0.918919  2.454982e-02
32  0.835366  0.945946  2.329465e-02
33  0.871951  0.945946  1.104319e-02
34  0.871951  0.972973  8.962515e-03
35  1.000000  0.972973  1.108379e-06
36  1.000000  1.000000  1.150955e-09

```

Creating the col of Diff

```
fpr_tpr['Diff']= np.abs(fpr_tpr['FPR']- fpr_tpr['TPR'])
```

```
fpr_tpr
```

	FPR	TPR	Threshold	Diff
0	0.000000	0.000000	1.927602e+00	0.000000
1	0.000000	0.027027	9.276018e-01	0.027027
2	0.000000	0.162162	6.999725e-01	0.162162
3	0.006098	0.162162	6.493904e-01	0.156065
4	0.006098	0.297297	5.853380e-01	0.291200
5	0.012195	0.297297	5.785498e-01	0.285102
6	0.012195	0.351351	5.727403e-01	0.339156
7	0.030488	0.351351	5.593429e-01	0.320864
8	0.030488	0.486486	5.174376e-01	0.455999
9	0.073171	0.486486	4.831217e-01	0.413316
10	0.073171	0.567568	4.585487e-01	0.494397
11	0.207317	0.567568	3.864647e-01	0.360250
12	0.207317	0.621622	3.852665e-01	0.414305
13	0.256098	0.621622	3.697918e-01	0.365524
14	0.256098	0.648649	3.674144e-01	0.392551
15	0.317073	0.648649	3.405885e-01	0.331575
16	0.317073	0.675676	3.392057e-01	0.358603
17	0.323171	0.675676	3.385553e-01	0.352505
18	0.323171	0.702703	3.375496e-01	0.379532
19	0.463415	0.702703	2.571651e-01	0.239288
20	0.463415	0.756757	2.469419e-01	0.293342
21	0.567073	0.756757	1.848688e-01	0.189684
22	0.567073	0.810811	1.771843e-01	0.243738
23	0.597561	0.810811	1.575910e-01	0.213250
24	0.597561	0.837838	1.550376e-01	0.240277
25	0.768293	0.837838	5.896333e-02	0.069545
26	0.768293	0.864865	4.777422e-02	0.096572
27	0.786585	0.864865	3.983319e-02	0.078279
28	0.786585	0.891892	3.760126e-02	0.105307
29	0.804878	0.891892	3.535798e-02	0.087014

30	0.804878	0.918919	3.220052e-02	0.114041
31	0.835366	0.918919	2.454982e-02	0.083553
32	0.835366	0.945946	2.329465e-02	0.110580
33	0.871951	0.945946	1.104319e-02	0.073995
34	0.871951	0.972973	8.962515e-03	0.101022
35	1.000000	0.972973	1.108379e-06	0.027027
36	1.000000	1.000000	1.150955e-09	0.000000

Sorting

```
fpr_tpr.sort_values('Diff',ascending=False)
```

	FPR	TPR	Threshold	Diff
10	0.073171	0.567568	4.585487e-01	0.494397
8	0.030488	0.486486	5.174376e-01	0.455999
12	0.207317	0.621622	3.852665e-01	0.414305
9	0.073171	0.486486	4.831217e-01	0.413316
14	0.256098	0.648649	3.674144e-01	0.392551
18	0.323171	0.702703	3.375496e-01	0.379532
13	0.256098	0.621622	3.697918e-01	0.365524
11	0.207317	0.567568	3.864647e-01	0.360250
16	0.317073	0.675676	3.392057e-01	0.358603
17	0.323171	0.675676	3.385553e-01	0.352505
6	0.012195	0.351351	5.727403e-01	0.339156
15	0.317073	0.648649	3.405885e-01	0.331575
7	0.030488	0.351351	5.593429e-01	0.320864
20	0.463415	0.756757	2.469419e-01	0.293342
4	0.006098	0.297297	5.853380e-01	0.291200
5	0.012195	0.297297	5.785498e-01	0.285102
22	0.567073	0.810811	1.771843e-01	0.243738
24	0.597561	0.837838	1.550376e-01	0.240277
19	0.463415	0.702703	2.571651e-01	0.239288
23	0.597561	0.810811	1.575910e-01	0.213250
21	0.567073	0.756757	1.848688e-01	0.189684
2	0.000000	0.162162	6.999725e-01	0.162162
3	0.006098	0.162162	6.493904e-01	0.156065
30	0.804878	0.918919	3.220052e-02	0.114041
32	0.835366	0.945946	2.329465e-02	0.110580
28	0.786585	0.891892	3.760126e-02	0.105307
34	0.871951	0.972973	8.962515e-03	0.101022
26	0.768293	0.864865	4.777422e-02	0.096572
29	0.804878	0.891892	3.535798e-02	0.087014
31	0.835366	0.918919	2.454982e-02	0.083553
27	0.786585	0.864865	3.983319e-02	0.078279
33	0.871951	0.945946	1.104319e-02	0.073995
25	0.768293	0.837838	5.896333e-02	0.069545
1	0.000000	0.027027	9.276018e-01	0.027027
35	1.000000	0.972973	1.108379e-06	0.027027
0	0.000000	0.000000	1.927602e+00	0.000000
36	1.000000	1.000000	1.150955e-09	0.000000

```
# Use the new cut-off
```

```
pred_df['New Predicted Class']=pred_df['Predicted Prob.'].map(  
    lambda x: 1 if x >0.526841 else 0 )
```

```
pred_df
```

	Actual Class	Predicted Prob.	Predicted Class	New Predicted Class
Class				
1099	0	0.016492	0	0
0				
1123	0	0.127642	0	0
0				
1264	0	0.001696	0	0
0				
224	1	0.337550	0	0
0				
1228	0	0.362362	0	0
0				
...
...				
247	0	0.239615	0	0
0				
510	0	0.379636	0	0
0				
1144	0	0.400206	0	0
0				
1024	0	0.069019	0	0
0				
243	0	0.004455	0	0
0				

```
[201 rows x 4 columns]
```

```
# New Confusion matrix
```

```
new_cm=confusion_matrix(pred_df['Actual Class'],  
                        pred_df['New Predicted Class'])
```

```
print(' The new CM:\n', new_cm)
```

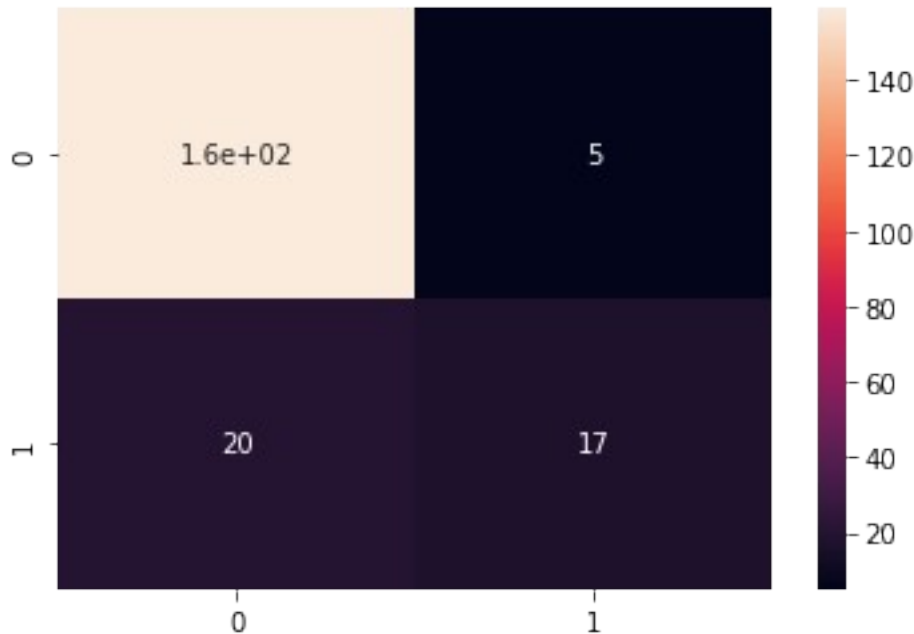
```
#cm=confusion_matrix(y_test,y_pred)
```

```
sns.heatmap(new_cm,annot=True);
```

```
The new CM:
```

```
[[159  5]
```

```
 [ 20 17]]
```



```
new_score=roc_auc_score(pred_df['Actual Class'],
                        pred_df['New Predicted Class'])
print(' The new score:', new_score)
```

The new score: 0.7144858272907053

Decision Tree Classifier

```
churn.keys()
```

```
Index(['customer_id', 'vintage', 'age', 'gender', 'dependents',
      'occupation',
      'city', 'customer_nw_category', 'branch_code',
      'days_since_last_transaction', 'current_balance',
      'previous_month_end_balance', 'average_monthly_balance_prevQ',
      'average_monthly_balance_prevQ2', 'current_month_credit',
      'previous_month_credit', 'current_month_debit',
      'previous_month_debit',
      'current_month_balance', 'previous_month_balance', 'churn'],
      dtype='object')
```

```
y= churn['churn']
```

```
y
```

```
type(y)
```

```
pandas.core.series.Series
```

```
target = pd.Series(churn['churn'])
```

```
# providing dtype
```

```
print(target.to_numpy(dtype = 'float32'))
```

```
#Dict =dict ('Data':churn['age','dependents'],'Target':churn['churn'])
```

```
[0. 1. 0. ... 0. 0. 0.]
```

```
#target =y
```

```
target = np.vstack((churn['churn'].head(150))).T  
data = np.vstack((churn['current_balance'].head(150),  
churn['days_since_last_transaction'].head(150),churn['vintage'].head(150),churn['current_month_credit'].head(150))).T
```

```
target
```

```
array([[0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1,  
0,  
0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 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, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0,  
0,  
0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1,  
1,  
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, 1, 0, 1, 0, 0, 1, 0, 0]])
```

```
target =target[0]
```

```
target
```

```
array([0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1,  
0,  
0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 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, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0,  
0,  
0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1,  
1,  
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, 1, 0, 1, 0, 0, 1, 0, 0])
```

```
len(target)
```

```
150
```

```
data
```

```
array([[1.4587100e+03, 2.2400000e+02, 3.1350000e+03, 2.0000000e-01],
       [9.2772000e+02, 5.8000000e+01, 2.5310000e+03, 3.3000000e-01],
       [1.5202200e+04, 6.0000000e+01, 2.6300000e+02, 3.6000000e-01],
       [7.0069300e+03, 9.8000000e+01, 5.9220000e+03, 6.4000000e-01],
       [1.0096580e+04, 1.7200000e+02, 1.1450000e+03, 2.7000000e-01],
       [1.3558600e+03, 1.9000000e+01, 2.1320000e+03, 7.1451000e+02],
       [4.9579500e+03, 0.0000000e+00, 3.3790000e+03, 6.9122900e+03],
       [1.9287600e+03, 5.0000000e+00, 6.6100000e+02, 4.4340000e+02],
       [6.8864000e+03, 2.0000000e+01, 7.1080000e+03, 7.5645300e+03],
       [5.5438000e+02, 4.7000000e+01, 2.4380000e+03, 3.3000000e-01],
       [4.5484800e+03, 3.0300000e+02, 5.7030000e+03, 6.1000000e-01],
       [5.4314200e+03, 5.2000000e+01, 2.3140000e+03, 6.6000000e-01],
       [1.4484900e+03, 0.0000000e+00, 2.7230000e+03, 1.9071000e+02],
       [5.2921300e+03, 3.0000000e+00, 6.1110000e+03, 3.9169100e+03],
       [3.5077100e+03, 6.9000000e+01, 5.8210000e+03, 5.6000000e-01],
       [3.0427000e+03, 3.1000000e+01, 3.5000000e+03, 3.0000000e-01],
       [2.1800000e+00, 2.3000000e+01, 5.7240000e+03, 7.9790000e+01],
       [6.8864000e+03, 2.0000000e+01, 7.1080000e+03, 7.5645300e+03],
       [5.5438000e+02, 4.7000000e+01, 2.4380000e+03, 3.3000000e-01],
       [4.5484800e+03, 3.0300000e+02, 5.7030000e+03, 6.1000000e-01],
       [2.5962100e+03, 4.7000000e+01, 7.5400000e+02, 6.0000000e-01],
       [2.0273430e+04, 2.0000000e+01, 2.6200000e+03, 7.8300000e+00],
       [7.1112900e+03, 9.0000000e+00, 1.3910000e+03, 1.4326000e+02],
       [6.4244600e+03, 9.0000000e+00, 4.1750000e+03, 6.3900000e+01],
       [9.7257000e+02, 2.7000000e+01, 6.0060000e+03, 1.8598440e+04],
       [1.0701320e+04, 3.6000000e+01, 2.9630000e+03, 1.6000000e-01],
       [7.6136100e+03, 1.2500000e+02, 2.6840000e+03, 1.9000000e-01],
       [2.2690000e+02, 5.0000000e+00, 5.8030000e+03, 3.7471690e+04],
       [1.4367100e+03, 7.7000000e+01, 5.5790000e+03, 4.4000000e-01],
       [5.5759500e+03, 1.0000000e+01, 2.3500000e+03, 3.5780000e+02],
       [3.2951700e+03, 9.7000000e+01, 4.7500000e+03, 4.3000000e-01],
       [1.3148580e+04, 3.0000000e+00, 6.8340000e+03, 4.2347000e+02],
       [7.6136100e+03, 1.2500000e+02, 2.6840000e+03, 1.9000000e-01],
       [2.2690000e+02, 5.0000000e+00, 5.8030000e+03, 3.7471690e+04],
       [5.7171300e+03, 1.6000000e+02, 9.3700000e+02, 1.0000000e-01],
       [3.8544400e+03, 1.4000000e+01, 3.4280000e+03, 1.4287600e+03],
       [3.5856200e+03, 7.0000000e+00, 1.7760000e+03, 3.2607100e+03],
       [4.4743800e+03, 9.5000000e+01, 2.7010000e+03, 5.1000000e-01],
       [1.4439500e+03, 1.7000000e+01, 1.9160000e+03, 3.2886000e+02],
       [2.1252860e+04, 3.0000000e+00, 2.2920000e+03, 7.8248000e+02],
       [8.9472000e+02, 2.0000000e+01, 4.8430000e+03, 4.8746000e+02],
       [9.1470000e+01, 0.0000000e+00, 7.3400000e+02, 9.5780000e+02],
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```
len(data)
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150
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```
data
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[3.7257300e+03, 1.4000000e+01, 1.3950000e+03, 1.8577000e+02],
[7.6348700e+03, 2.3100000e+02, 6.9200000e+02, 1.6000000e-01],
[3.1580800e+03, 2.7000000e+01, 3.2800000e+03, 4.2863600e+03],
[2.4045600e+03, 3.0000000e+00, 8.2200000e+02, 2.1431300e+03],
[2.0590400e+03, 8.7000000e+01, 1.9710000e+03, 6.1000000e-01],
[5.7182000e+03, 3.5000000e+01, 5.0400000e+02, 3.1000000e-01],
[6.8881900e+03, 8.6000000e+01, 1.4880000e+03, 6.9000000e-01],
[8.8362800e+03, 0.0000000e+00, 4.0020000e+03, 6.2323100e+03],
[1.4712000e+03, 4.8000000e+01, 2.4680000e+03, 5.3000000e-01],
[5.1000000e-01, 1.2900000e+02, 8.5300000e+02, 5.1000000e-01],
[1.0657760e+04, 6.1000000e+01, 1.6830000e+03, 1.0000000e-02],
[3.2781100e+03, 2.0500000e+02, 2.6090000e+03, 5.6000000e-01],
[1.6332000e+03, 3.0000000e+00, 2.9600000e+03, 7.1437000e+02],
[1.1651820e+04, 2.5700000e+02, 6.0600000e+02, 5.9000000e-01],
[1.4901340e+04, 2.1000000e+01, 4.7220000e+03, 2.8299000e+02],
[2.3542900e+03, 6.0000000e+00, 2.4910000e+03, 2.3600000e+00],
[2.9599740e+04, 6.0000000e+00, 1.4490000e+03, 8.1428590e+04],
[1.7999400e+03, 1.3200000e+02, 4.3670000e+03, 2.9000000e-01],
[1.0309020e+04, 2.0900000e+02, 3.8240000e+03, 5.6000000e-01],
[4.9701300e+03, 5.3000000e+01, 1.5760000e+03, 5.4000000e-01],
[7.1543500e+03, 2.4000000e+01, 2.8000000e+03, 1.4974400e+03],
[1.4040000e+03, 2.4000000e+01, 1.2410000e+03, 2.5714400e+03],
[1.8985400e+03, 7.7000000e+01, 3.1460000e+03, 5.1000000e-01],
[1.7398100e+03, 9.5000000e+01, 4.9700000e+03, 1.0000000e-01],
[2.4626500e+03, 3.0000000e+00, 3.7360000e+03, 6.7700000e+02],
[2.6303600e+03, 7.0000000e+00, 2.7980000e+03, 2.8591000e+02],
[1.0725200e+04, 1.3500000e+02, 1.3890000e+03, 5.1000000e-01],
[6.6533000e+02, 1.8000000e+01, 2.1800000e+03, 7.5290000e+01],
[4.6176300e+03, 3.1000000e+01, 4.1150000e+03, 7.0000000e-01],

```
[2.9470100e+03, 2.5000000e+01, 2.0080000e+03, 1.8576000e+02],
[1.4334800e+03, 2.1000000e+01, 6.1130000e+03, 3.1336000e+03],
[5.8233600e+03, 1.4900000e+02, 4.6130000e+03, 1.1000000e-01],
[1.3871000e+02, 9.0000000e+00, 2.6830000e+03, 2.5092919e+05],
[2.1915100e+03, 2.8600000e+02, 2.9820000e+03, 1.1000000e-01],
[1.7569400e+03, 1.1000000e+01, 3.3940000e+03, 6.7164000e+02],
[1.4332100e+03, 2.1000000e+01, 3.0050000e+03, 2.8574000e+03],
[2.0768100e+03, 0.0000000e+00, 3.1430000e+03, 2.8706400e+03],
[3.7312000e+03, 3.0000000e+00, 1.1400000e+03, 2.8630000e+02]])
```

```
target.shape, data.shape
```

```
((150,), (150, 4))
```

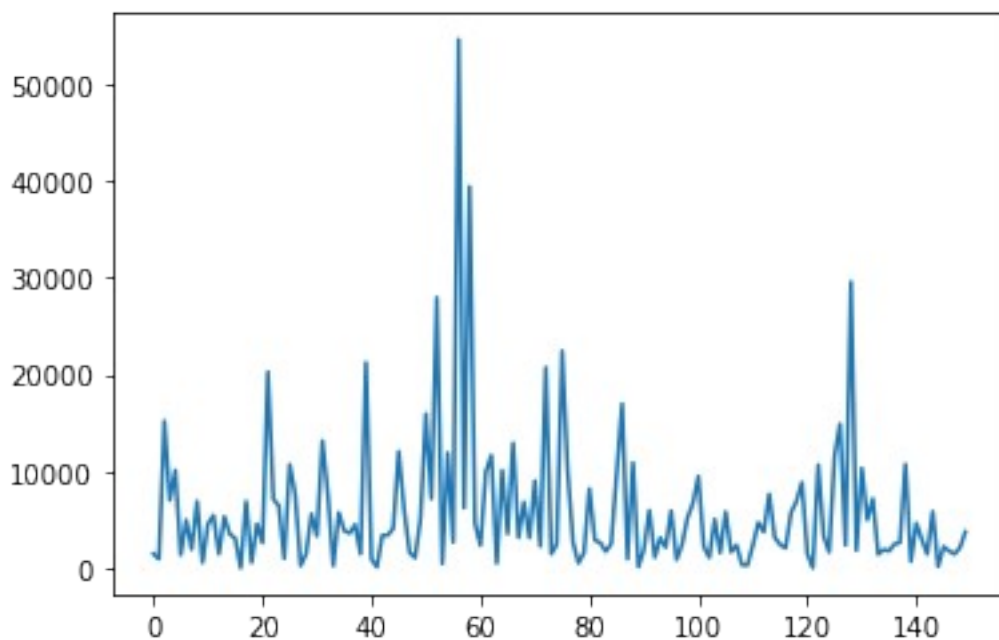
```
-----
-----
AttributeError                                Traceback (most recent call
last)
Input In [234], in <cell line: 1>()
----> 1 target=target.head(150)
      2 data=data.head(150)
```

```
AttributeError: 'numpy.ndarray' object has no attribute 'head'
```

Visualisation

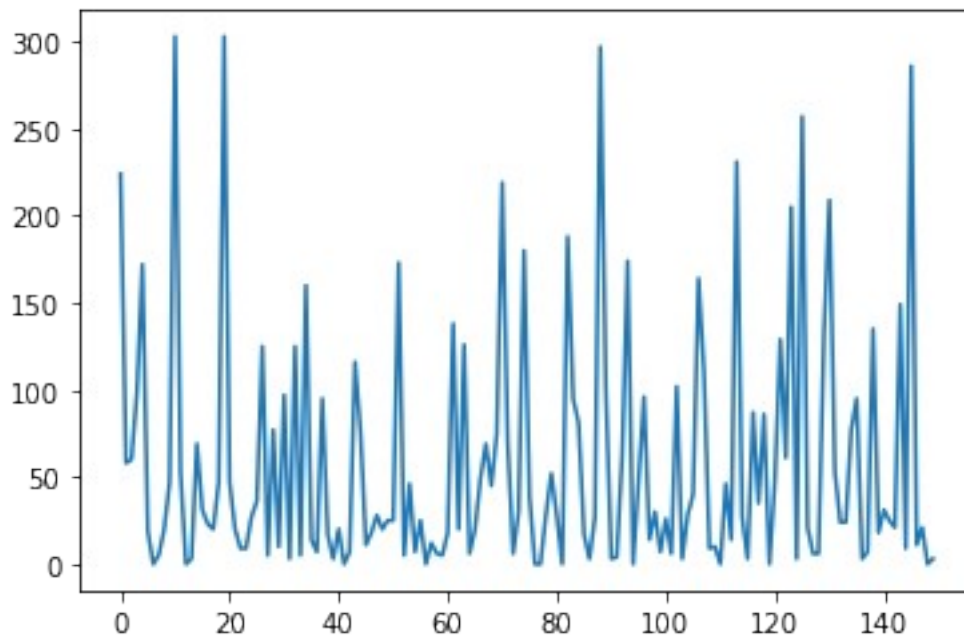
```
plt.plot(data[:,0])
```

```
[<matplotlib.lines.Line2D at 0x277d7d81fa0>]
```



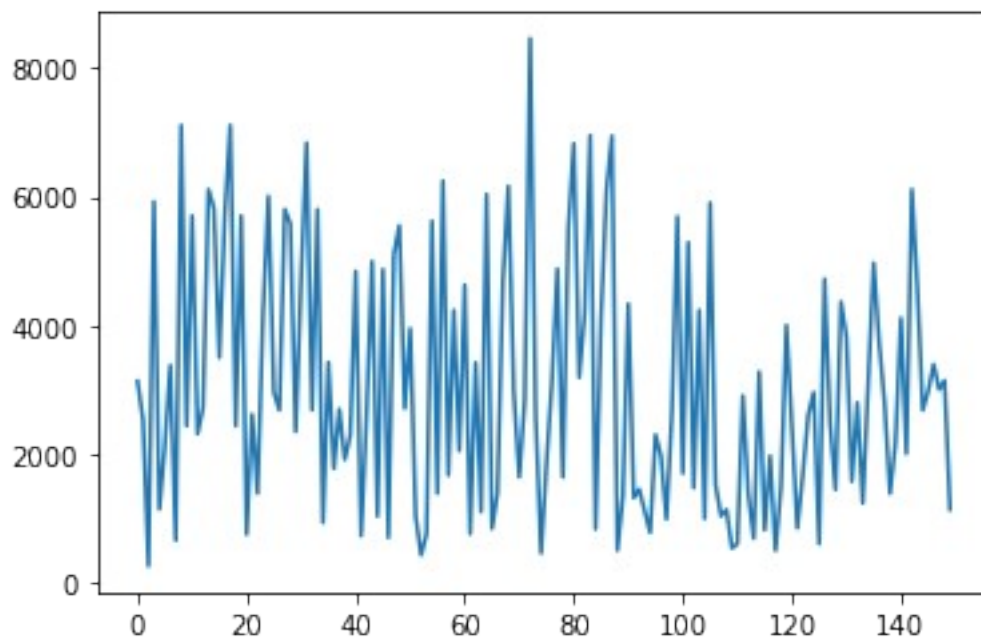
```
plt.plot(data[:,1])
```

```
[<matplotlib.lines.Line2D at 0x277d7db9340>]
```



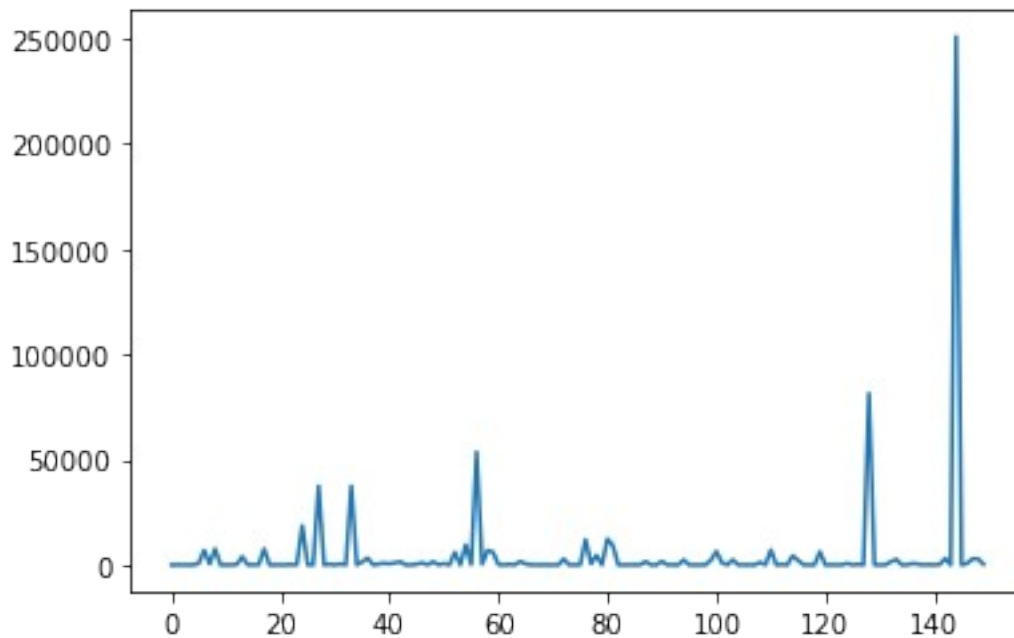
```
plt.plot(data[:,2])
```

```
[<matplotlib.lines.Line2D at 0x277d7e0fbb0>]
```



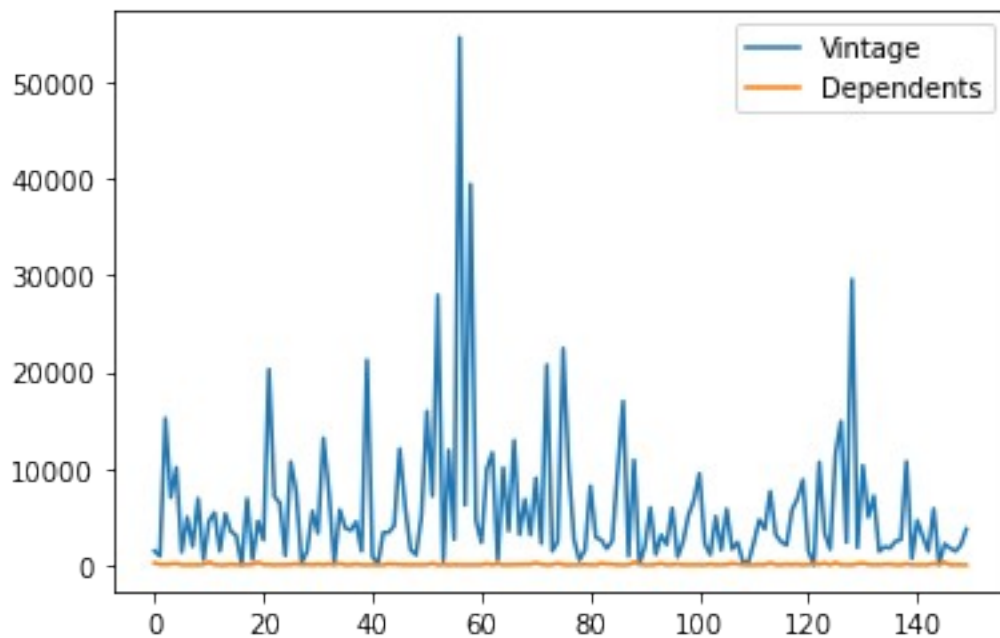
```
plt.plot(data[:,3])
```

```
[<matplotlib.lines.Line2D at 0x277d7f4c940>]
```



```
plt.plot(data[:,0],label='Vintage')  
plt.plot(data[:,1],label='Dependents')
```

```
plt.legend();
```



Splitting the data: train and test

```
from sklearn.model_selection import train_test_split
```

```
X_train,X_test,y_train,y_test=train_test_split(
    data,target,test_size=0.2,random_state=100)
```

```
X_train.shape,X_test.shape,y_train.shape,y_test.shape
((120, 4), (30, 4), (120,), (30,))
```

Building the model

```
from sklearn.tree import DecisionTreeClassifier
```

```
dt_1=DecisionTreeClassifier()
```

```
## Training the model
```

```
dt_1=dt_1.fit(X_train,y_train)
```

```
dt_1
```

```
DecisionTreeClassifier()
```

Predicting

```
y_pred=dt_1.predict(X_test)
y_pred
```

```
array([0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0,
        0, 0, 0, 0, 1, 0, 0, 1, 1])
```

```
type(y_test )
```

```
numpy.ndarray
```

```
y_test=y_test.to_numpy(dtype = 'float32')
```

```
-----
-----
```

```
AttributeError                                Traceback (most recent call
last)
```

```
Input In [244], in <cell line: 1>()
```

```
----> 1 y_test=y_test.to_numpy(dtype = 'float32')
```

```
AttributeError: 'numpy.ndarray' object has no attribute 'to_numpy'
```

```
y_test
```

```
array([0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1,
        0, 0, 0, 0, 0, 0, 1, 1, 0])
```

```
type(X)
```

```
pandas.core.frame.DataFrame
```

Finding the performance measures

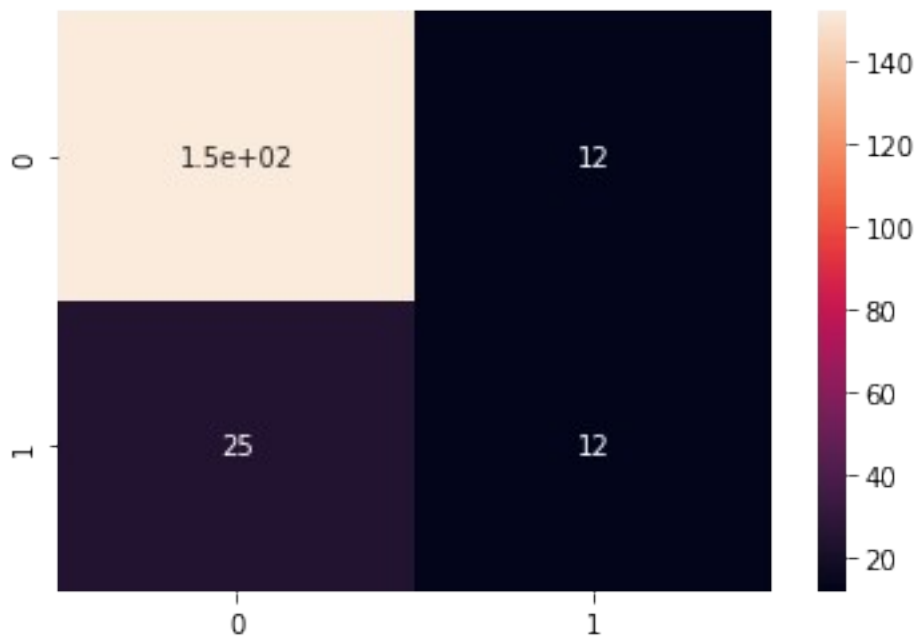
```
from sklearn.metrics import  
confusion_matrix, classification_report, roc_curve, roc_auc_score
```

```
cm=confusion_matrix(y_test,y_pred)
```

```
sns.heatmap(cm,annot=True);  
score=roc_auc_score(pred_df['Actual Class'],  
                    pred_df['Predicted Class'])
```

```
score
```

```
0.7127554383651944
```

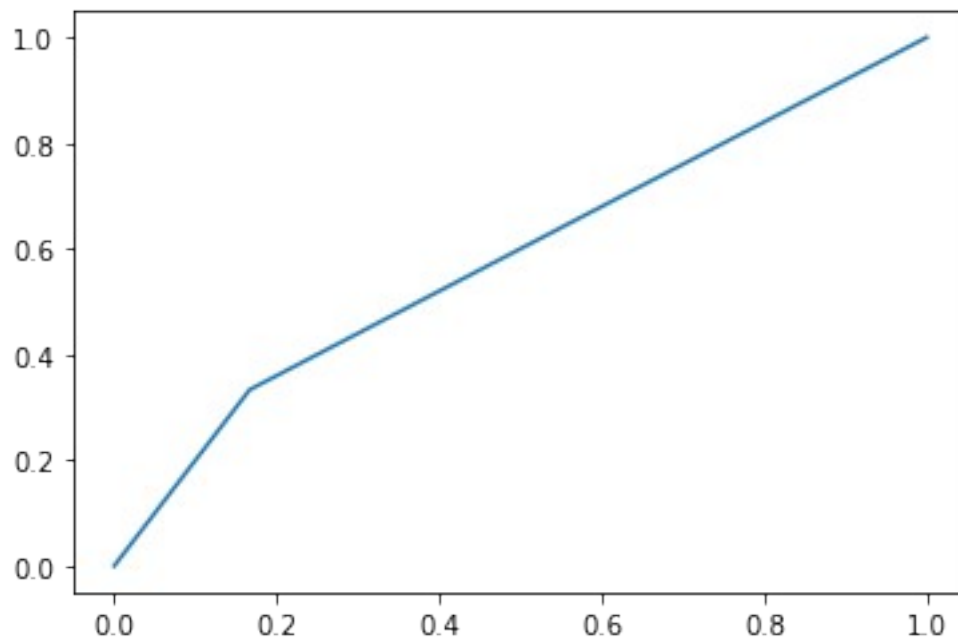


```
report=classification_report(y_test,y_pred)  
print(' The classification report:\n',report)
```

```
The classification report:
```

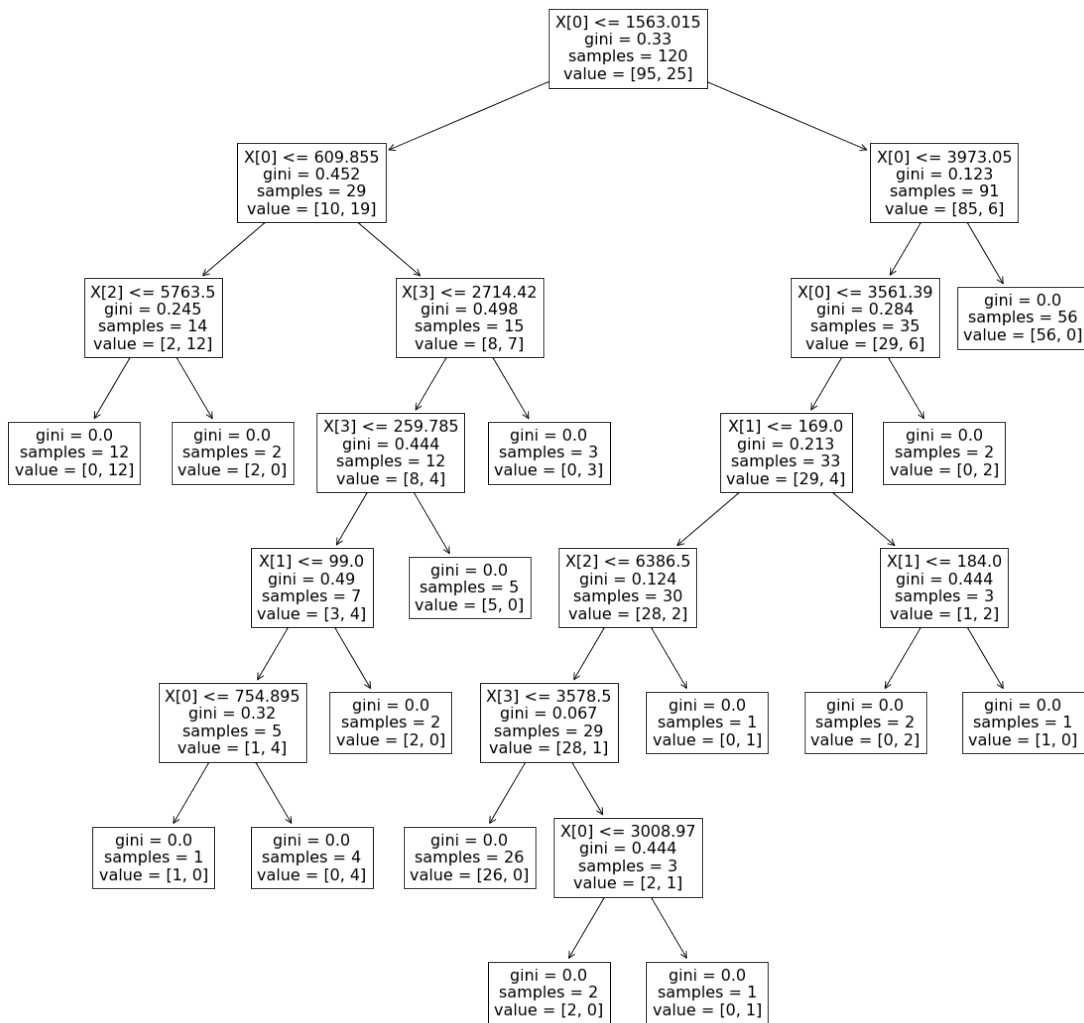
	precision	recall	f1-score	support
0	0.83	0.83	0.83	24
1	0.33	0.33	0.33	6
accuracy			0.73	30
macro avg	0.58	0.58	0.58	30
weighted avg	0.73	0.73	0.73	30

```
fpr,tpr,_=roc_curve(y_test,y_pred)
plt.plot(fpr,tpr);
```

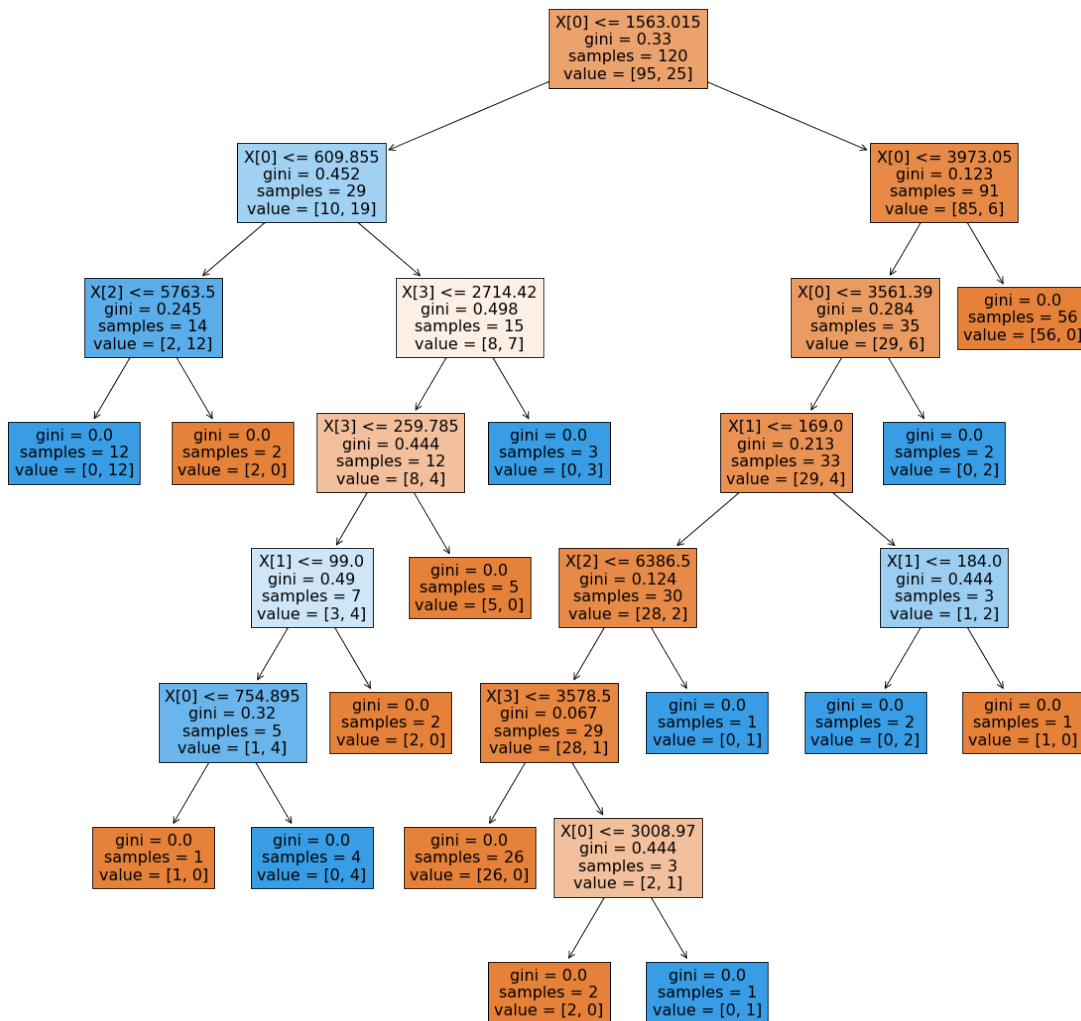


Visualisation of the tree

```
from sklearn.tree import plot_tree
plt.figure(figsize=(20,20))
plot_tree(dt_1);
```

```
plt.figure(figsize=(20,20))
plot_tree(dt_1,filled=True);
```



gini = 1- \sum p^2

gini= 1- (95/120)**2 - (25/120)**2

print('Gini:', gini)

```
#data = np.vstack((churn['current_balance'].head(150),
churn['days_since_last_transaction'].head(150),churn['vintage'].head(1
50),churn['current_month_credit'].head(150))).T
```

Gini: 0.32986111111111116

```
data1= {'feature_names':
['current_balance','days_since_last_transaction','vintage','current_mo
nth_credit']}
```

```
data1['feature_names']
```

```
['current_balance',
 'days_since_last_transaction',
 'vintage',
 'current_month_credit']
```

Decision rules

```
from sklearn.tree import export_text
```

```
text=export_text(dt_1,feature_names=data1['feature_names'])
print(text)
```

```
|--- current_balance <= 1563.02
|   |--- current_balance <= 609.86
|   |   |--- vintage <= 5763.50
|   |   |   |--- class: 1
|   |   |--- vintage > 5763.50
|   |   |   |--- class: 0
|   |--- current_balance > 609.86
|   |   |--- current_month_credit <= 2714.42
|   |   |   |--- current_month_credit <= 259.78
|   |   |   |   |--- days_since_last_transaction <= 99.00
|   |   |   |   |   |--- current_balance <= 754.90
|   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- current_balance > 754.90
|   |   |   |   |   |   |--- class: 1
|   |   |   |   |--- days_since_last_transaction > 99.00
|   |   |   |   |   |--- class: 0
|   |   |   |--- current_month_credit > 259.78
|   |   |   |   |--- class: 0
|   |   |--- current_month_credit > 2714.42
|   |   |   |--- class: 1
|--- current_balance > 1563.02
|   |--- current_balance <= 3973.05
|   |   |--- current_balance <= 3561.39
|   |   |   |--- days_since_last_transaction <= 169.00
|   |   |   |   |--- vintage <= 6386.50
|   |   |   |   |   |--- current_month_credit <= 3578.50
|   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |--- current_month_credit > 3578.50
|   |   |   |   |   |   |--- current_balance <= 3008.97
|   |   |   |   |   |   |   |--- class: 0
|   |   |   |   |   |   |--- current_balance > 3008.97
|   |   |   |   |   |   |   |--- class: 1
|   |   |   |   |--- vintage > 6386.50
|   |   |   |   |   |--- class: 1
|   |   |--- days_since_last_transaction > 169.00
|   |   |   |--- days_since_last_transaction <= 184.00
|   |   |   |   |--- class: 1
|   |   |   |--- days_since_last_transaction > 184.00
|   |   |   |   |--- class: 0
```

```

|      |      |--- current_balance > 3561.39
|      |      |      |--- class: 1
|      |--- current_balance > 3973.05
|      |      |--- class: 0

```

```
dt_1.criterion
```

```
'gini'
```

```
dt_1.tree_.max_depth
```

```
7
```

```
dt_1.criterion
```

```
'gini'
```

```
dt_1.tree_.max_depth
```

```
7
```

Modifying the model

```
dt_2=DecisionTreeClassifier(criterion='entropy',max_depth=3)
```

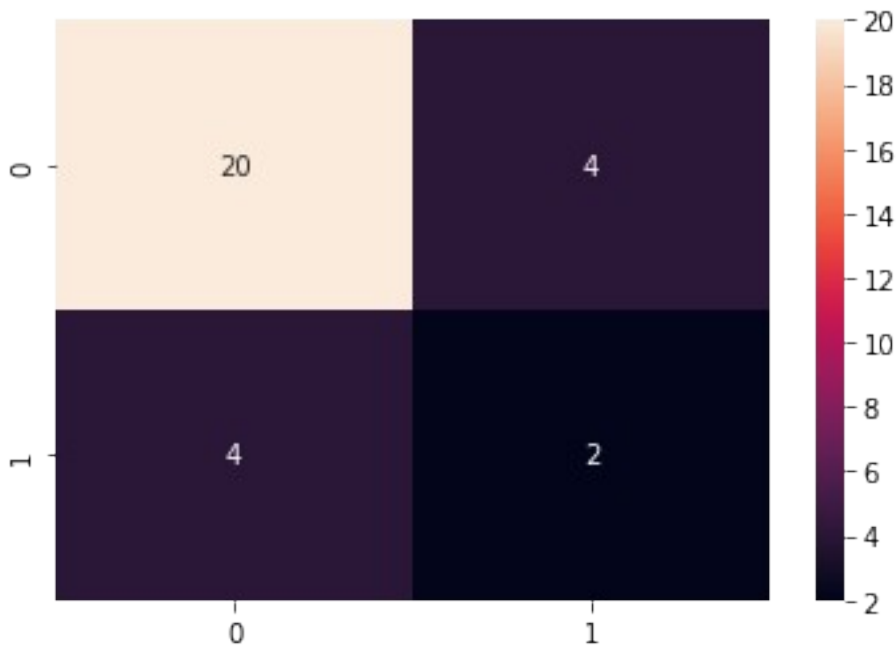
```
dt_2=dt_2.fit(X_train,y_train)
```

```
y_pred_2=dt_2.predict(X_test)
```

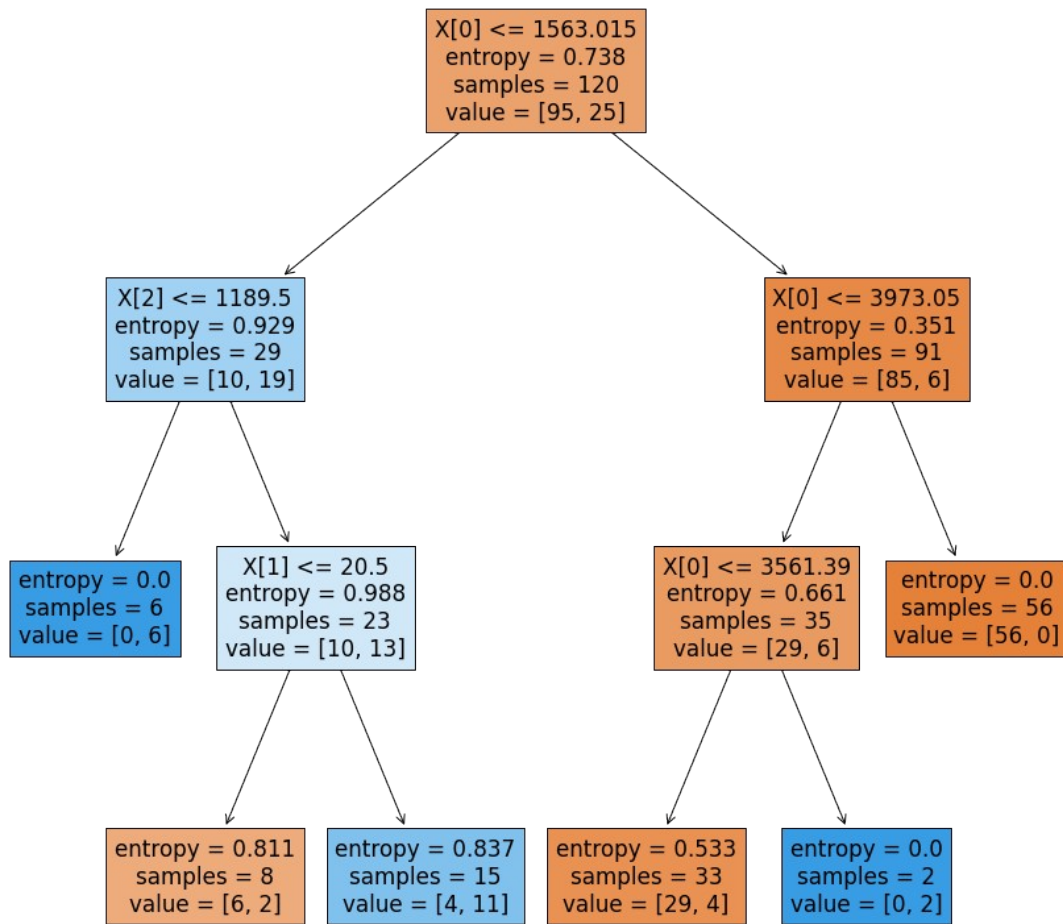
```
cm_2=confusion_matrix(y_test,y_pred_2)
```

```
sns.heatmap(cm_2,annot=True);
```

```
score=roc_auc_score(pred_df['Actual Class'],
                    pred_df['Predicted Class'])
```



```
plt.figure(figsize=(15,15))
plot_tree(dt_2,filled=True);
```



Implementation of SVC

Accessing the dataset

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

```
churn.isnull().sum()
```

```
customer_id    0
vintage        0
```

```

age                                0
gender                             0
dependents                         0
occupation                         0
city                               0
customer_nw_category              0
branch_code                        0
days_since_last_transaction       0
current_balance                    0
previous_month_end_balance         0
average_monthly_balance_prevQ     0
average_monthly_balance_prevQ2    0
current_month_credit               0
previous_month_credit              0
current_month_debit                0
previous_month_debit               0
current_month_balance              0
previous_month_balance             0
churn                              0
dtype: int64

```

```
y = target
```

```
y
```

```

0      0
4      1
5      0
6      0
7      0
..
1294   0
1295   1
1297   0
1298   0
1299   0

```

```
Name: churn, Length: 1001, dtype: int64
```

```
y.value_counts()
```

```

0      804
1      197

```

```
Name: churn, dtype: int64
```

```
churn.count()
```

```

customer_id      1001
vintage          1001
age              1001
gender           1001
dependents       1001
occupation       1001

```

```

city 1001
customer_nw_category 1001
branch_code 1001
days_since_last_transaction 1001
current_balance 1001
previous_month_end_balance 1001
average_monthly_balance_prevQ 1001
average_monthly_balance_prevQ2 1001
current_month_credit 1001
previous_month_credit 1001
current_month_debit 1001
previous_month_debit 1001
current_month_balance 1001
previous_month_balance 1001
churn 1001
dtype: int64

```

```
y.value_counts()
```

```

0    804
1    197
Name: churn, dtype: int64

```

```
type(X)
```

```
pandas.core.frame.DataFrame
```

```
X
```

```

      customer_id  vintage  age  gender  dependents  occupation \
0                1    3135   66   Male         0.0  self_employed
4                6    2531   42   Male         2.0  self_employed
5                7     263   42  Female         0.0  self_employed
6                8    5922   72   Male         0.0        retired
7                9    1145   46   Male         0.0  self_employed
...           ...      ...   ...   ...         ...      ...
1294            1379    1921   71  Female         0.0  self_employed
1295            1380     766   10  Female         0.0        student
1297            1382    2993   59   Male         4.0        salaried
1298            1383    1766   13   Male         0.0        student
1299            1384    7306   77  Female         0.0  self_employed

```

```

      city  customer_nw_category  branch_code \
0    Chicago                2         755
4  Arlington                3         388
5   Cambridge                2        1666
6     Revere                 1           1
7     Arvada                 2         317
...           ...      ...         ...
1294    Tucson                2        1264
1295  Los Angeles            2        2497

```

1297	Philadelphia	3	411
1298	Philadelphia	1	542
1299	Philadelphia	1	240

	days_since_last_transaction	current_balance	\
0	224.0	1458.71	
4	58.0	927.72	
5	60.0	15202.20	
6	98.0	7006.93	
7	172.0	10096.58	
...	
1294	87.0	14734.45	
1295	27.0	6785.93	
1297	0.0	5209.62	
1298	339.0	4616.88	
1299	62.0	14834.26	

	previous_month_end_balance	average_monthly_balance_prevQ	\
0	1458.71	1458.71	
4	1401.72	1643.31	
5	16059.34	15211.29	
6	7714.19	7859.74	
7	8519.53	6511.82	
...	
1294	10439.08	11546.06	
1295	119.03	2419.19	
1297	4116.26	3775.87	
1298	4545.45	4512.45	
1299	15014.05	13910.17	

	average_monthly_balance_prevQ2	current_month_credit	\
0	1449.07	0.20	
4	1871.12	0.33	
5	13798.82	0.36	
6	11232.37	0.64	
7	16314.17	0.27	
...	
1294	10473.96	0.50	
1295	118.29	7630.32	
1297	3463.84	1321.96	
1298	4272.54	0.23	
1299	23436.02	0.34	

	previous_month_credit	current_month_debit	previous_month_debit
\			
0	0.20	0.20	0.20
4	714.61	588.62	1538.06
5	0.36	857.50	286.07

6	0.64	1299.64	439.26
7	0.27	443.13	5688.44
...
1294	0.50	30714.79	0.50
1295	0.21	963.42	0.21
1297	773.34	142.89	407.17
1298	0.23	0.23	0.23
1299	0.34	180.13	73.78

	current_month_balance	previous_month_balance
0	1458.71	1458.71
4	1157.15	1677.16
5	15719.44	15349.75
6	7076.06	7755.98
7	8563.84	5317.04
...
1294	12808.61	10439.08
1295	7019.52	119.03
1297	3991.89	3690.78
1298	4582.40	4513.19
1299	14890.06	14461.60

[1001 rows x 20 columns]

```
X=churn.drop(['churn','gender','customer_id','age','occupation','city',
```

```
,
'branch_code','previous_month_end_balance','average_monthly_balance_pr
```

```
evQ',
'average_monthly_balance_prevQ2','previous_month_credit','previous_mon
```

```
th_debit',
'current_month_balance','previous_month_balance'],axis=1)
```

```
X
```

	vintage	dependents	customer_nw_category
days_since_last_transaction \			
0	3135	0.0	2

224.0			
4	2531	2.0	3
58.0			
5	263	0.0	2
60.0			
6	5922	0.0	1
98.0			
7	1145	0.0	2
172.0			
...
...			
1294	1921	0.0	2
87.0			
1295	766	0.0	2
27.0			
1297	2993	4.0	3
0.0			
1298	1766	0.0	1
339.0			
1299	7306	0.0	1
62.0			

	current_balance	current_month_credit	current_month_debit
0	1458.71	0.20	0.20
4	927.72	0.33	588.62
5	15202.20	0.36	857.50
6	7006.93	0.64	1299.64
7	10096.58	0.27	443.13
...
1294	14734.45	0.50	30714.79
1295	6785.93	7630.32	963.42
1297	5209.62	1321.96	142.89
1298	4616.88	0.23	0.23
1299	14834.26	0.34	180.13

[1001 rows x 7 columns]

```
from sklearn.model_selection import train_test_split
```

```
X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.2,random_state=10)
```

```
X_train.shape,X_test.shape,y_train.shape,y_test.shape
((800, 7), (201, 7), (800,), (201,))
```

Building the model

```
from sklearn.svm import SVC
```

```

svc_lin=SVC(kernel='linear',probability=True)
svc_lin=svc_lin.fit(X_train, y_train)
y_pred=svc_lin.predict(X_test)
y_pred
array([0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0,
      1, 1, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0,
      0, 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, 0, 0, 0, 0,
0,
      0, 0, 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, 0, 0, 0, 0, 1, 0, 0, 0,
0,
      0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 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, 1, 0, 0, 0, 0, 0,
0,
      0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,
1,
      0, 0, 0], dtype=int64)

```

y_pred

```

y_pred_prob=svc_lin.predict_proba(X_test)
y_pred_prob

```

```

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```

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[0.79775872, 0.20224128]])
```

y_test

```
1099    0
1123    0
1264    0
224      1
1228    0
..
247      0
510      0
1144     0
1024     0
243      0
```

Name: churn, Length: 201, dtype: int64

Checking the performance

```
from sklearn.metrics import
confusion_matrix,classification_report,roc_curve,roc_auc_score
```

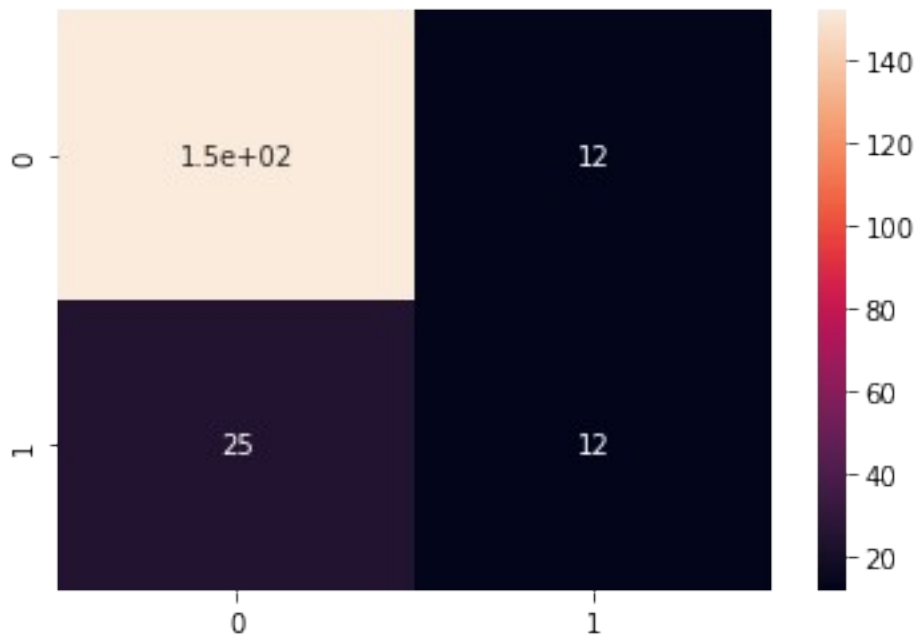
```
cm=confusion_matrix(y_test,y_pred)
report=classification_report(y_test,y_pred)
score=roc_auc_score(y_test,y_pred)
fpr,tpr,_=roc_curve(y_test,y_pred_prob[:,1])
```

```
sns.heatmap(cm,annot=True)
print(' The Report:\n', report)
print(' The ROC-AUC-Score:',score)
```

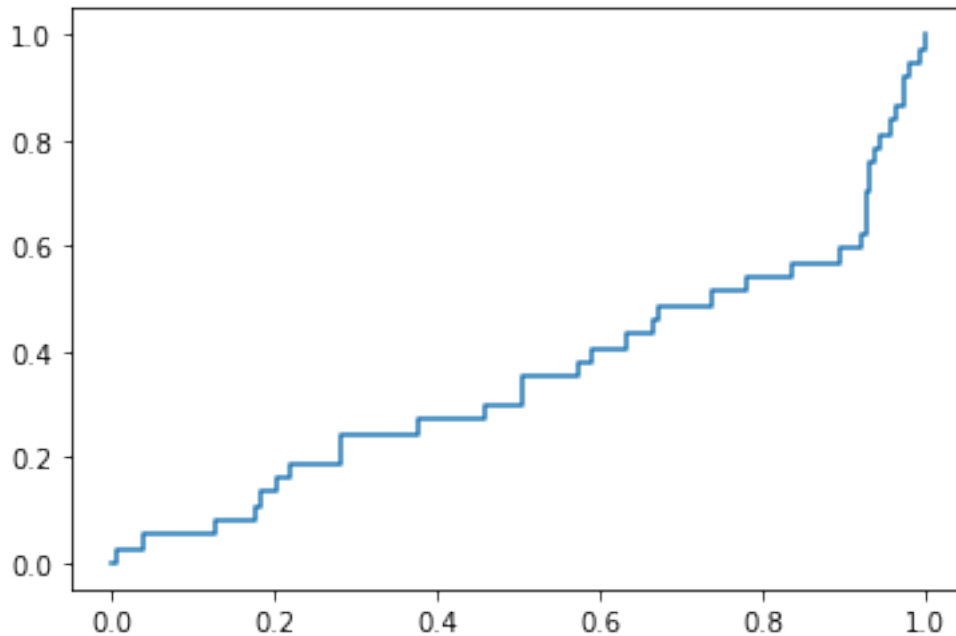
The Report:

	precision	recall	f1-score	support
0	0.86	0.93	0.89	164
1	0.50	0.32	0.39	37
accuracy			0.82	201
macro avg	0.68	0.63	0.64	201
weighted avg	0.79	0.82	0.80	201

The ROC-AUC-Score: 0.6255767963085036



```
plt.plot(fpr,tpr);
```

Hyper parameter tuning

kernel

```
def SVC_tuning_kernel(kernel):
    model=SVC(kernel=kernel)
    model=model.fit(X_train,y_train)
    y_pred=model.predict(X_test)
    cm=confusion_matrix(y_test,y_pred)
    report=classification_report(y_test,y_pred)
    score=roc_auc_score(y_test,y_pred)
    print(' The SVC with kernel:',kernel)
    print()
    print(' ***** ')
    print(' Confusion Matrix:\n',cm)
    print(' The report:\n', report)
    print(' The ROC-AUC-Score:', score)
    sns.heatmap(cm,annot=True);
```

Calling the fn

```
SVC_tuning_kernel('linear')
```

The SVC with kernel: linear

Confusion Matrix:

```
[[152  12]
```

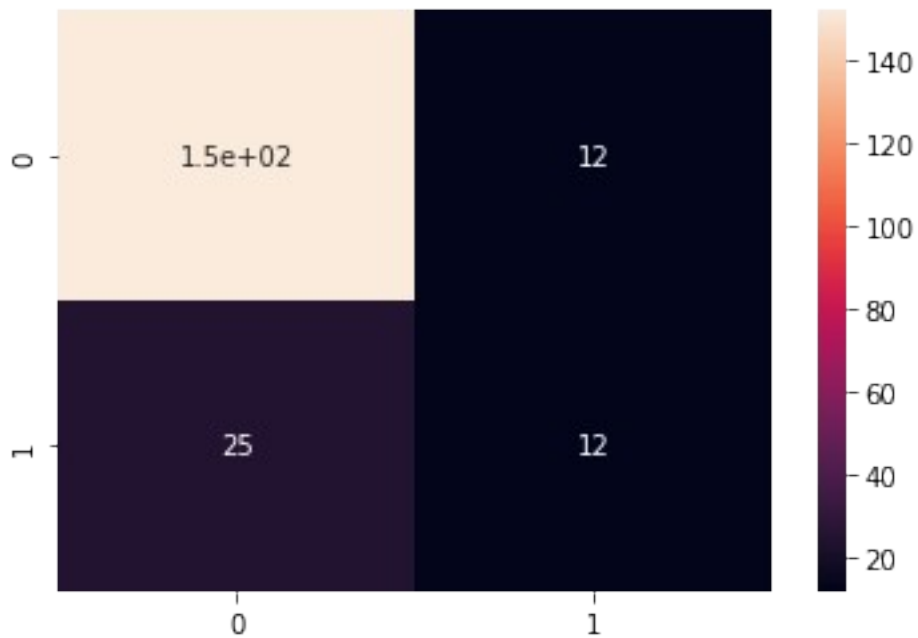
```
[ 25  12]]
```

The report:

	precision	recall	f1-score	support
--	-----------	--------	----------	---------

	0	0.86	0.93	0.89	164
	1	0.50	0.32	0.39	37
accuracy				0.82	201
macro avg		0.68	0.63	0.64	201
weighted avg		0.79	0.82	0.80	201

The ROC-AUC-Score: 0.6255767963085036



SVC_tuning_kernel('poly')

The SVC with kernel: poly

Confusion Matrix:

[[164 0]

[37 0]]

The report:

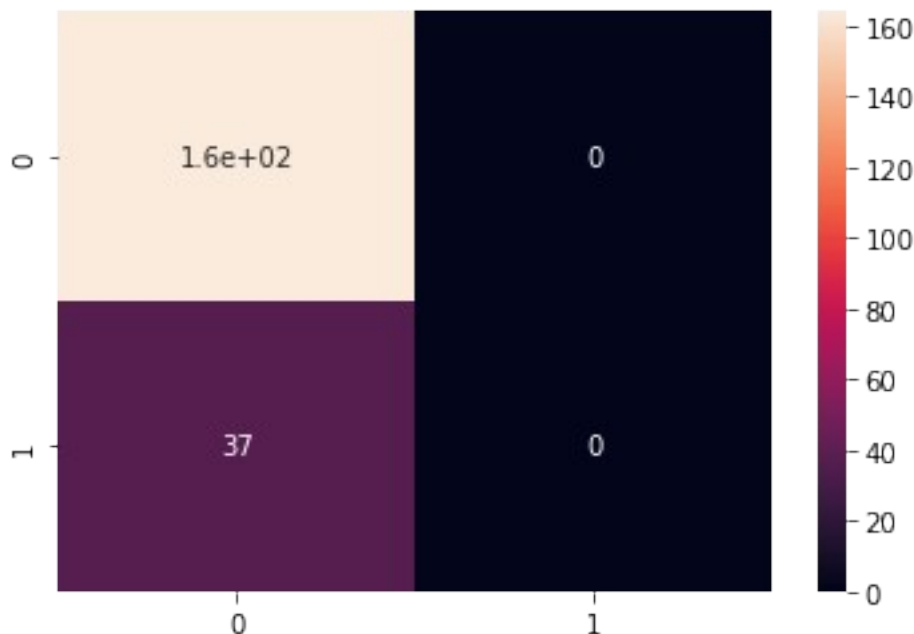
	precision	recall	f1-score	support
0	0.82	1.00	0.90	164
1	0.00	0.00	0.00	37
accuracy			0.82	201
macro avg	0.41	0.50	0.45	201
weighted avg	0.67	0.82	0.73	201

The ROC-AUC-Score: 0.5

```

C:\Users\hp\anaconda3\lib\site-packages\sklearn\metrics\
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\hp\anaconda3\lib\site-packages\sklearn\metrics\
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
C:\Users\hp\anaconda3\lib\site-packages\sklearn\metrics\
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))

```



SVC_tuning_kernel('rbf')

The SVC with kernel: rbf

Confusion Matrix:

```

[[163  1]
 [ 36  1]]

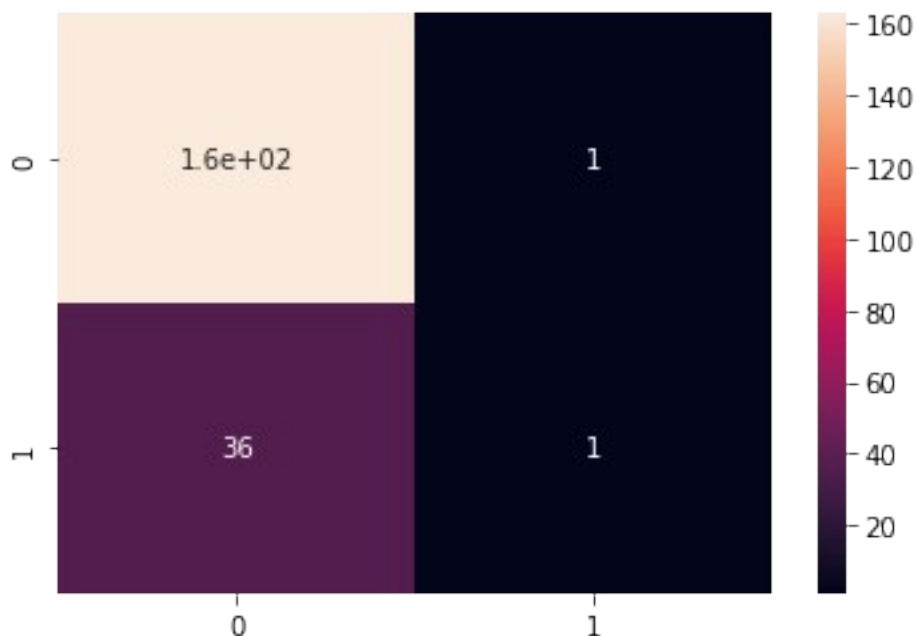
```

The report:

	precision	recall	f1-score	support
0	0.82	0.99	0.90	164
1	0.50	0.03	0.05	37

accuracy			0.82	201
macro avg	0.66	0.51	0.47	201
weighted avg	0.76	0.82	0.74	201

The ROC-AUC-Score: 0.5104647330257086



SVC_tuning_kernel('sigmoid')

The SVC with kernel: sigmoid

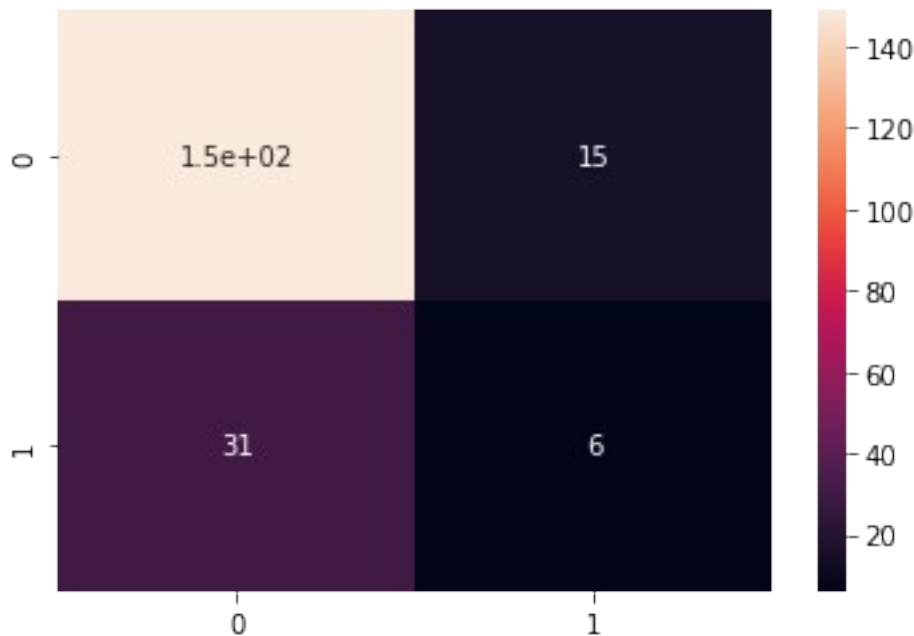
Confusion Matrix:

```
[[149  15]
 [ 31   6]]
```

The report:

	precision	recall	f1-score	support
0	0.83	0.91	0.87	164
1	0.29	0.16	0.21	37
accuracy			0.77	201
macro avg	0.56	0.54	0.54	201
weighted avg	0.73	0.77	0.74	201

The ROC-AUC-Score: 0.5353493737640079



The best kernel after tuning: linear

Tuning regularisation parameter

```
def SVC_tuning_C(C_list):
    for c in C_list:
        model=SVC(kernel='linear',C=c)
        model=model.fit(X_train,y_train)
        y_pred=model.predict(X_test)
        score=roc_auc_score(y_test,y_pred)
        print('C:',c,'==>','Score:',score)
```

```
C_list=[0.1,1,2,3,4,5,10,15,20,25,30]
```

```
SVC_tuning_C(C_list)
```

```
C: 0.1 ==> Score: 0.5911338167435728
C: 1 ==> Score: 0.6255767963085036
C: 2 ==> Score: 0.6255767963085036
C: 3 ==> Score: 0.6255767963085036
C: 4 ==> Score: 0.6255767963085036
C: 5 ==> Score: 0.6255767963085036
C: 10 ==> Score: 0.6255767963085036
C: 15 ==> Score: 0.6120632827949902
C: 20 ==> Score: 0.6255767963085036
C: 25 ==> Score: 0.6255767963085036
C: 30 ==> Score: 0.6255767963085036
```

```
C_list=[18,19,21,22]
```

```
SVC_tuning_C(C_list)
```

```
C: 18 ==> Score: 0.6255767963085036
C: 19 ==> Score: 0.6255767963085036
C: 21 ==> Score: 0.6255767963085036
C: 22 ==> Score: 0.6255767963085036
```

Afer tuing, the best value of C : 20

So, the best model is the one with kernel='linear' and C=20

The final model

```
svc=SVC(kernel='linear',C=20,probability=True)
svc=svc.fit(X_train,y_train)
y_pred=svc.predict(X_test)
y_pred_prob=svc.predict_proba(X_test)
```

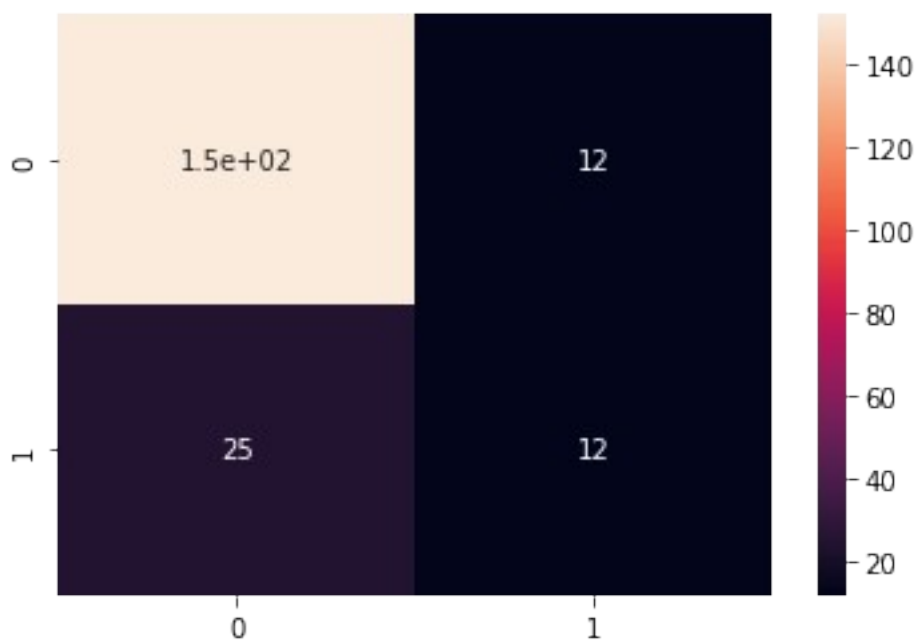
```
cm=confusion_matrix(y_test,y_pred)
score=roc_auc_score(y_test,y_pred)
report=classification_report(y_test,y_pred)
fpr,tpr,_=roc_curve(y_test,y_pred_prob[:,1])
```

```
print('The Confusion Matrix:')
sns.heatmap(cm,annot=True)
print('ROC-AUC-Score:',score)
print(' The report:',report)
```

The Confusion Matrix:

ROC-AUC-Score: 0.6255767963085036

The report:		precision	recall	f1-score	support
	0	0.86	0.93	0.89	164
	1	0.50	0.32	0.39	37
	accuracy			0.82	201
	macro avg	0.68	0.63	0.64	201
	weighted avg	0.79	0.82	0.80	201



Gradient Descent, Errors

Accessing the dataset

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

Data set

```
churn=pd.read_csv('churn_prediction1.csv')
```

churn

	customer_id	vintage	age	gender	dependents	occupation	\
0	1	3135	66	Male	0.0	self_employed	
1	2	310	35	Male	0.0	self_employed	
2	4	2356	31	Male	0.0	salaried	
3	5	478	90	NaN	NaN	self_employed	
4	6	2531	42	Male	2.0	self_employed	
...	
1295	1380	766	10	Female	0.0	student	
1296	1381	1314	49	Female	0.0	self_employed	
1297	1382	2993	59	Male	4.0	salaried	
1298	1383	1766	13	Male	0.0	student	
1299	1384	7306	77	Female	0.0	self_employed	

	city	customer_nw_category	branch_code	\
0	Chicago	2	755	
1	NaN	2	3214	
2	Chicago	2	41	
3	Revere	2	582	
4	Arlington	3	388	
...	
1295	Los Angeles	2	2497	
1296	NaN	3	1349	
1297	Philadelphia	3	411	
1298	Philadelphia	1	542	
1299	Philadelphia	1	240	

	days_since_last_transaction	...	previous_month_end_balance	\
0	224.0	...	1458.71	
1	60.0	...	8704.66	
2	NaN	...	5815.29	
3	147.0	...	2291.91	
4	58.0	...	1401.72	
...	
1295	27.0	...	119.03	
1296	97.0	...	15383.49	
1297	0.0	...	4116.26	

1298	339.0	...	4545.45
1299	62.0	...	15014.05

	average_monthly_balance_prevQ	average_monthly_balance_prevQ2	\
0	1458.71	1449.07	
1	7799.26	12419.41	
2	4910.17	2815.94	
3	2084.54	1006.54	
4	1643.31	1871.12	
...	
1295	2419.19	118.29	
1296	16546.57	7883.34	
1297	3775.87	3463.84	
1298	4512.45	4272.54	
1299	13910.17	23436.02	

	current_month_credit	previous_month_credit	current_month_debit
\			
0	0.20	0.20	0.20
1	0.56	0.56	5486.27
2	0.61	0.61	6046.73
3	0.47	0.47	0.47
4	0.33	714.61	588.62
...
1295	7630.32	0.21	963.42
1296	0.54	0.54	1725.80
1297	1321.96	773.34	142.89
1298	0.23	0.23	0.23
1299	0.34	0.34	180.13

	previous_month_debit	current_month_balance
previous_month_balance	\	
0	0.20	1458.71
1458.71		
1	100.56	6496.78
8787.61		
2	259.23	5006.28
5070.14		

3	2143.33	2291.91
1669.79		
4	1538.06	1157.15
1677.16		
...
...		
1295	0.21	7019.52
119.03		
1296	2502.37	14993.75
16766.38		
1297	407.17	3991.89
3690.78		
1298	0.23	4582.40
4513.19		
1299	73.78	14890.06
14461.60		

	churn
0	0
1	0
2	0
3	1
4	1
...	...
1295	1
1296	0
1297	0
1298	0
1299	0

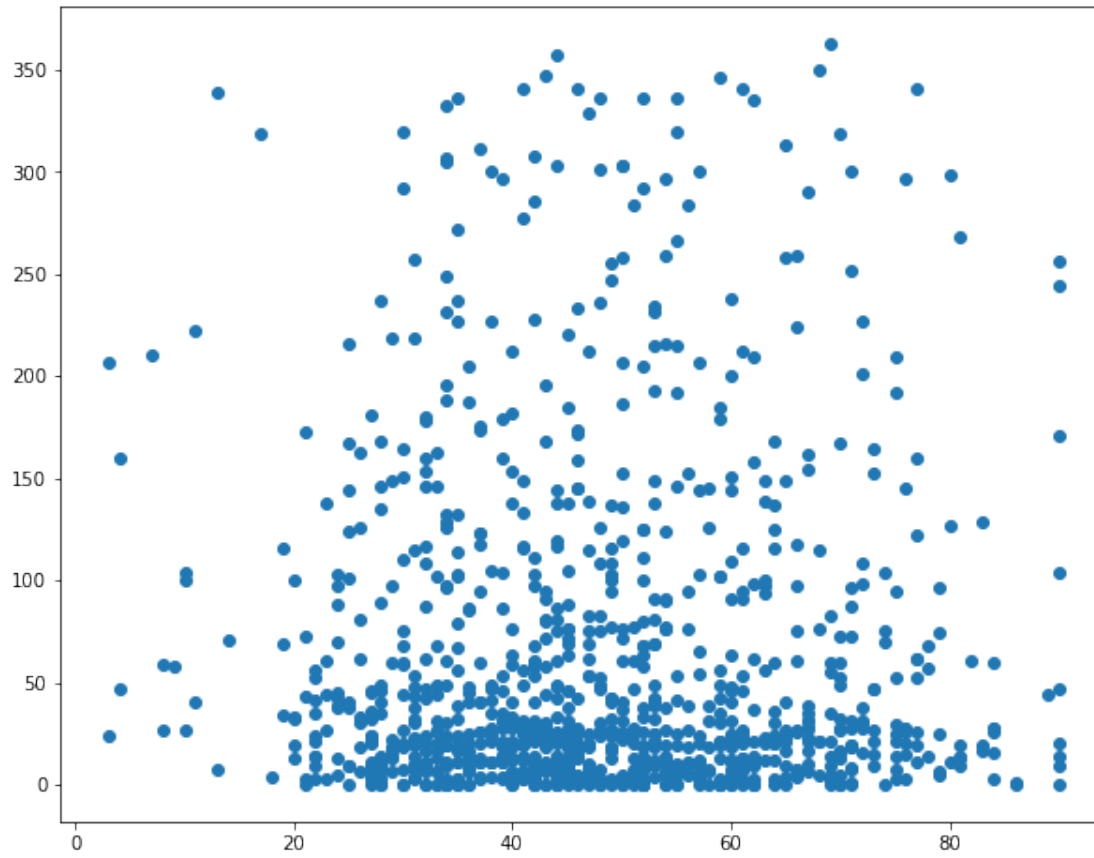
[1300 rows x 21 columns]

X=churn['age']

y=churn['days_since_last_transaction']

Plotting

```
plt.figure(figsize=(10,8))
plt.scatter(X,y);
```



```
churn.isnull().sum()
```

customer_id	0
vintage	0
age	0
gender	0
dependents	0
occupation	0
city	0
customer_nw_category	0
branch_code	0
days_since_last_transaction	0
current_balance	0
previous_month_end_balance	0
average_monthly_balance_prevQ	0
average_monthly_balance_prevQ2	0
current_month_credit	0
previous_month_credit	0
current_month_debit	0
previous_month_debit	0
current_month_balance	0
previous_month_balance	0
churn	0
dtype:	int64

```

churn.dropna(inplace=True)

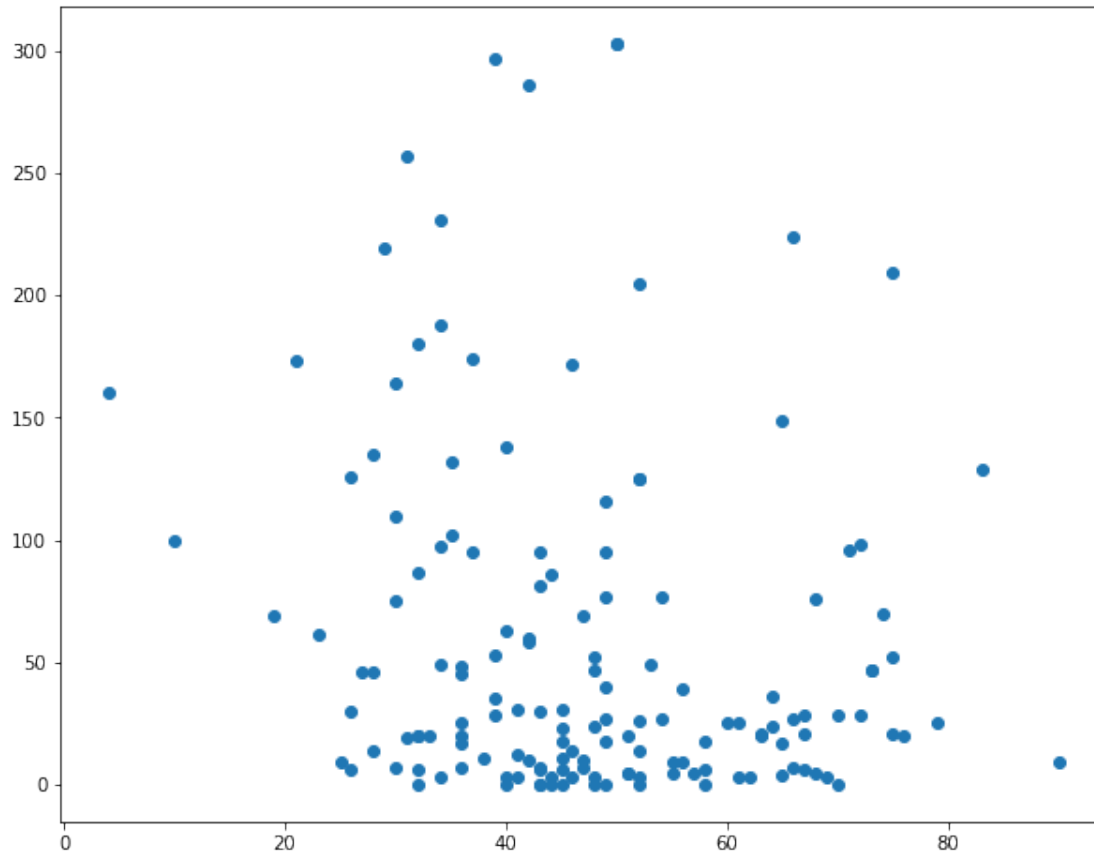
churn.isnull().sum()

customer_id          0
vintage              0
age                  0
gender               0
dependents           0
occupation           0
city                 0
customer_nw_category 0
branch_code          0
days_since_last_transaction 0
current_balance      0
previous_month_end_balance 0
average_monthly_balance_prevQ 0
average_monthly_balance_prevQ2 0
current_month_credit 0
previous_month_credit 0
current_month_debit  0
previous_month_debit 0
current_month_balance 0
previous_month_balance 0
churn                0
dtype: int64

X=churn['age'].head(150)
y=churn['days_since_last_transaction'].head(150)

plt.figure(figsize=(10,8))
plt.scatter(X,y);

```



Designing a simple LR model

```
from sklearn.linear_model import LinearRegression
```

```
lr=LinearRegression()
```

```
lr.fit(X.to_numpy().reshape(-1,1),y)
```

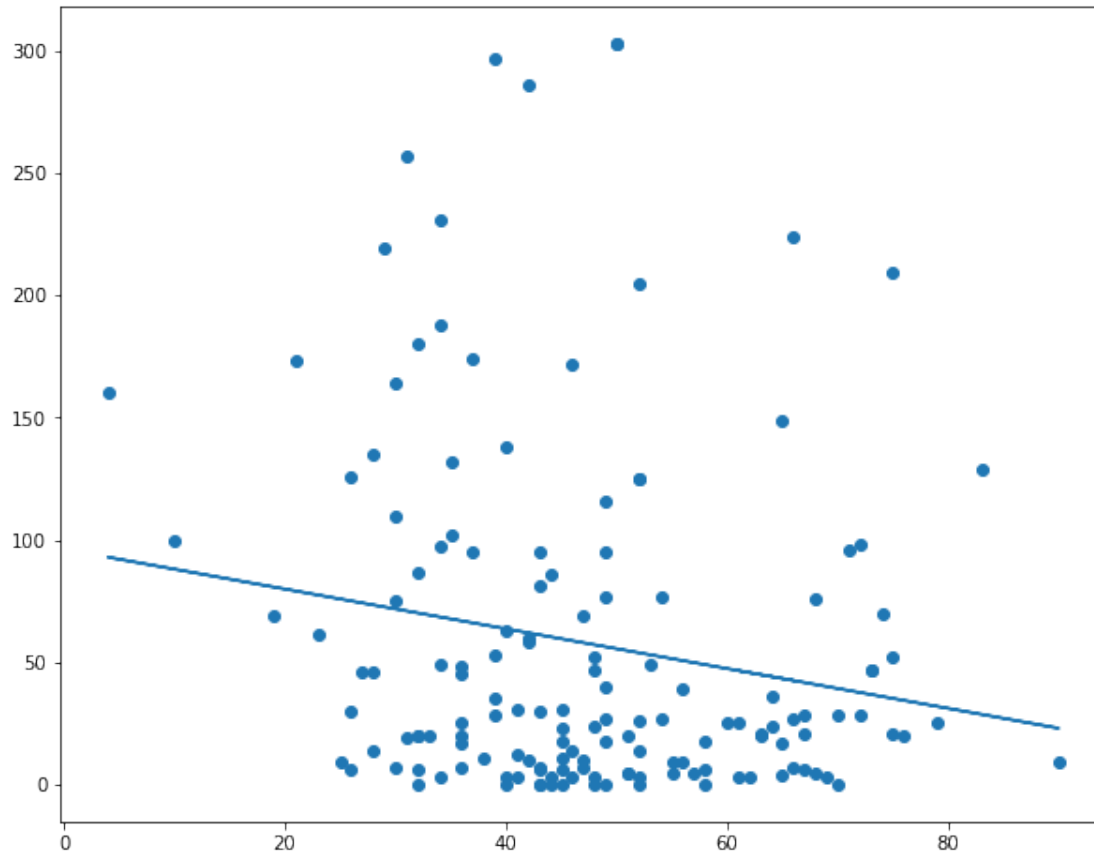
```
LinearRegression()
```

```
# Plotting
```

```
plt.figure(figsize=(10,8))
```

```
plt.scatter(X,y)
```

```
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)));
```



Polynomial Regression

```
from sklearn.preprocessing import PolynomialFeatures
```

```
p2=PolynomialFeatures(degree=2)
```

```
Xp2=p2.fit_transform(X.to_numpy().reshape(-1,1))
```

```
Xp2
```

```
array([[1.000e+00, 6.600e+01, 4.356e+03],
       [1.000e+00, 4.200e+01, 1.764e+03],
       [1.000e+00, 4.200e+01, 1.764e+03],
       [1.000e+00, 7.200e+01, 5.184e+03],
       [1.000e+00, 4.600e+01, 2.116e+03],
       [1.000e+00, 3.100e+01, 9.610e+02],
       [1.000e+00, 4.000e+01, 1.600e+03],
       [1.000e+00, 6.800e+01, 4.624e+03],
       [1.000e+00, 3.200e+01, 1.024e+03],
       [1.000e+00, 7.300e+01, 5.329e+03],
       [1.000e+00, 5.000e+01, 2.500e+03],
       [1.000e+00, 4.800e+01, 2.304e+03],
       [1.000e+00, 4.900e+01, 2.401e+03],
       [1.000e+00, 5.200e+01, 2.704e+03],
```

[1.000e+00, 4.700e+01, 2.209e+03],
[1.000e+00, 4.100e+01, 1.681e+03],
[1.000e+00, 4.500e+01, 2.025e+03],
[1.000e+00, 3.200e+01, 1.024e+03],
[1.000e+00, 7.300e+01, 5.329e+03],
[1.000e+00, 5.000e+01, 2.500e+03],
[1.000e+00, 4.800e+01, 2.304e+03],
[1.000e+00, 3.600e+01, 1.296e+03],
[1.000e+00, 5.600e+01, 3.136e+03],
[1.000e+00, 5.500e+01, 3.025e+03],
[1.000e+00, 6.600e+01, 4.356e+03],
[1.000e+00, 6.400e+01, 4.096e+03],
[1.000e+00, 5.200e+01, 2.704e+03],
[1.000e+00, 5.100e+01, 2.601e+03],
[1.000e+00, 5.400e+01, 2.916e+03],
[1.000e+00, 4.700e+01, 2.209e+03],
[1.000e+00, 3.400e+01, 1.156e+03],
[1.000e+00, 6.900e+01, 4.761e+03],
[1.000e+00, 5.200e+01, 2.704e+03],
[1.000e+00, 5.100e+01, 2.601e+03],
[1.000e+00, 4.000e+00, 1.600e+01],
[1.000e+00, 5.200e+01, 2.704e+03],
[1.000e+00, 3.000e+01, 9.000e+02],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 6.500e+01, 4.225e+03],
[1.000e+00, 3.400e+01, 1.156e+03],
[1.000e+00, 5.100e+01, 2.601e+03],
[1.000e+00, 4.400e+01, 1.936e+03],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 4.900e+01, 2.401e+03],
[1.000e+00, 6.800e+01, 4.624e+03],
[1.000e+00, 4.500e+01, 2.025e+03],
[1.000e+00, 4.500e+01, 2.025e+03],
[1.000e+00, 6.700e+01, 4.489e+03],
[1.000e+00, 7.600e+01, 5.776e+03],
[1.000e+00, 6.000e+01, 3.600e+03],
[1.000e+00, 7.900e+01, 6.241e+03],
[1.000e+00, 2.100e+01, 4.410e+02],
[1.000e+00, 5.700e+01, 3.249e+03],
[1.000e+00, 2.700e+01, 7.290e+02],
[1.000e+00, 4.700e+01, 2.209e+03],
[1.000e+00, 6.100e+01, 3.721e+03],
[1.000e+00, 7.000e+01, 4.900e+03],
[1.000e+00, 4.100e+01, 1.681e+03],
[1.000e+00, 3.200e+01, 1.024e+03],
[1.000e+00, 5.500e+01, 3.025e+03],
[1.000e+00, 5.800e+01, 3.364e+03],
[1.000e+00, 4.000e+01, 1.600e+03],
[1.000e+00, 6.300e+01, 3.969e+03],
[1.000e+00, 2.600e+01, 6.760e+02],

[1.000e+00, 5.800e+01, 3.364e+03],
[1.000e+00, 3.300e+01, 1.089e+03],
[1.000e+00, 5.300e+01, 2.809e+03],
[1.000e+00, 1.900e+01, 3.610e+02],
[1.000e+00, 3.600e+01, 1.296e+03],
[1.000e+00, 3.000e+01, 9.000e+02],
[1.000e+00, 2.900e+01, 8.410e+02],
[1.000e+00, 7.400e+01, 5.476e+03],
[1.000e+00, 6.700e+01, 4.489e+03],
[1.000e+00, 2.600e+01, 6.760e+02],
[1.000e+00, 3.200e+01, 1.024e+03],
[1.000e+00, 5.600e+01, 3.136e+03],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 4.800e+01, 2.304e+03],
[1.000e+00, 7.200e+01, 5.184e+03],
[1.000e+00, 7.500e+01, 5.625e+03],
[1.000e+00, 7.000e+01, 4.900e+03],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 3.400e+01, 1.156e+03],
[1.000e+00, 4.900e+01, 2.401e+03],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 3.600e+01, 1.296e+03],
[1.000e+00, 6.200e+01, 3.844e+03],
[1.000e+00, 5.400e+01, 2.916e+03],
[1.000e+00, 3.900e+01, 1.521e+03],
[1.000e+00, 1.000e+01, 1.000e+02],
[1.000e+00, 4.800e+01, 2.304e+03],
[1.000e+00, 6.500e+01, 4.225e+03],
[1.000e+00, 4.000e+01, 1.600e+03],
[1.000e+00, 3.700e+01, 1.369e+03],
[1.000e+00, 5.800e+01, 3.364e+03],
[1.000e+00, 3.400e+01, 1.156e+03],
[1.000e+00, 7.100e+01, 5.041e+03],
[1.000e+00, 4.600e+01, 2.116e+03],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 6.600e+01, 4.356e+03],
[1.000e+00, 5.200e+01, 2.704e+03],
[1.000e+00, 4.500e+01, 2.025e+03],
[1.000e+00, 3.500e+01, 1.225e+03],
[1.000e+00, 4.100e+01, 1.681e+03],
[1.000e+00, 3.900e+01, 1.521e+03],
[1.000e+00, 4.900e+01, 2.401e+03],
[1.000e+00, 3.000e+01, 9.000e+02],
[1.000e+00, 3.000e+01, 9.000e+02],
[1.000e+00, 2.500e+01, 6.250e+02],
[1.000e+00, 4.200e+01, 1.764e+03],
[1.000e+00, 4.500e+01, 2.025e+03],
[1.000e+00, 2.800e+01, 7.840e+02],
[1.000e+00, 2.800e+01, 7.840e+02],
[1.000e+00, 3.400e+01, 1.156e+03],


```
[1.000e+00, 4.900e+01, 2.401e+03],
[1.000e+00, 4.000e+01, 1.600e+03],
[1.000e+00, 3.200e+01, 1.024e+03],
[1.000e+00, 3.900e+01, 1.521e+03],
[1.000e+00, 4.400e+01, 1.936e+03],
[1.000e+00, 5.200e+01, 2.704e+03],
[1.000e+00, 3.600e+01, 1.296e+03],
[1.000e+00, 8.300e+01, 6.889e+03],
[1.000e+00, 2.300e+01, 5.290e+02],
[1.000e+00, 5.200e+01, 2.704e+03],
[1.000e+00, 4.600e+01, 2.116e+03],
[1.000e+00, 3.100e+01, 9.610e+02],
[1.000e+00, 6.300e+01, 3.969e+03],
[1.000e+00, 2.600e+01, 6.760e+02],
[1.000e+00, 4.300e+01, 1.849e+03],
[1.000e+00, 3.500e+01, 1.225e+03],
[1.000e+00, 7.500e+01, 5.625e+03],
[1.000e+00, 3.900e+01, 1.521e+03],
[1.000e+00, 6.400e+01, 4.096e+03],
[1.000e+00, 4.800e+01, 2.304e+03],
[1.000e+00, 4.900e+01, 2.401e+03],
[1.000e+00, 3.700e+01, 1.369e+03],
[1.000e+00, 4.400e+01, 1.936e+03],
[1.000e+00, 3.600e+01, 1.296e+03],
[1.000e+00, 2.800e+01, 7.840e+02],
[1.000e+00, 4.900e+01, 2.401e+03],
[1.000e+00, 4.500e+01, 2.025e+03],
[1.000e+00, 3.600e+01, 1.296e+03],
[1.000e+00, 6.700e+01, 4.489e+03],
[1.000e+00, 6.500e+01, 4.225e+03],
[1.000e+00, 9.000e+01, 8.100e+03],
[1.000e+00, 4.200e+01, 1.764e+03],
[1.000e+00, 3.800e+01, 1.444e+03],
[1.000e+00, 7.500e+01, 5.625e+03],
[1.000e+00, 3.200e+01, 1.024e+03],
[1.000e+00, 6.100e+01, 3.721e+03]]])
```

X

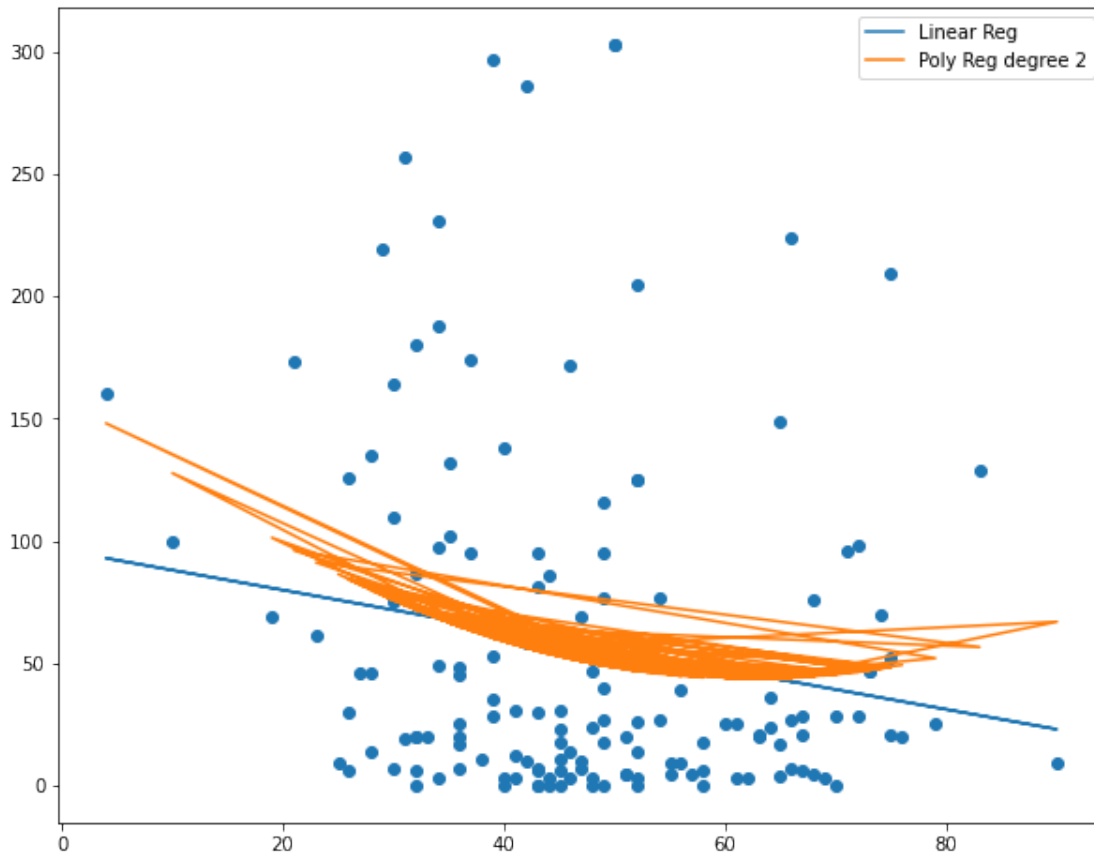
```
0      66
4      42
5      42
6      72
7      46
      ..
190    42
191    38
192    75
193    32
194    61
```

Name: age, Length: 150, dtype: int64

```
lr2=LinearRegression()  
pr2=lr2.fit(Xp2,y)
```

```
# Plotting
```

```
plt.figure(figsize=(10,8))  
plt.scatter(X,y)  
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')  
plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )  
plt.legend();
```



```
# Degree 3
```

```
p3=PolynomialFeatures(degree=3)
```

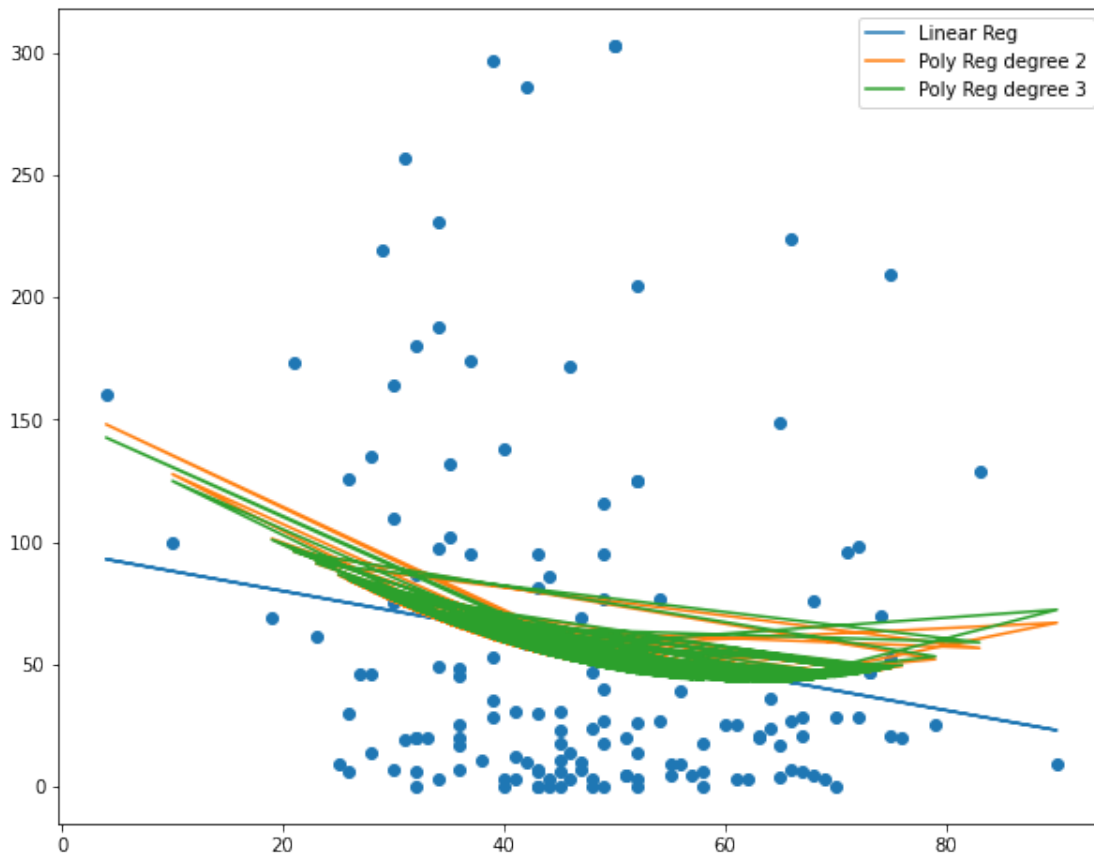
```
Xp3=p3.fit_transform(X.to_numpy().reshape(-1,1))
```

```
Xp3
```

```
lr3= LinearRegression()  
pr3=lr3.fit(Xp3,y)
```

```
# Plotting
```

```
plt.figure(figsize=(10,8))
plt.scatter(X,y)
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')
plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )
plt.plot(X,pr3.predict(Xp3), label='Poly Reg degree 3')
plt.legend();
```



Degree 5

```
p5=PolynomialFeatures(degree=5)
```

```
Xp5=p5.fit_transform(X.to_numpy().reshape(-1,1))
```

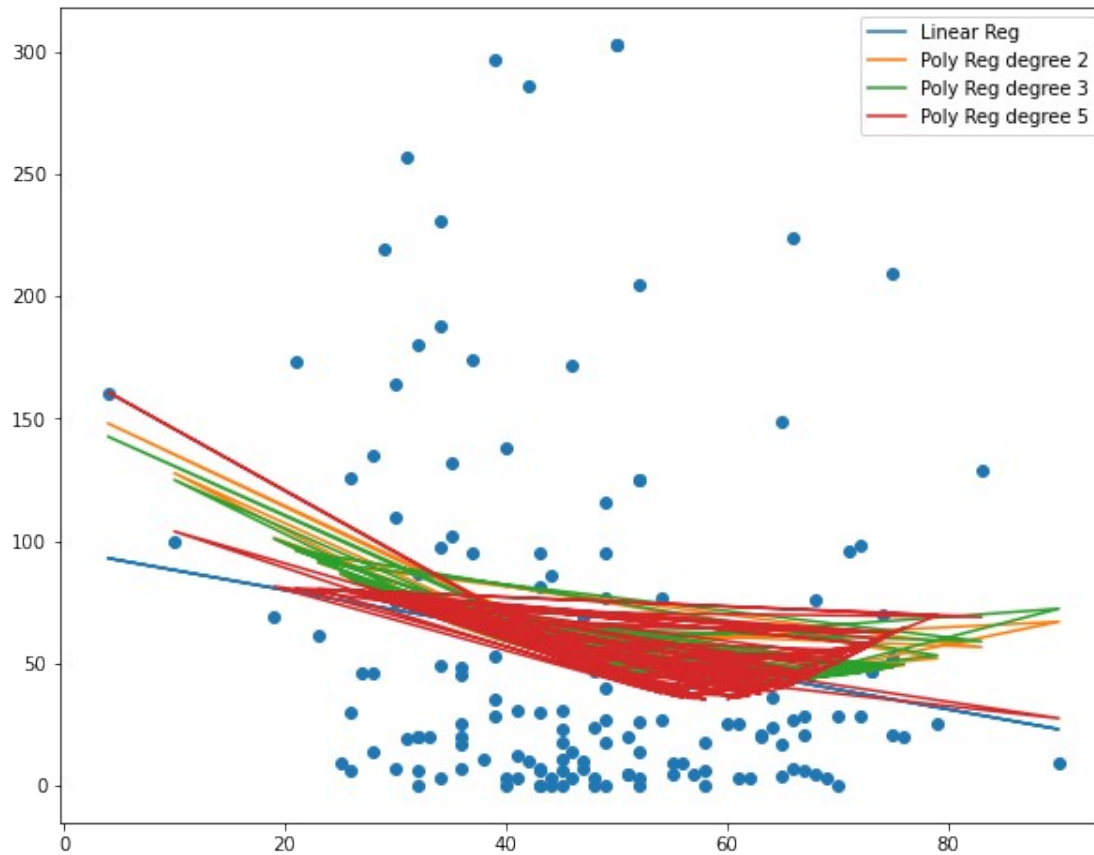
```
lr5= LinearRegression()
```

```
pr5=lr5.fit(Xp5,y)
```

Plotting

```
plt.figure(figsize=(10,8))
plt.scatter(X,y)
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')
plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )
plt.plot(X,pr3.predict(Xp3), label='Poly Reg degree 3')
```

```
plt.plot(X,pr5.predict(Xp5), label='Poly Reg degree 5')
plt.legend();
```



Degree 10

```
p10=PolynomialFeatures(degree=10)
```

```
Xp10=p10.fit_transform(X.to_numpy().reshape(-1,1))
```

```
lr10= LinearRegression()
```

```
pr10=lr10.fit(Xp10,y)
```

Plotting

```
plt.figure(figsize=(10,8))
```

```
plt.scatter(X,y)
```

```
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')
```

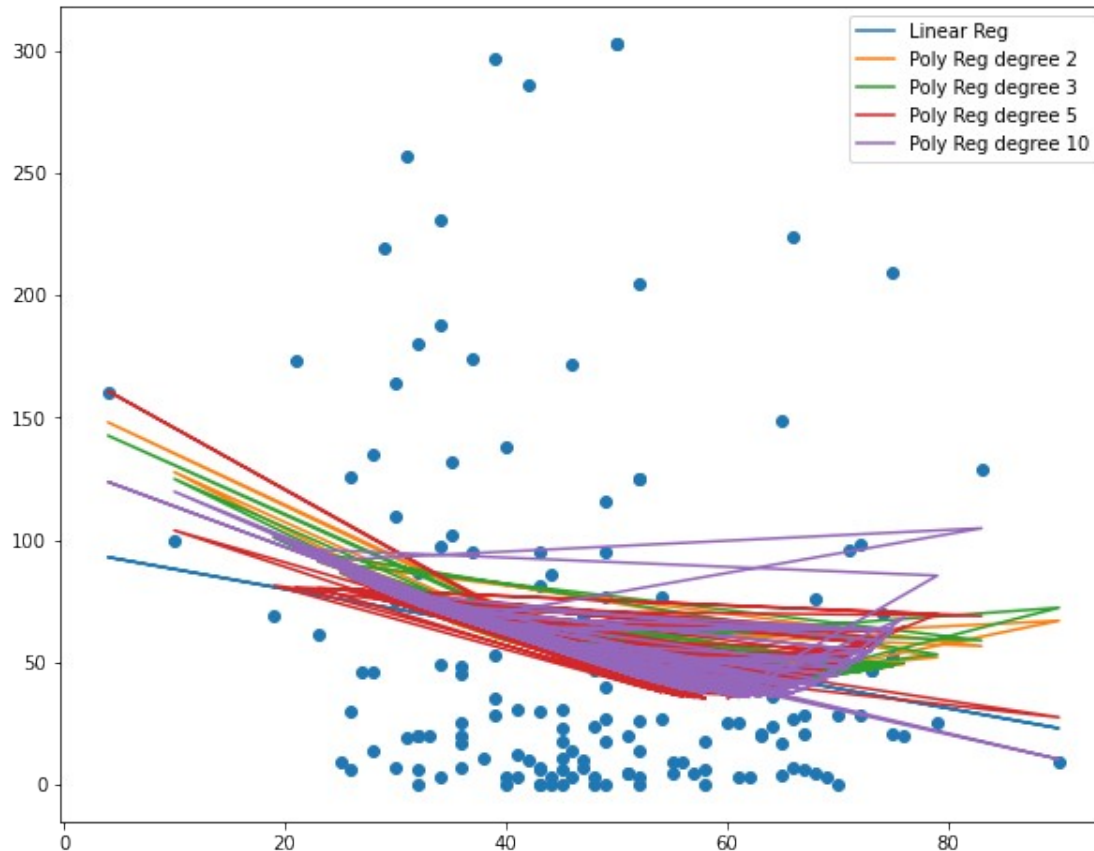
```
plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )
```

```
plt.plot(X,pr3.predict(Xp3), label='Poly Reg degree 3')
```

```
plt.plot(X,pr5.predict(Xp5), label='Poly Reg degree 5')
```

```
plt.plot(X,pr10.predict(Xp10), label='Poly Reg degree 10')
```

```
plt.legend();
```



Degree 25

```
p25=PolynomialFeatures(degree=25)
```

```
Xp25=p25.fit_transform(X.to_numpy().reshape(-1,1))
```

```
lr25= LinearRegression()
```

```
pr25=lr25.fit(Xp25,y)
```

Plotting

```
plt.figure(figsize=(10,8))
```

```
plt.scatter(X,y)
```

```
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')
```

```
plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )
```

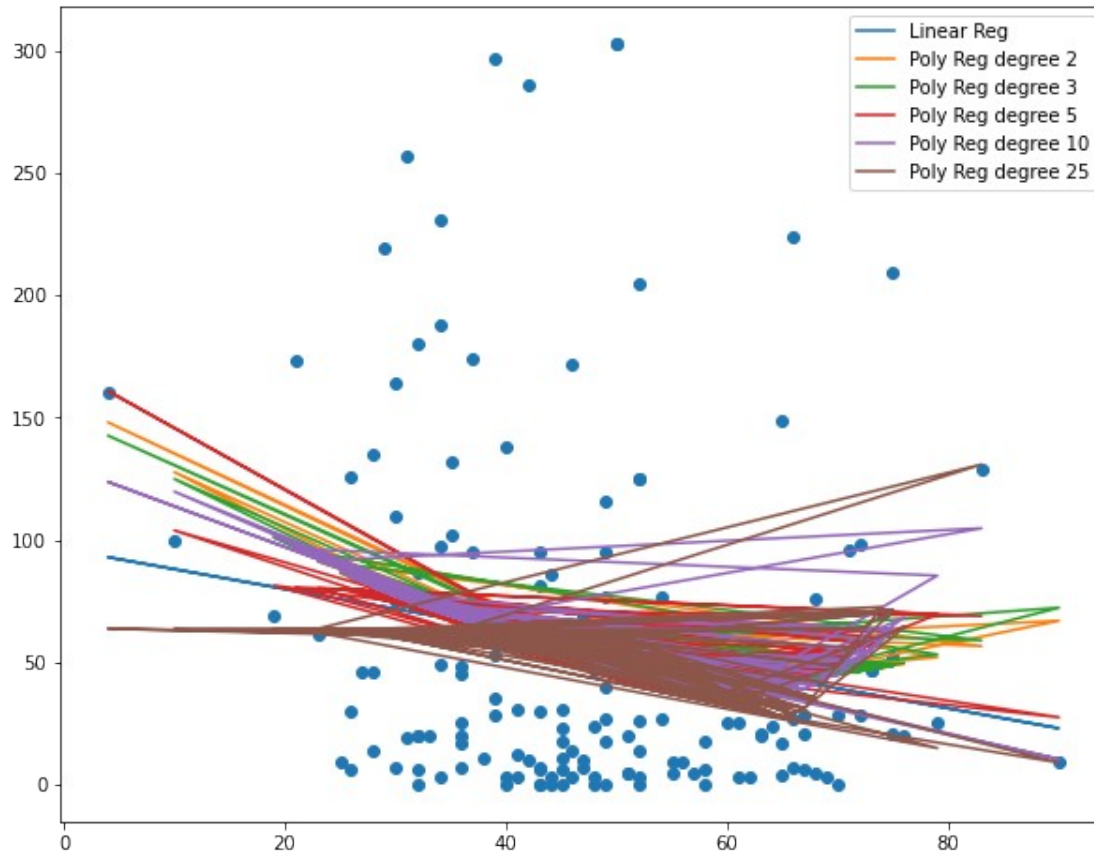
```
plt.plot(X,pr3.predict(Xp3), label='Poly Reg degree 3')
```

```
plt.plot(X,pr5.predict(Xp5), label='Poly Reg degree 5')
```

```
plt.plot(X,pr10.predict(Xp10), label='Poly Reg degree 10')
```

```
plt.plot(X,pr25.predict(Xp25), label='Poly Reg degree 25')
```

```
plt.legend();
```



Degree 75

```
p75=PolynomialFeatures(degree=75)
```

```
Xp75=p75.fit_transform(X.to_numpy().reshape(-1,1))
```

```
lr75= LinearRegression()
```

```
pr75=lr75.fit(Xp75,y)
```

```
plt.figure(figsize=(10,8))
```

```
plt.scatter(X,y)
```

```
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')
```

```
plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )
```

```
plt.plot(X,pr3.predict(Xp3), label='Poly Reg degree 3')
```

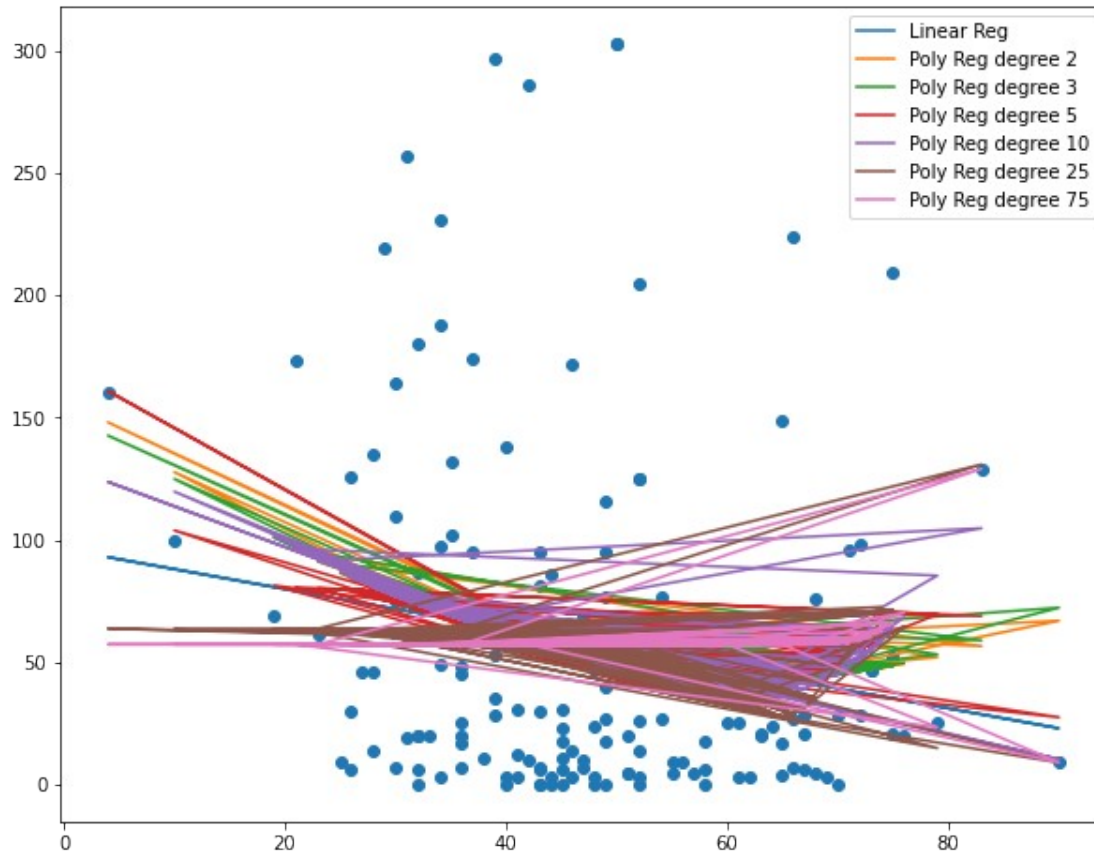
```
plt.plot(X,pr5.predict(Xp5), label='Poly Reg degree 5')
```

```
plt.plot(X,pr10.predict(Xp10), label='Poly Reg degree 10')
```

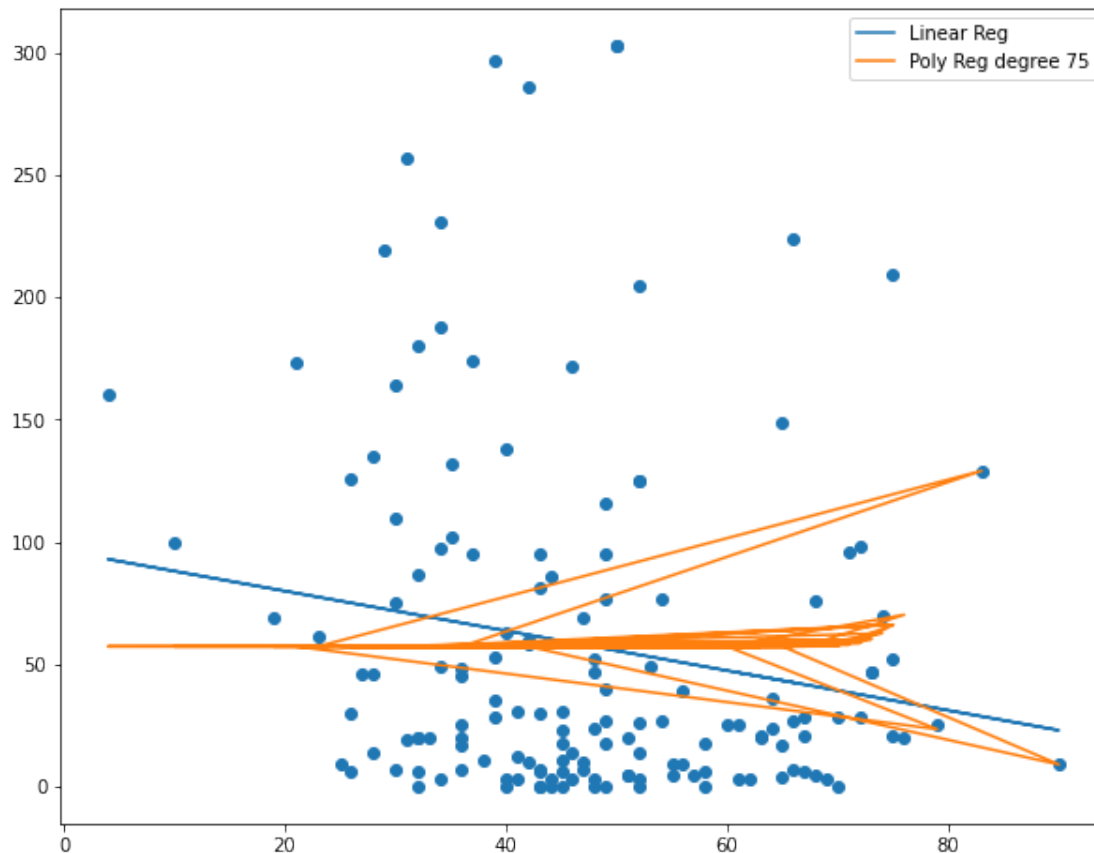
```
plt.plot(X,pr25.predict(Xp25), label='Poly Reg degree 25')
```

```
plt.plot(X,pr75.predict(Xp75), label='Poly Reg degree 75')
```

```
plt.legend();
```



```
plt.figure(figsize=(10,8))
plt.scatter(X,y)
plt.plot(X,lr.predict(X.to_numpy().reshape(-1,1)),label='Linear Reg')
# plt.plot(X,pr2.predict(Xp2), label='Poly Reg degree 2' )
# plt.plot(X,pr3.predict(Xp3), label='Poly Reg degree 3')
# plt.plot(X,pr5.predict(Xp5), label='Poly Reg degree 5')
# plt.plot(X,pr10.predict(Xp10), label='Poly Reg degree 10')
# plt.plot(X,pr25.predict(Xp25), label='Poly Reg degree 25')
plt.plot(X,pr75.predict(Xp75), label='Poly Reg degree 75')
plt.legend();
```



Overfitting and resolving it

Overfitting

Cross validation- k fold cross validation

Regularisation - LR

Lasso

Ridge

Elastic Net

Overfitting:

Phenomenon where training performance is good, but testing performance not good.

Sourcing the data

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```



```
X=churn.drop(['churn','gender','customer_id','age','occupation','city',
,
'branch_code','previous_month_end_balance','average_monthly_balance_prevQ',
'average_monthly_balance_prevQ2','previous_month_credit','previous_month_debit',
'current_month_balance','previous_month_balance'],axis=1)
```

X

	vintage	dependents	customer_nw_category
days_since_last_transaction \			
0	3135	0.0	2
224.0			
4	2531	2.0	3
58.0			
5	263	0.0	2
60.0			
6	5922	0.0	1
98.0			
7	1145	0.0	2
172.0			
...
...			
1294	1921	0.0	2
87.0			
1295	766	0.0	2
27.0			
1297	2993	4.0	3
0.0			
1298	1766	0.0	1
339.0			
1299	7306	0.0	1
62.0			

	current_balance	current_month_credit	current_month_debit
0	1458.71	0.20	0.20
4	927.72	0.33	588.62
5	15202.20	0.36	857.50
6	7006.93	0.64	1299.64
7	10096.58	0.27	443.13
...
1294	14734.45	0.50	30714.79
1295	6785.93	7630.32	963.42
1297	5209.62	1321.96	142.89
1298	4616.88	0.23	0.23
1299	14834.26	0.34	180.13

```
[1001 rows x 7 columns]
```

```
X=X.churn.drop(['churn','gender','customer_id','age','occupation','city'],
```

```
'branch_code','previous_month_end_balance','average_monthly_balance_prevQ',
```

```
'average_monthly_balance_prevQ2','previous_month_credit','previous_month_debit',
```

```
'current_month_balance','previous_month_balance','vintage','dependents',  
'customer_nw_category','current_balance'],axis=1)
```

```
X=X.head(150)
```

```
X
```

	days_since_last_transaction	current_month_credit
current_month_debit		
0	224.0	0.20
0.20		
4	58.0	0.33
588.62		
5	60.0	0.36
857.50		
6	98.0	0.64
1299.64		
7	172.0	0.27
443.13		
..
...		
190	286.0	0.11
45.67		
191	11.0	671.64
528.79		
192	21.0	2857.40
14285.97		
193	0.0	2870.64
3837.13		
194	3.0	286.30
286.30		

```
[150 rows x 3 columns]
```

```
y=churn['current_balance']
```

```
y=y.head(150)
```

Standardisation of features

```
from sklearn.preprocessing import StandardScaler
scaler=StandardScaler()
X_scaled=scaler.fit_transform(X)
X_scaled
```

```
array([[ 2.36678418e+00, -1.94656136e-01, -2.33473030e-01],
       [ 6.44590373e-03, -1.94650278e-01, -1.98272849e-01],
       [ 3.48837143e-02, -1.94648926e-01, -1.82188038e-01],
       [ 5.75202115e-01, -1.94636307e-01, -1.55738550e-01],
       [ 1.62740111e+00, -1.94652982e-01, -2.06976283e-01],
       [-5.48091403e-01, -1.62463954e-01, -1.90741918e-01],
       [-8.18250603e-01,  1.16854641e-01, -1.20583834e-01],
       [-7.47156077e-01, -1.74682210e-01, -2.33452690e-01],
       [-5.33872497e-01,  1.46249482e-01,  3.59221268e-01],
       [-1.49962054e-01, -1.94650278e-01,  7.15389676e-02],
       [ 3.49007770e+00, -1.94637659e-01, -1.28912187e-01],
       [-7.88675280e-02, -1.94635405e-01, -2.33445512e-01],
       [-8.18250603e-01, -1.86070323e-01, -8.62247447e-02],
       [-7.75593887e-01, -1.81397172e-02, -2.33468842e-01],
       [ 1.62853862e-01, -1.94639912e-01, -2.29178443e-01],
       [-3.77464539e-01, -1.94651630e-01, -2.27237234e-01],
       [-4.91215781e-01, -1.91069212e-01, -1.87999065e-02],
       [-5.33872497e-01,  1.46249482e-01,  3.59221268e-01],
       [-1.49962054e-01, -1.94650278e-01,  7.15389676e-02],
       [ 3.49007770e+00, -1.94637659e-01, -1.28912187e-01],
       [-1.49962054e-01, -1.94638109e-01, -1.95464827e-01],
       [-5.33872497e-01, -1.94312271e-01, -1.82451851e-01],
       [-6.90280456e-01, -1.88208777e-01, -2.33289976e-01],
       [-6.90280456e-01, -1.91785335e-01, -2.23586925e-01],
       [-4.34340160e-01,  6.43520478e-01, -2.21975333e-01],
       [-3.06370013e-01, -1.94657939e-01, -2.10455502e-01],
       [ 9.59112558e-01, -1.94656587e-01, -1.68223302e-01],
       [-7.47156077e-01,  1.49409111e+00,  2.08228750e+00],
       [ 2.76605104e-01, -1.94645320e-01, -2.33458673e-01],
       [-6.76061550e-01, -1.78539990e-01, -2.33445512e-01],
       [ 5.60983210e-01, -1.94645771e-01, -2.33459271e-01],
       [-7.75593887e-01, -1.75580406e-01, -2.33448503e-01],
       [ 9.59112558e-01, -1.94656587e-01, -1.68223302e-01],
       [-7.47156077e-01,  1.49409111e+00,  2.08228750e+00],
       [ 1.45677424e+00, -1.94660643e-01, -2.27068538e-01],
       [-6.19185929e-01, -1.30274475e-01, -2.28799174e-01],
       [-7.18718266e-01, -4.77130260e-02,  6.40935774e-01],
       [ 5.32545399e-01, -1.94642166e-01, -1.05265337e-01],
       [-5.76529213e-01, -1.79844244e-01, -2.08543607e-01],
       [-7.75593887e-01, -1.59400714e-01, -2.12880069e-01],
       [-5.33872497e-01, -1.72696535e-01, -2.26287867e-01],
       [-8.18250603e-01, -1.51499476e-01, -2.33445512e-01],
       [-7.18718266e-01, -1.30251491e-01, -2.33443119e-01],
       [ 8.31142411e-01, -1.94640813e-01, -2.33452690e-01],
```

[2.62386199e-01, -1.94656136e-01, -2.33473030e-01],
[-6.61842645e-01, -1.79211046e-01, -2.33481405e-01],
[-5.62310308e-01, -1.51955109e-01, -2.33444914e-01],
[-4.20121255e-01, -1.92814677e-01, 5.59154368e-01],
[-5.33872497e-01, -1.27109383e-01, -1.48010208e-01],
[-4.62777971e-01, -1.91699707e-01, -2.03939742e-01],
[-4.62777971e-01, -1.67401101e-01, -1.56532980e-01],
[1.64162001e+00, -1.94647123e-01, -2.33461065e-01],
[-7.47156077e-01, 7.44280743e-02, 8.92706652e-02],
[-1.64180960e-01, -1.94648475e-01, -4.25729796e-02],
[-7.18718266e-01, 2.33057644e-01, 6.05731406e-01],
[-4.62777971e-01, -1.88199763e-01, -2.29176050e-01],
[-8.18250603e-01, 2.21877644e+00, 8.35184632e-01],
[-6.47623740e-01, -1.81207987e-01, -1.62230980e-01],
[-7.32937171e-01, 1.16512578e-01, -2.86967792e-02],
[-7.47156077e-01, 7.66404391e-02, 4.28545476e-02],
[-5.62310308e-01, -1.88221846e-01, -2.16386208e-01],
[1.14395833e+00, -1.94647123e-01, -2.33461065e-01],
[-5.33872497e-01, -1.83729065e-01, -1.38105558e-01],
[9.73331463e-01, -1.94651630e-01, -2.33467048e-01],
[-7.32937171e-01, -1.20721062e-01, -2.33447306e-01],
[-5.33872497e-01, -1.73394631e-01, -2.29179639e-01],
[-1.21524244e-01, -1.94657939e-01, -2.26553474e-01],
[1.62853862e-01, -1.94664699e-01, -2.33398851e-01],
[-1.78399865e-01, -1.94651630e-01, -2.01095827e-01],
[2.48167294e-01, -1.94643968e-01, -2.33456878e-01],
[2.29568966e+00, -1.94657488e-01, -2.11566986e-01],
[1.77072767e-01, -1.94652982e-01, -2.25777589e-01],
[-7.32937171e-01, -6.93724777e-02, -2.26122759e-01],
[-3.91683444e-01, -1.94649827e-01, -6.13575359e-02],
[1.74115235e+00, -1.94658840e-01, -1.48017386e-01],
[-2.63713297e-01, -1.94647574e-01, -2.21985503e-01],
[-8.18250603e-01, 3.42930013e-01, -2.56075958e-02],
[-8.18250603e-01, -1.69657632e-01, -1.86669269e-01],
[-4.20121255e-01, 1.13682437e-02, 2.47558889e+00],
[-7.88675280e-02, -1.94638109e-01, 4.55243821e-02],
[-4.20121255e-01, 3.59282313e-01, -1.86861894e-01],
[-8.18250603e-01, 2.20614501e-01, -2.15177215e-01],
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[5.32545399e-01, -1.94639912e-01, -2.25771607e-01],
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[-5.76529213e-01, -1.94049528e-01, -1.41475903e-01],
[-7.75593887e-01, -1.92799805e-01, -1.06972045e-01],
[-4.34340160e-01, -1.25042136e-01, -3.45862081e-02],
[3.40476427e+00, -1.94664699e-01, -2.33484396e-01],
[6.03639926e-01, -1.94639461e-01, -1.90720980e-01],
[-7.75593887e-01, -1.18932332e-01, 3.12238042e-01],
[-7.61374982e-01, -1.93305463e-01, -1.57566696e-01],
[7.75404302e-02, -1.94643968e-01, -2.01392542e-01],
[1.65583892e+00, -1.94649827e-01, -2.33464655e-01],

[-8.18250603e-01, -8.57216231e-02, -1.46857447e-01],
[-1.21524244e-01, -1.94660193e-01, -2.07840105e-01],
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[-6.19185929e-01, -1.89165560e-01, -2.18894525e-01],
[-3.91683444e-01, -1.94646672e-01, -2.33460467e-01],
[-7.18718266e-01, -9.54471947e-02, 1.50227298e+00],
[-4.48559066e-01, 9.50744081e-02, -6.25396092e-02],
[-7.32937171e-01, -1.47880554e-01, -2.31708893e-01],
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[-7.75593887e-01, -8.52907776e-02, -1.35980698e-01],
[-4.20121255e-01, -1.93680875e-01, -2.27984405e-01],
[-2.49494391e-01, -1.94657488e-01, -1.82199404e-01],
[1.51364986e+00, -1.94640813e-01, -2.33452690e-01],
[7.45828979e-01, -1.94656136e-01, -2.33473030e-01],
[-6.90280456e-01, -1.42389527e-01, -1.54141914e-01],
[-6.76061550e-01, -1.91870513e-01, -2.26631840e-01],
[-8.18250603e-01, 1.23456132e-01, -2.17793210e-01],
[-1.64180960e-01, -1.94661094e-01, -2.33479610e-01],
[-6.19185929e-01, -1.86292956e-01, -1.90025256e-01],
[2.46631652e+00, -1.94657939e-01, -1.96420177e-01],
[-4.34340160e-01, -1.48952070e-03, -2.33446708e-01],
[-7.75593887e-01, -9.80795887e-02, -2.33468842e-01],
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[-3.20588918e-01, -1.94651179e-01, -1.39033390e-01],
[4.04575252e-01, -1.94634053e-01, -2.33443717e-01],
[-8.18250603e-01, 8.62096263e-02, -2.23031183e-01],
[-1.35743149e-01, -1.94641264e-01, -2.12506184e-01],
[1.01598818e+00, -1.94642166e-01, -2.33454485e-01],
[4.91026196e-02, -1.94664699e-01, -2.33484396e-01],
[2.09662498e+00, -1.94639912e-01, -2.18923837e-01],
[-7.75593887e-01, -1.62470263e-01, -2.33479610e-01],
[2.83600806e+00, -1.94638560e-01, -2.33449699e-01],
[-5.19653592e-01, -1.81911492e-01, -1.70770503e-01],
[-7.32937171e-01, -1.94558791e-01, -1.94763719e-01],
[-7.32937171e-01, 3.47511973e+00, -1.88099003e-01],
[1.05864490e+00, -1.94652080e-01, 1.24911730e-01],
[2.15350060e+00, -1.94639912e-01, -2.33451494e-01],
[-6.46486227e-02, -1.94640813e-01, -2.12262711e-01],
[-4.76996876e-01, -1.27179238e-01, -2.15620493e-01],
[-4.76996876e-01, -7.87767178e-02, -2.32013385e-01],
[2.76605104e-01, -1.94642166e-01, -2.33454485e-01],
[5.32545399e-01, -1.94660643e-01, -2.33479012e-01],
[-7.75593887e-01, -1.64154437e-01, -2.01213077e-01],
[-7.18718266e-01, -1.81779894e-01, -1.58129018e-01],
[1.10130161e+00, -1.94642166e-01, 1.72477617e-01],
[-5.62310308e-01, -1.91272016e-01, -1.88435798e-01],
[-3.77464539e-01, -1.94633603e-01, 6.37868126e-01],
[-4.62777971e-01, -1.86293407e-01, -2.33482601e-01],
[-5.19653592e-01, -5.34415589e-02, 2.25441201e-01],
[1.30036629e+00, -1.94660193e-01, -2.33478414e-01],

```

[-6.90280456e-01,  1.11140920e+01,  1.11625516e+01],
[ 3.24835631e+00, -1.94660193e-01, -2.30752945e-01],
[-6.61842645e-01, -1.64395999e-01, -2.01851971e-01],
[-5.19653592e-01, -6.58892088e-02,  6.21123483e-01],
[-8.18250603e-01, -6.52925148e-02, -3.94203495e-03],
[-7.75593887e-01, -1.81762318e-01, -2.16358092e-01]])

```

Splitting to train and test

```

from sklearn.model_selection import train_test_split

X_train,X_test,y_train,y_test=train_test_split(X_scaled,y,
test_size=0.2,random_state=10)
X_train.shape,X_test.shape,y_train.shape,y_test.shape

((120, 3), (30, 3), (120,), (30,))

from sklearn.linear_model import LinearRegression

lr =LinearRegression()

lr.fit(X_train,y_train)

LinearRegression()

```

Model performance

```

from sklearn.metrics import r2_score,mean_squared_error

r2_train=r2_score(y_train,lr.predict(X_train))
r2_test=r2_score(y_test,lr.predict(X_test))

mse_train=mean_squared_error(y_train,lr.predict(X_train))
mse_test=mean_squared_error(y_test,lr.predict(X_test))

print('R2 score- training:',r2_train)
print('R2 score- testing:',r2_test)

print('MSE- training:',mse_train)
print('MSE- testing:',mse_test)

```

```

R2 score- training: 0.17967307485814676
R2 score- testing: -0.02646793049098295
MSE- training: 45537487.38102582
MSE- testing: 38801065.057938494

```

Remark:

There is overfitting

LR using k fold cross validation

```
from sklearn.model_selection import cross_val_score, cross_val_predict
lr=LinearRegression()
cv_score=cross_val_score(lr,X_train,y_train,cv=5)
print('CV_Score:',cv_score)
```

```
CV_Score: [ 0.00591321 -0.81918986  0.22513681  0.00472868 -
0.11283417]
```

```
print('CV_Score mean:', cv_score.mean())
```

```
CV_Score mean: -0.1392490653998443
```

```
# cv=4
```

```
lr=LinearRegression()
cv_score=cross_val_score(lr,X_train,y_train,cv=4)
print('CV_Score:',cv_score)
print('CV_Score mean:', cv_score.mean())
```

```
CV_Score: [ 0.04451588  0.27405206 -0.05009663 -0.14642979]
CV_Score mean: 0.030510380670514925
```

```
# cv=3
```

```
lr=LinearRegression()
cv_score=cross_val_score(lr,X_train,y_train,cv=3)
print('CV_Score:',cv_score)
print('CV_Score mean:', cv_score.mean())
```

```
CV_Score: [ 0.05127783  0.12149084 -0.03279811]
CV_Score mean: 0.04665685327111446
```

```
# cv=10
```

```
lr=LinearRegression()
cv_score=cross_val_score(lr,X_train,y_train,cv=10)
print('CV_Score:',cv_score)
print('CV_Score mean:', cv_score.mean())
```

```
CV_Score: [ 0.058213   -0.07911335 -1.15734997 -0.45078844  0.40435663
-0.05349947
-0.43866065 -0.09648437 -0.04697697 -0.13699457]
CV_Score mean: -0.1997298162066931
```

n= # of the training data

k fold validation

k=1, usual training

k=n, Leave One Out Cross Validation

k=2,3,4,....., K- fold cross validation

```
# k=3 is the chosen value of cv
```

```
y_pred=cross_val_predict(lr, X_test,y_test,cv=3)  
y_pred
```

```
array([ 5990.29502299,  8167.99863237,  3614.89340666,  7928.08312767,  
        8125.23529006,  8332.9751722 ,  8011.01468443,  7858.04169012,  
        8355.73597874,  8373.18601123,  8248.50527344,  3415.94097617,  
        6305.32806222,  7754.9079969 ,  1952.51397255,  8542.71368569,  
        7978.41672831,  8660.63792429,  8364.06075456,  8773.3912858 ,  
        7260.03753669, 11416.22119477,  6165.84239321, 64598.08484351,  
        7208.43799154,  5614.17792405,  6482.94731966, -5554.08260476,  
        37440.39329568,  4213.79479275])
```

```
y_test
```

```
113      909.84  
146     4689.26  
13      4548.48  
119     5945.69  
66      5065.29  
79      2335.05  
94     20741.22  
87      3144.56  
53     21252.86  
73      2662.21  
86     12913.08  
186     1433.48  
70      431.67  
4       927.72  
23      4548.48  
147     3725.73  
111     9572.43  
52      1443.95  
26     20273.43  
48      3854.44  
136     1072.56  
171     7154.35  
164     14901.34  
30       972.57  
80      9931.34  
5      15202.20  
125     5899.01  
117     1905.79  
99     10152.97  
152     5718.20
```

```
Name: current_balance, dtype: float64
```

Cross validation is a general tool, which can applied on any ML technique

Regularisation - LR

Lasso

Ridge

Elastic Net

Lasso

```
from sklearn.linear_model import Lasso

lasso=Lasso(alpha=0.1)
lasso.fit(X_train,y_train)

r2_lasso_train=r2_score(y_train,lasso.predict(X_train))
r2_lasso_test=r2_score(y_test,lasso.predict(X_test))

print(' R2 score: Lasso - Train',r2_lasso_train)
print(' R2 score: Lasso - Test',r2_lasso_test)

mse_lasso_train=mean_squared_error(y_train,lasso.predict(X_train))
mse_lasso_test=mean_squared_error(y_test,lasso.predict(X_test))

print(' MSE: Lasso - Train',mse_lasso_train)
print(' MSE: Lasso - Test',mse_lasso_test)

R2 score: Lasso - Train 0.1796730716296624
R2 score: Lasso - Test -0.026464676900515904
MSE: Lasso - Train 45537487.56024348
MSE: Lasso - Test 38800942.07038902
```

Ridge

```
from sklearn.linear_model import Ridge

ridge=Ridge(alpha=0.1)
ridge.fit(X_train,y_train)

r2_ridge_train=r2_score(y_train,ridge.predict(X_train))
r2_ridge_test=r2_score(y_test,ridge.predict(X_test))

print(' R2 score: ridge - Train',r2_ridge_train)
print(' R2 score: ridge - Test',r2_ridge_test)

mse_ridge_train=mean_squared_error(y_train,ridge.predict(X_train))
mse_ridge_test=mean_squared_error(y_test,ridge.predict(X_test))

print(' MSE: ridge - Train',mse_ridge_train)
print(' MSE: ridge - Test',mse_ridge_test)
```

```
R2 score: ridge - Train 0.17966473778724756
R2 score: ridge - Test -0.026152016593580463
MSE: ridge - Train 45537950.18341501
MSE: ridge - Test 38789123.33494676
```

```
from sklearn.linear_model import Ridge
```

```
ridge=Ridge(alpha=0.5)
ridge.fit(X_train,y_train)
```

```
r2_ridge_train=r2_score(y_train,ridge.predict(X_train))
r2_ridge_test=r2_score(y_test,ridge.predict(X_test))
```

```
print(' R2 score: ridge - Train',r2_ridge_train)
print(' R2 score: ridge - Test',r2_ridge_test)
```

```
mse_ridge_train=mean_squared_error(y_train,ridge.predict(X_train))
mse_ridge_test=mean_squared_error(y_test,ridge.predict(X_test))
```

```
print(' MSE: ridge - Train',mse_ridge_train)
print(' MSE: ridge - Test',mse_ridge_test)
```

```
R2 score: ridge - Train 0.17947572985910698
R2 score: ridge - Test -0.02497231369715247
MSE: ridge - Train 45548442.27611467
MSE: ridge - Test 38744529.90199709
```

```
from sklearn.linear_model import Ridge
```

```
ridge=Ridge(alpha=0.9)
ridge.fit(X_train,y_train)
```

```
r2_ridge_train=r2_score(y_train,ridge.predict(X_train))
r2_ridge_test=r2_score(y_test,ridge.predict(X_test))
```

```
print(' R2 score: ridge - Train',r2_ridge_train)
print(' R2 score: ridge - Test',r2_ridge_test)
```

```
mse_ridge_train=mean_squared_error(y_train,ridge.predict(X_train))
mse_ridge_test=mean_squared_error(y_test,ridge.predict(X_test))
```

```
print(' MSE: ridge - Train',mse_ridge_train)
print(' MSE: ridge - Test',mse_ridge_test)
```

```
R2 score: ridge - Train 0.17906679218703514
R2 score: ridge - Test -0.02391529918585311
MSE: ridge - Train 45571142.97447146
MSE: ridge - Test 38704574.159005195
```

```

from sklearn.linear_model import Ridge

ridge=Ridge(alpha=0.01)
ridge.fit(X_train,y_train)

r2_ridge_train=r2_score(y_train,ridge.predict(X_train))
r2_ridge_test=r2_score(y_test,ridge.predict(X_test))

print(' R2 score: ridge - Train',r2_ridge_train)
print(' R2 score: ridge - Test',r2_ridge_test)

mse_ridge_train=mean_squared_error(y_train,ridge.predict(X_train))
mse_ridge_test=mean_squared_error(y_test,ridge.predict(X_test))

print(' MSE: ridge - Train',mse_ridge_train)
print(' MSE: ridge - Test',mse_ridge_test)

R2 score: ridge - Train 0.17967299043865448
R2 score: ridge - Test -0.026435942019107372
MSE: ridge - Train 45537492.06726913
MSE: ridge - Test 38799855.875711285

```

```

from sklearn.linear_model import Ridge

ridge=Ridge(alpha=0.001)
ridge.fit(X_train,y_train)

r2_ridge_train=r2_score(y_train,ridge.predict(X_train))
r2_ridge_test=r2_score(y_test,ridge.predict(X_test))

print(' R2 score: ridge - Train',r2_ridge_train)
print(' R2 score: ridge - Test',r2_ridge_test)

mse_ridge_train=mean_squared_error(y_train,ridge.predict(X_train))
mse_ridge_test=mean_squared_error(y_test,ridge.predict(X_test))

print(' MSE: ridge - Train',mse_ridge_train)
print(' MSE: ridge - Test',mse_ridge_test)

R2 score: ridge - Train 0.17967307401289223
R2 score: ridge - Test -0.026464727632185436
MSE: ridge - Train 45537487.427947074
MSE: ridge - Test 38800943.98807466

```

```

from sklearn.linear_model import Ridge

ridge=Ridge(alpha=0.0)
ridge.fit(X_train,y_train)

r2_ridge_train=r2_score(y_train,ridge.predict(X_train))

```

```

r2_ridge_test=r2_score(y_test,ridge.predict(X_test))

print(' R2 score: ridge - Train',r2_ridge_train)
print(' R2 score: ridge - Test',r2_ridge_test)

mse_ridge_train=mean_squared_error(y_train,ridge.predict(X_train))
mse_ridge_test=mean_squared_error(y_test,ridge.predict(X_test))

print(' MSE: ridge - Train',mse_ridge_train)
print(' MSE: ridge - Test',mse_ridge_test)

R2 score: ridge - Train 0.17967307485814676
R2 score: ridge - Test -0.026467930490983393
MSE: ridge - Train 45537487.38102582
MSE: ridge - Test 38801065.05793851

```

Elastic Net

```

from sklearn.linear_model import ElasticNet

enet=ElasticNet()
enet.fit(X_train,y_train)

r2_enet_train=r2_score(y_train,enet.predict(X_train))
r2_enet_test=r2_score(y_test,enet.predict(X_test))

print(' R2 score: enet - Train',r2_enet_train)
print(' R2 score: enet - Test',r2_enet_test)

mse_enet_train=mean_squared_error(y_train,enet.predict(X_train))
mse_enet_test=mean_squared_error(y_test,enet.predict(X_test))

print(' MSE: enet - Train',mse_enet_train)
print(' MSE: enet - Test',mse_enet_test)

R2 score: enet - Train 0.06602328236730137
R2 score: enet - Test -0.021578456717382455
MSE: enet - Train 51846345.26779231
MSE: enet - Test 38616240.19945722

```

Ensemble Learning

Agenda:

Ensemble learning

What are the different types?

Bagging

Boosting

Stacking

Random Forest - bagging technique

Introduce the Diabetes.csv for performing RF

Identify the best parameters using GridSearchCV

Build the best RF model

Important Features based on the model.

Conclude

Accessing the data

```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
```

Data set

```
churn=pd.read_csv('churn_prediction1.csv')
```

```
churn.isnull().sum()
```

customer_id	0
vintage	0
age	0
gender	25
dependents	111
occupation	7
city	42
customer_nw_category	0
branch_code	0
days_since_last_transaction	151
current_balance	0
previous_month_end_balance	0

```

average_monthly_balance_prevQ      0
average_monthly_balance_prevQ2     0
current_month_credit                0
previous_month_credit               0
current_month_debit                 0
previous_month_debit                0
current_month_balance               0
previous_month_balance              0
churn                               0
dtype: int64

```

```
churn.dropna(inplace=True)
```

```
churn.isnull().sum()
```

```

customer_id      0
vintage          0
age              0
gender           0
dependents       0
occupation       0
city             0
customer_nw_category 0
branch_code      0
days_since_last_transaction 0
current_balance  0
previous_month_end_balance 0
average_monthly_balance_prevQ 0
average_monthly_balance_prevQ2 0
current_month_credit 0
previous_month_credit 0
current_month_debit 0
previous_month_debit 0
current_month_balance 0
previous_month_balance 0
churn             0
dtype: int64

```

```
X=churn.drop(['churn','gender','customer_id','age','occupation','city',
```

```
,
'branch_code','previous_month_end_balance','average_monthly_balance_prevQ',
```

```
'average_monthly_balance_prevQ2','previous_month_credit','previous_month_debit',
```

```
'current_month_balance','previous_month_balance'],axis=1)
```

```
X
```

	vintage	dependents	customer_nw_category
days_since_last_transaction \			
0	3135	0.0	2
224.0			
4	2531	2.0	3
58.0			
5	263	0.0	2
60.0			
6	5922	0.0	1
98.0			
7	1145	0.0	2
172.0			
...
...			
1294	1921	0.0	2
87.0			
1295	766	0.0	2
27.0			
1297	2993	4.0	3
0.0			
1298	1766	0.0	1
339.0			
1299	7306	0.0	1
62.0			

	current_balance	current_month_credit	current_month_debit
0	1458.71	0.20	0.20
4	927.72	0.33	588.62
5	15202.20	0.36	857.50
6	7006.93	0.64	1299.64
7	10096.58	0.27	443.13
...
1294	14734.45	0.50	30714.79
1295	6785.93	7630.32	963.42
1297	5209.62	1321.96	142.89
1298	4616.88	0.23	0.23
1299	14834.26	0.34	180.13

[1001 rows x 7 columns]

y=churn['churn']

y

0	0
4	1
5	0
6	0
7	0
...	...
1294	0

```
1295    1
1297    0
1298    0
1299    0
Name: churn, Length: 1001, dtype: int64
```

Standardisation

```
from sklearn.preprocessing import StandardScaler

scaler=StandardScaler()
X_scaled=scaler.fit_transform(X)
X_scaled

array([[ 0.26881447, -0.45186224, -0.29729134, ..., -0.36357065,
        -0.18176148, -0.20549922],
       [-0.07821333,  1.62297309,  1.15436051, ..., -0.39958594,
        -0.18175502, -0.1698577 ],
       [-1.38129121, -0.45186224, -0.29729134, ...,  0.56860465,
        -0.18175352, -0.15357122],
       ...,
       [ 0.18722847,  3.69780842,  1.15436051, ..., -0.10915888,
        -0.116036  , -0.19685627],
       [-0.51774357, -0.45186224, -1.74894318, ..., -0.14936246,
        -0.18175999, -0.2054974 ],
       [ 2.66525974, -0.45186224, -1.74894318, ...,  0.54364851,
        -0.18175452, -0.19460058]])
```

Splitting the data to train and test

```
from sklearn.model_selection import train_test_split

X_train,X_test,y_train,y_test =
train_test_split(X_scaled,y,test_size=0.2, random_state=100)

X_train.shape,X_test.shape,y_train.shape,y_test.shape

((800, 7), (201, 7), (800,), (201,))
```

Building the model- Random Forest Classifier

```
from sklearn.ensemble import RandomForestClassifier

rfc=RandomForestClassifier(random_state=100)

rfc.fit(X_train,y_train)

RandomForestClassifier(random_state=100)
```

Model performance

```
from sklearn.metrics import classification_report, confusion_matrix

cm=confusion_matrix(y_test,rfc.predict(X_test))
```



```
report=classification_report(y_test,rfc.predict(X_test))
```

```
print('CM:\n',cm)
print('Report:\n',report)
```

CM:

```
[[153  10]
 [ 25  13]]
```

Report:

	precision	recall	f1-score	support
0	0.86	0.94	0.90	163
1	0.57	0.34	0.43	38
accuracy			0.83	201
macro avg	0.71	0.64	0.66	201
weighted avg	0.80	0.83	0.81	201

Hyper parameter tuning using GridSearchCV

```
from sklearn.model_selection import GridSearchCV
```

```
rfc_gs=GridSearchCV(rfc,{'n_estimators':range(75,125),
                        'criterion':['gini','entropy']})
```

```
rfc_gs.fit(X_train,y_train)
```

```
GridSearchCV(estimator=RandomForestClassifier(random_state=100),
              param_grid={'criterion': ['gini', 'entropy'],
                           'n_estimators': range(75, 125)})
```

Best parameters

```
rfc_gs.best_params_
```

```
{'criterion': 'entropy', 'n_estimators': 77}
```

Building a revised RF model

```
rfc_new=RandomForestClassifier(n_estimators=122,
                              criterion='entropy',random_state=10)
```

```
rfc_new.fit(X_train,y_train)
```

```
RandomForestClassifier(criterion='entropy', n_estimators=122,
                      random_state=10)
```

Performance

```
cm=confusion_matrix(y_test,rfc_new.predict(X_test))
report=classification_report(y_test,rfc_new.predict(X_test))
```

```
print('CM:\n',cm)
```

```
print('Report:\n',report)
score=roc_auc_score(pred_df['Actual Class'],
                    pred_df['Predicted Class'])
score
```

CM:

```
[[153  10]
 [ 27  11]]
```

Report:

	precision	recall	f1-score	support
0	0.85	0.94	0.89	163
1	0.52	0.29	0.37	38
accuracy			0.82	201
macro avg	0.69	0.61	0.63	201
weighted avg	0.79	0.82	0.79	201

```
-----
-----
NameError                                Traceback (most recent call
last)
Input In [28], in <cell line: 8>()
      6 print('CM:\n',cm)
      7 print('Report:\n',report)
----> 8 score=roc_auc_score(pred_df['Actual Class'],
      9                      pred_df['Predicted Class'])
     10 score
```

NameError: name 'roc_auc_score' is not defined

Important features

```
rfc_new.feature_importances_
```

```
array([0.17194046, 0.0258198 , 0.03786422, 0.12733436, 0.32549956,
       0.14419823, 0.16734337])
```

Creating a DF

```
df=pd.DataFrame({'Feature':X.columns,'Feature
Imp':rfc_new.feature_importances_})
df
```

	Feature	Feature Imp
0	vintage	0.171940
1	dependents	0.025820
2	customer_nw_category	0.037864
3	days_since_last_transaction	0.127334
4	current_balance	0.325500

```
5         current_month_credit    0.144198
6         current_month_debit    0.167343
```

```
df=df.sort_values(['Feature Imp'],ascending=False)
df
```

```

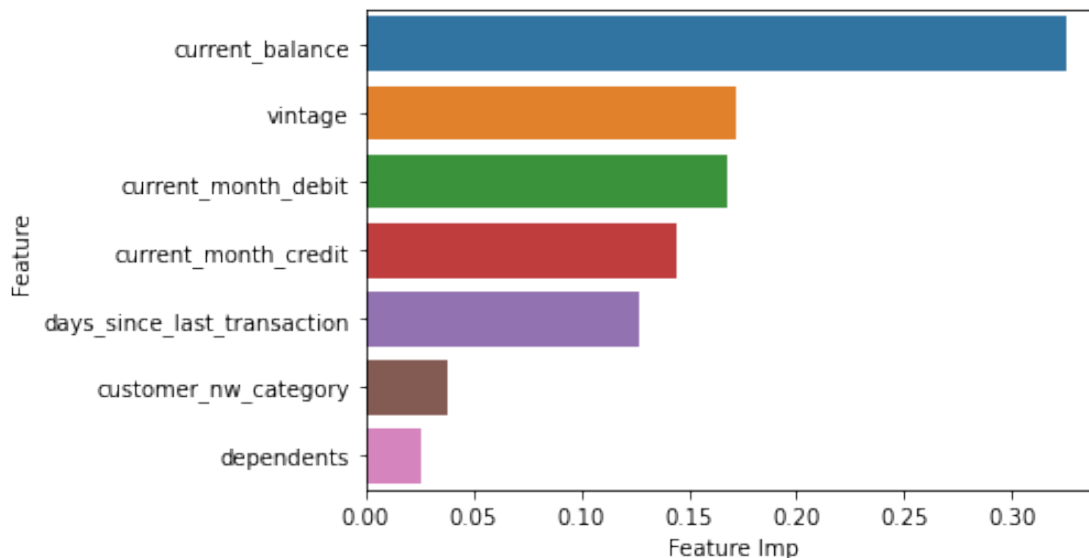
Feature Feature Imp
4  current_balance    0.325500
0      vintage        0.171940
6  current_month_debit 0.167343
5  current_month_credit 0.144198
3  days_since_last_transaction 0.127334
2  customer_nw_category 0.037864
1      dependents     0.025820
```

```
df=df.sort_values(['Feature Imp'],ascending=False)
df
```

```

Feature Feature Imp
4  current_balance    0.325500
0      vintage        0.171940
6  current_month_debit 0.167343
5  current_month_credit 0.144198
3  days_since_last_transaction 0.127334
2  customer_nw_category 0.037864
1      dependents     0.025820
```

```
sns.barplot(x=df['Feature Imp'],y=df['Feature'],data=df);
```



Boosting

Boosting

Different types:

AdaBoost

GradientBoost

XGBoost

Perform boosting on diabetes dataset

Tune the hyper parameter and get better models

Compare the models.

Adaboost

```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
```

Data set

```
churn=pd.read_csv('churn_prediction1.csv')
```

```
churn.isnull().sum()
```

customer_id	0
vintage	0
age	0
gender	25
dependents	111
occupation	7
city	42
customer_nw_category	0
branch_code	0
days_since_last_transaction	151
current_balance	0
previous_month_end_balance	0
average_monthly_balance_prevQ	0
average_monthly_balance_prevQ2	0
current_month_credit	0
previous_month_credit	0
current_month_debit	0
previous_month_debit	0
current_month_balance	0

```
previous_month_balance      0
churn                        0
dtype: int64
```

```
churn.dropna(inplace=True)
```

```
churn.isnull().sum()
```

```
customer_id      0
vintage          0
age              0
gender           0
dependents       0
occupation       0
city             0
customer_nw_category 0
branch_code      0
days_since_last_transaction 0
current_balance  0
previous_month_end_balance  0
average_monthly_balance_prevQ 0
average_monthly_balance_prevQ2 0
current_month_credit 0
previous_month_credit 0
current_month_debit 0
previous_month_debit 0
current_month_balance 0
previous_month_balance 0
churn            0
dtype: int64
```

```
X=churn.drop(['churn','gender','customer_id','age','occupation','city',
```

```
,'branch_code','previous_month_end_balance','average_monthly_balance_prevQ',
```

```
'average_monthly_balance_prevQ2','previous_month_credit','previous_month_debit',
```

```
'current_month_balance','previous_month_balance'],axis=1)
```

```
X
```

```
      vintage  dependents  customer_nw_category
days_since_last_transaction \
0          3135         0.0                    2
224.0
4          2531         2.0                    3
58.0
5           263         0.0                    2
```

60.0			
6	5922	0.0	1
98.0			
7	1145	0.0	2
172.0			
...
...			
1294	1921	0.0	2
87.0			
1295	766	0.0	2
27.0			
1297	2993	4.0	3
0.0			
1298	1766	0.0	1
339.0			
1299	7306	0.0	1
62.0			

	current_balance	current_month_credit	current_month_debit
0	1458.71	0.20	0.20
4	927.72	0.33	588.62
5	15202.20	0.36	857.50
6	7006.93	0.64	1299.64
7	10096.58	0.27	443.13
...
1294	14734.45	0.50	30714.79
1295	6785.93	7630.32	963.42
1297	5209.62	1321.96	142.89
1298	4616.88	0.23	0.23
1299	14834.26	0.34	180.13

[1001 rows x 7 columns]

y = churn['churn']

y

0	0
4	1
5	0
6	0
7	0
...	..
1294	0
1295	1
1297	0
1298	0
1299	0

Name: churn, Length: 1001, dtype: int64

```

from sklearn.preprocessing import StandardScaler
scaler=StandardScaler()
X_scaled=scaler.fit_transform(X)
X_scaled
array([[ 0.26881447, -0.45186224, -0.29729134, ..., -0.36357065,
        -0.18176148, -0.20549922],
       [-0.07821333,  1.62297309,  1.15436051, ..., -0.39958594,
        -0.18175502, -0.1698577 ],
       [-1.38129121, -0.45186224, -0.29729134, ...,  0.56860465,
        -0.18175352, -0.15357122],
       ...,
       [ 0.18722847,  3.69780842,  1.15436051, ..., -0.10915888,
        -0.116036  , -0.19685627],
       [-0.51774357, -0.45186224, -1.74894318, ..., -0.14936246,
        -0.18175999, -0.2054974 ],
       [ 2.66525974, -0.45186224, -1.74894318, ...,  0.54364851,
        -0.18175452, -0.19460058]])

from sklearn.model_selection import train_test_split
X_train,X_test,y_train,y_test=train_test_split(X_scaled,y,test_size=0.
2,random_state=10)
X_train.shape,X_test.shape,y_train.shape,y_test.shape
((800, 7), (201, 7), (800,), (201,))

```

Building- AdaBoostClassifier

```

from sklearn.ensemble import AdaBoostClassifier
abc=AdaBoostClassifier(random_state=10)
abc.fit(X_train,y_train)

AdaBoostClassifier(random_state=10)

from sklearn.metrics import classification_report
report=classification_report(y_test,abc.predict(X_test))
print('Report:\n',report)

```

Report:

	precision	recall	f1-score	support
0	0.86	0.97	0.91	164
1	0.69	0.30	0.42	37
accuracy			0.85	201
macro avg	0.77	0.63	0.66	201
weighted avg	0.83	0.85	0.82	201

Improving the model using hyper parameter tuning

```
from sklearn.model_selection import GridSearchCV
```

```
abc_gs=GridSearchCV(abc,{'n_estimators':range(25,75),  
                          'learning_rate':[0,0.25,0.5,0.75,1]})
```

```
abc_gs.fit(X_train, y_train)
```

```
C:\Users\hp\anaconda3\lib\site-packages\sklearn\model_selection\  
_validation.py:372: FitFailedWarning:
```

```
250 fits failed out of a total of 1250.
```

```
The score on these train-test partitions for these parameters will be  
set to nan.
```

```
If these failures are not expected, you can try to debug them by  
setting error_score='raise'.
```

Below are more details about the failures:

250 fits failed with the following error:

Traceback (most recent call last):

```
File "C:\Users\hp\anaconda3\lib\site-packages\sklearn\  
model_selection\_validation.py", line 680, in _fit_and_score  
    estimator.fit(X_train, y_train, **fit_params)
```

```
File "C:\Users\hp\anaconda3\lib\site-packages\sklearn\ensemble\  
_weight_boosting.py", line 486, in fit  
    return super().fit(X, y, sample_weight)
```

```
File "C:\Users\hp\anaconda3\lib\site-packages\sklearn\ensemble\  
_weight_boosting.py", line 114, in fit  
    raise ValueError("learning_rate must be greater than zero")
```

ValueError: learning_rate must be greater than zero

```
warnings.warn(some_fits_failed_message, FitFailedWarning)
```

```
C:\Users\hp\anaconda3\lib\site-packages\sklearn\model_selection\  
_search.py:969: UserWarning: One or more of the test scores are non-
```

```
finite: [ nan      nan      nan      nan      nan      nan      nan  
nan      nan
```

```
      nan      nan      nan      nan      nan      nan      nan      nan
```

```
nan      nan      nan      nan      nan      nan      nan      nan
```

```
      nan      nan      nan      nan      nan      nan      nan      nan
```

```
nan      nan      nan      nan      nan      nan      nan      nan
```

```
      nan      nan      nan      nan      nan      nan      nan      nan
```

```
nan      nan      nan      nan      nan      nan      nan      nan
```

```
      nan      nan      nan      nan      nan      nan      nan      nan
```

```
nan      nan      nan      nan      nan      nan      nan      nan
```

```
      nan      nan      nan      nan      nan      nan      nan      nan
```

```
0.8225 0.8225 0.8225 0.82375 0.82375 0.82125 0.82 0.82
```

```
0.81875 0.81875 0.82125 0.81875 0.82 0.81875 0.82 0.82
```

```
0.81875 0.81875 0.82125 0.81875 0.82 0.81875 0.82 0.82
```



```

0.8175
0.81875 0.81875 0.82    0.81875 0.8175 0.82    0.81875 0.81875
0.81875
0.815    0.81875 0.82    0.82    0.82    0.81875 0.8175 0.81375
0.81625
0.81625 0.81625 0.81625 0.81875 0.81875 0.81875 0.8175 0.8175
0.8175
0.8175 0.8175 0.8175 0.81875 0.81875 0.82    0.81875 0.8225
0.82125
0.8225 0.8175 0.81875 0.8225 0.8175 0.8175 0.81875 0.8175
0.81875
0.82125 0.81875 0.82    0.82125 0.825 0.825 0.82375 0.82
0.82125
0.82125 0.82    0.8225 0.81875 0.8225 0.8175 0.82    0.81875
0.81875
0.81625 0.81875 0.81875 0.8175 0.82125 0.8175 0.8175 0.8175
0.81875
0.8175 0.81625 0.8175 0.8175 0.8175 0.81625 0.81875 0.82
0.8175
0.81625 0.81625 0.8175 0.81875 0.81625 0.8175 0.82125 0.81875 0.82
0.81875 0.8175 0.815 0.815 0.81625 0.81625 0.8175 0.81375 0.815
0.81625 0.81625 0.82    0.81875 0.81875 0.82125 0.82125 0.8175
0.81875
0.8175 0.81875 0.82    0.82125 0.82    0.82    0.82    0.815
0.8175
0.8125 0.815 0.81375 0.81375 0.8175 0.8175 0.8175 0.81625 0.815
0.8175 0.82    0.815 0.815 0.81375 0.81625 0.81625 0.81625
0.82125
0.8175 0.8175 0.82125 0.82125 0.81625 0.815 0.81125 0.81625
0.81625
0.81625 0.81625 0.815 0.815 0.815 0.81625 0.81375 0.815 0.815
0.81375 0.815 0.815 0.8175 0.815 0.81625 0.81625 0.8125
0.81625
0.81625 0.815 0.81625 0.81375 0.81375 0.815 0.81625 0.81625
0.8125
0.81125 0.81125 0.81125 0.81125 0.81125 0.80625 0.81    ]
warnings.warn(

```

```

GridSearchCV(estimator=AdaBoostClassifier(random_state=10),
              param_grid={'learning_rate': [0, 0.25, 0.5, 0.75, 1],
                           'n_estimators': range(25, 75)})

```

```

abc_gs.best_params_

```

```

{'learning_rate': 0.5, 'n_estimators': 46}

```

```

## Building the best model

```

```

ada_best=AdaBoostClassifier(learning_rate=0.25,n_estimators=53,random_
state=10)
ada_best.fit(X_train,y_train)

```



```

gbc_gs.best_params_
{'max_depth': 2, 'n_estimators': 81}
grad_best=GradientBoostingClassifier(max_depth=2,n_estimators=76,random_state=10)
grad_best.fit(X_train,y_train)
GradientBoostingClassifier(max_depth=2, n_estimators=76,
random_state=10)
report=classification_report(y_test,grad_best.predict(X_test))

print('Report:\n',report)

```

```

Report:

```

	precision	recall	f1-score	support
0	0.86	0.98	0.91	164
1	0.73	0.30	0.42	37
accuracy			0.85	201
macro avg	0.80	0.64	0.67	201
weighted avg	0.84	0.85	0.82	201

XGBoost

```

from xgboost import XGBClassifier

C:\Users\hp\anaconda3\lib\site-packages\xgboost\compat.py:36:
FutureWarning: pandas.Int64Index is deprecated and will be removed
from pandas in a future version. Use pandas.Index with the appropriate
dtype instead.
  from pandas import MultiIndex, Int64Index

conda install -c conda-forge xgboost

Retrieving notices: ...working... done
Note: you may need to restart the kernel to use updated packages.

Collecting package metadata (current_repodata.json): ...working...
done
Solving environment: ...working... done

## Package Plan ##

environment location: C:\Users\hp\anaconda3

added / updated specs:
- xgboost

```

The following packages will be downloaded:

package	build	
conda-22.11.1	py39hcbf5309_1	908 KB

Total:		908 KB

The following packages will be SUPERSEDED by a higher-priority channel:

```
conda pkgs/main::conda-22.11.1-py39haa95532~ --> conda-
forge::conda-22.11.1-py39hcbf5309_1
```

Downloading and Extracting Packages

conda-22.11.1	908 KB		0%
conda-22.11.1	908 KB	1	2%
conda-22.11.1	908 KB	#####	100%
conda-22.11.1	908 KB	#####	100%

```
Preparing transaction: ...working... done
Verifying transaction: ...working... done
Executing transaction: ...working... done
```

```
xg=XGBClassifier()
xg.fit(X_train,y_train)
```

```
C:\Users\hp\anaconda3\lib\site-packages\xgboost\sklearn.py:1224:
UserWarning: The use of label encoder in XGBClassifier is deprecated
and will be removed in a future release. To remove this warning, do
the following: 1) Pass option use_label_encoder=False when
constructing XGBClassifier object; and 2) Encode your labels (y) as
integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
[16:55:16] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\
xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in
XGBoost 1.3.0, the default evaluation metric used with the objective
'binary:logistic' was changed from 'error' to 'logloss'. Explicitly
set eval_metric if you'd like to restore the old behavior.
```

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
               colsample_bynode=1, colsample_bytree=1,
```

```

enable_categorical=False,
    gamma=0, gpu_id=-1, importance_type=None,
    interaction_constraints='', learning_rate=0.300000012,
    max_delta_step=0, max_depth=6, min_child_weight=1,
missing=nan,
    monotone_constraints='()', n_estimators=100, n_jobs=8,
    num_parallel_tree=1, predictor='auto', random_state=0,
    reg_alpha=0, reg_lambda=1, scale_pos_weight=1,
subsample=1,
    tree_method='exact', validate_parameters=1,
verbosity=None)

```

```

report=classification_report(y_test,xg.predict(X_test))
print('Report:\n',report)

```

Report:

	precision	recall	f1-score	support
0	0.86	0.93	0.89	164
1	0.52	0.32	0.40	37
accuracy			0.82	201
macro avg	0.69	0.63	0.65	201
weighted avg	0.80	0.82	0.80	201

hyper parameter tuning

```

xg_gs=GridSearchCV(xg,{'n_estimators':range(75,125),
    'max_depth':range(1,5)})

```

```

xg_gs.fit(X_train,y_train)

```

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xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in
XGBoost 1.3.0, the default evaluation metric used with the objective
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```
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```

```
[16:56:59] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\
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[16:57:02] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\
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```
[16:57:11] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\
xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in
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```

```
warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
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integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
```

```
warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
[16:57:42] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\
xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in
XGBoost 1.3.0, the default evaluation metric used with the objective
'binary:logistic' was changed from 'error' to 'logloss'. Explicitly
set eval_metric if you'd like to restore the old behavior.
```

```
[16:57:43] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\
xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in
XGBoost 1.3.0, the default evaluation metric used with the objective
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```

[16:57:43] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.

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```

```
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```

```
[16:57:45] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
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```
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```
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```
warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
[16:57:46] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
```

```
[16:57:46] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
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```
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```

```
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```
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```
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```

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[16:57:48] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[16:57:48] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.

C:\Users\hp\anaconda3\lib\site-packages\xgboost\sklearn.py:1224:
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warnings.warn(label_encoder_deprecation_msg, UserWarning)
C:\Users\hp\anaconda3\lib\site-packages\xgboost\sklearn.py:1224:
UserWarning: The use of label encoder in XGBClassifier is deprecated and will be removed in a future release. To remove this warning, do the following: 1) Pass option use_label_encoder=False when constructing XGBClassifier object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
warnings.warn(label_encoder_deprecation_msg, UserWarning)

[16:57:48] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.

C:\Users\hp\anaconda3\lib\site-packages\xgboost\sklearn.py:1224:
UserWarning: The use of label encoder in XGBClassifier is deprecated and will be removed in a future release. To remove this warning, do the following: 1) Pass option use_label_encoder=False when constructing XGBClassifier object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
warnings.warn(label_encoder_deprecation_msg, UserWarning)

[16:57:48] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[16:57:49] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective

'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.

C:\Users\hp\anaconda3\lib\site-packages\xgboost\sklearn.py:1224:
UserWarning: The use of label encoder in XGBClassifier is deprecated and will be removed in a future release. To remove this warning, do the following: 1) Pass option use_label_encoder=False when constructing XGBClassifier object; and 2) Encode your labels (y) as integers starting with 0, i.e. 0, 1, 2, ..., [num_class - 1].
warnings.warn(label_encoder_deprecation_msg, UserWarning)

```
GridSearchCV(estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                     colsample_bylevel=1,
                                     colsample_bynode=1,
                                     colsample_bytree=1,
                                     enable_categorical=False,
                                     gamma=0,
                                     gpu_id=-1, importance_type=None,
                                     interaction_constraints='',
                                     learning_rate=0.300000012,
                                     max_delta_step=0, max_depth=6,
                                     min_child_weight=1, missing=nan,
                                     monotone_constraints='()',
                                     n_estimators=100, n_jobs=8,
                                     num_parallel_tree=1,
                                     predictor='auto',
                                     random_state=0, reg_alpha=0,
                                     reg_lambda=1,
                                     scale_pos_weight=1, subsample=1,
                                     tree_method='exact',
                                     validate_parameters=1,
                                     verbosity=None),
              param_grid={'max_depth': range(1, 5),
                          'n_estimators': range(75, 125)})

xg_gs.best_params_
{'max_depth': 2, 'n_estimators': 75}
```

Best XGBoost model

```
xg_best=XGBClassifier(max_depth=1, n_estimators=88)
```

```
xg_best.fit(X_train,y_train)
```

[16:58:17] WARNING: C:\Windows\Temp\abs_557yfx631l\croots\recipe\xgboost-split_1659548953302\work\src\learner.cc:1115: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1,
```



```

enable_categorical=False,
    gamma=0, gpu_id=-1, importance_type=None,
    interaction_constraints='', learning_rate=0.300000012,
    max_delta_step=0, max_depth=1, min_child_weight=1,
missing=nan,
    monotone_constraints='()', n_estimators=88, n_jobs=8,
    num_parallel_tree=1, predictor='auto', random_state=0,
    reg_alpha=0, reg_lambda=1, scale_pos_weight=1,
subsample=1,
    tree_method='exact', validate_parameters=1,
verbosity=None)

report=classification_report(y_test,xg_best.predict(X_test))
print('Report:\n',report)

```

Report:

	precision	recall	f1-score	support
0	0.86	0.97	0.91	164
1	0.71	0.32	0.44	37
accuracy			0.85	201
macro avg	0.79	0.65	0.68	201
weighted avg	0.84	0.85	0.83	201

The best model so far is w rt gradient boost

```
grad_best.feature_importances_
```

```
array([1.35615311e-01, 5.32937191e-04, 7.92170652e-03, 4.48660365e-03,
        6.80020565e-01, 3.10375939e-02, 1.40385282e-01])
```

```
df=pd.DataFrame({'Feature':X.columns,
'Imp':grad_best.feature_importances_})
df
```

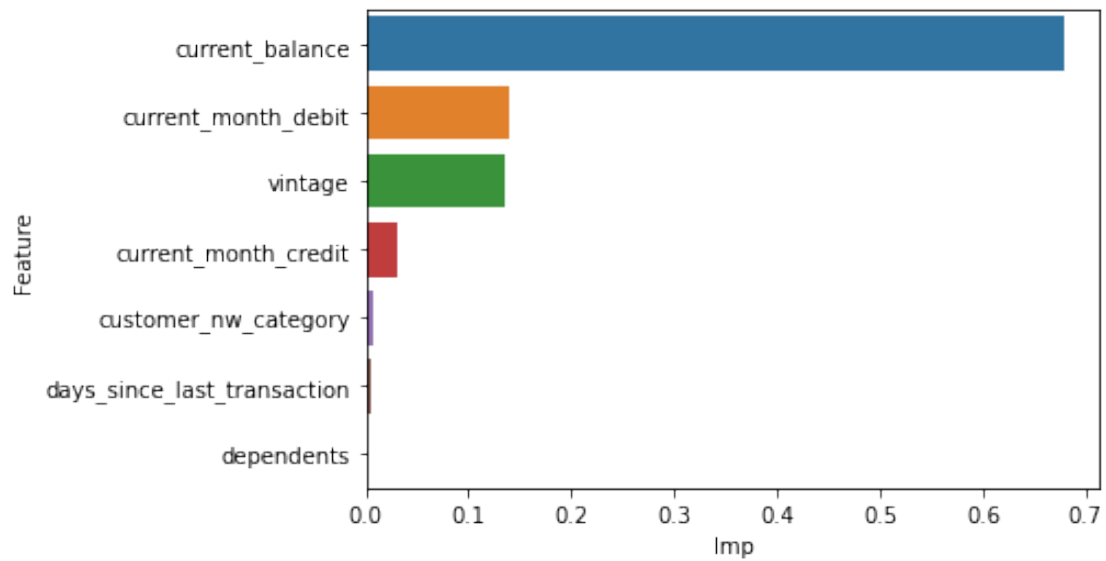
	Feature	Imp
0	vintage	0.135615
1	dependents	0.000533
2	customer_nw_category	0.007922
3	days_since_last_transaction	0.004487
4	current_balance	0.680021
5	current_month_credit	0.031038
6	current_month_debit	0.140385

```
df1=df.sort_values(['Imp'],ascending=False)
df1
```

	Feature	Imp
4	current_balance	0.680021
6	current_month_debit	0.140385

```
0          vintage 0.135615
5  current_month_credit 0.031038
2  customer_nw_category 0.007922
3  days_since_last_transaction 0.004487
1          dependents 0.000533
```

```
sns.barplot(x=df1['Imp'],y=df1['Feature'],data=df1);
```



Clustering - K Means Clustering

Clustering

K Means Clustering

K ? Elbow method

Silhouette method

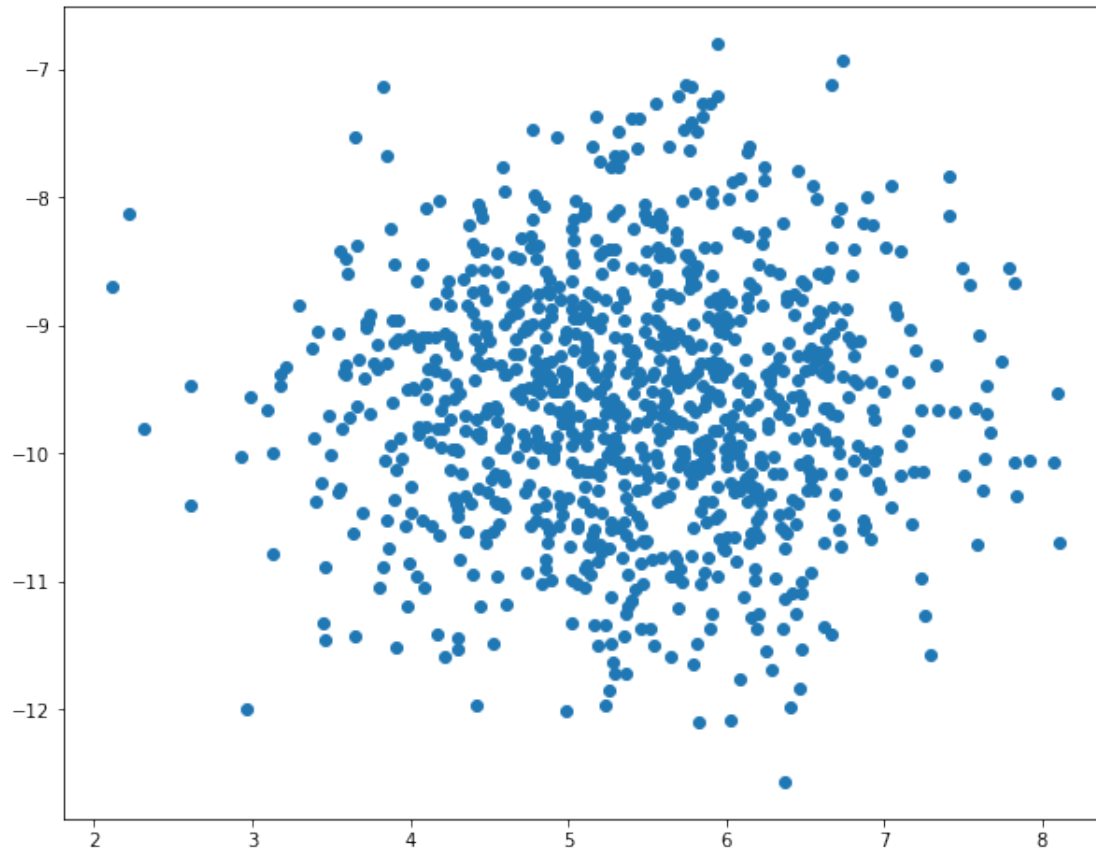
Implement K means on a simulated dataset

Also, implement k means on a standard dataset

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.datasets import make_blobs

plt.figure(figsize=(10,8))

X,y=make_blobs(n_samples=1000, n_features=2,centers=1,random_state=10)
plt.scatter(X[:,0],X[:,1]);
```



Data set

```
churn=pd.read_csv('churn_prediction1.csv')
```

```
churn.dropna(inplace=True)
```

churn

	customer_id	vintage	age	gender	dependents	occupation	\
0	1	3135	66	Male	0.0	self_employed	
4	6	2531	42	Male	2.0	self_employed	
5	7	263	42	Female	0.0	self_employed	
6	8	5922	72	Male	0.0	retired	
7	9	1145	46	Male	0.0	self_employed	
...	
1294	1379	1921	71	Female	0.0	self_employed	
1295	1380	766	10	Female	0.0	student	
1297	1382	2993	59	Male	4.0	salaried	
1298	1383	1766	13	Male	0.0	student	
1299	1384	7306	77	Female	0.0	self_employed	

	city	customer_nw_category	branch_code	\
0	Chicago	2	755	
4	Arlington	3	388	

5	Cambridge	2	1666
6	Revere	1	1
7	Arvada	2	317
...
1294	Tucson	2	1264
1295	Los Angeles	2	2497
1297	Philadelphia	3	411
1298	Philadelphia	1	542
1299	Philadelphia	1	240

	days_since_last_transaction	...	previous_month_end_balance	\
0	224.0	...	1458.71	
4	58.0	...	1401.72	
5	60.0	...	16059.34	
6	98.0	...	7714.19	
7	172.0	...	8519.53	
...	
1294	87.0	...	10439.08	
1295	27.0	...	119.03	
1297	0.0	...	4116.26	
1298	339.0	...	4545.45	
1299	62.0	...	15014.05	

	average_monthly_balance_prevQ	average_monthly_balance_prevQ2	\
0	1458.71	1449.07	
4	1643.31	1871.12	
5	15211.29	13798.82	
6	7859.74	11232.37	
7	6511.82	16314.17	
...	
1294	11546.06	10473.96	
1295	2419.19	118.29	
1297	3775.87	3463.84	
1298	4512.45	4272.54	
1299	13910.17	23436.02	

	current_month_credit	previous_month_credit	current_month_debit
\			
0	0.20	0.20	0.20
4	0.33	714.61	588.62
5	0.36	0.36	857.50
6	0.64	0.64	1299.64
7	0.27	0.27	443.13
...

1294	0.50	0.50	30714.79
1295	7630.32	0.21	963.42
1297	1321.96	773.34	142.89
1298	0.23	0.23	0.23
1299	0.34	0.34	180.13

	previous_month_debit	current_month_balance
previous_month_balance \		
0	0.20	1458.71
1458.71		
4	1538.06	1157.15
1677.16		
5	286.07	15719.44
15349.75		
6	439.26	7076.06
7755.98		
7	5688.44	8563.84
5317.04		
...
...		
1294	0.50	12808.61
10439.08		
1295	0.21	7019.52
119.03		
1297	407.17	3991.89
3690.78		
1298	0.23	4582.40
4513.19		
1299	73.78	14890.06
14461.60		

	churn
0	0
4	1
5	0
6	0
7	0
...	...
1294	0
1295	1
1297	0
1298	0
1299	0

[1001 rows x 21 columns]

churn=churn.head(1000)

churn

	customer_id	vintage	age	gender	dependents	occupation	\
0	1	3135	66	Male	0.0	self_employed	
4	6	2531	42	Male	2.0	self_employed	
5	7	263	42	Female	0.0	self_employed	
6	8	5922	72	Male	0.0	retired	
7	9	1145	46	Male	0.0	self_employed	
...	
1293	1378	662	48	Female	2.0	self_employed	
1294	1379	1921	71	Female	0.0	self_employed	
1295	1380	766	10	Female	0.0	student	
1297	1382	2993	59	Male	4.0	salaried	
1298	1383	1766	13	Male	0.0	student	

	city	customer_nw_category	branch_code	\
0	Chicago	2	755	
4	Arlington	3	388	
5	Cambridge	2	1666	
6	Revere	1	1	
7	Arvada	2	317	
...	
1293	Philadelphia	1	12	
1294	Tucson	2	1264	
1295	Los Angeles	2	2497	
1297	Philadelphia	3	411	
1298	Philadelphia	1	542	

	days_since_last_transaction	...	previous_month_end_balance	\
0	224.0	...	1458.71	
4	58.0	...	1401.72	
5	60.0	...	16059.34	
6	98.0	...	7714.19	
7	172.0	...	8519.53	
...	
1293	336.0	...	2638.42	
1294	87.0	...	10439.08	
1295	27.0	...	119.03	
1297	0.0	...	4116.26	
1298	339.0	...	4545.45	

	average_monthly_balance_prevQ	average_monthly_balance_prevQ2	\
0	1458.71	1449.07	
4	1643.31	1871.12	
5	15211.29	13798.82	

6	7859.74	11232.37
7	6511.82	16314.17
...
1293	4000.38	12284.94
1294	11546.06	10473.96
1295	2419.19	118.29
1297	3775.87	3463.84
1298	4512.45	4272.54

	current_month_credit	previous_month_credit	current_month_debit
\			
0	0.20	0.20	0.20
4	0.33	714.61	588.62
5	0.36	0.36	857.50
6	0.64	0.64	1299.64
7	0.27	0.27	443.13
...
1293	0.49	0.49	0.49
1294	0.50	0.50	30714.79
1295	7630.32	0.21	963.42
1297	1321.96	773.34	142.89
1298	0.23	0.23	0.23

	previous_month_debit	current_month_balance
previous_month_balance \		
0	0.20	1458.71
1458.71		
4	1538.06	1157.15
1677.16		
5	286.07	15719.44
15349.75		
6	439.26	7076.06
7755.98		
7	5688.44	8563.84
5317.04		
...
...		
1293	0.49	2623.89

2514.24		
1294	0.50	12808.61
10439.08		
1295	0.21	7019.52
119.03		
1297	407.17	3991.89
3690.78		
1298	0.23	4582.40
4513.19		

	churn
0	0
4	1
5	0
6	0
7	0
...	...
1293	0
1294	0
1295	1
1297	0
1298	0

[1000 rows x 21 columns]

```
data = np.vstack((churn['current_balance'].head(150),
churn['days_since_last_transaction'].head(150), churn['vintage'].head(150), churn['current_month_credit'].head(150))).T
```

data

```
array([[1.4587100e+03, 2.2400000e+02, 3.1350000e+03, 2.0000000e-01],
       [9.2772000e+02, 5.8000000e+01, 2.5310000e+03, 3.3000000e-01],
       [1.5202200e+04, 6.0000000e+01, 2.6300000e+02, 3.6000000e-01],
       [7.0069300e+03, 9.8000000e+01, 5.9220000e+03, 6.4000000e-01],
       [1.0096580e+04, 1.7200000e+02, 1.1450000e+03, 2.7000000e-01],
       [1.3558600e+03, 1.9000000e+01, 2.1320000e+03, 7.1451000e+02],
       [4.9579500e+03, 0.0000000e+00, 3.3790000e+03, 6.9122900e+03],
       [1.9287600e+03, 5.0000000e+00, 6.6100000e+02, 4.4340000e+02],
       [6.8864000e+03, 2.0000000e+01, 7.1080000e+03, 7.5645300e+03],
       [5.5438000e+02, 4.7000000e+01, 2.4380000e+03, 3.3000000e-01],
       [4.5484800e+03, 3.0300000e+02, 5.7030000e+03, 6.1000000e-01],
       [5.4314200e+03, 5.2000000e+01, 2.3140000e+03, 6.6000000e-01],
       [1.4484900e+03, 0.0000000e+00, 2.7230000e+03, 1.9071000e+02],
       [5.2921300e+03, 3.0000000e+00, 6.1110000e+03, 3.9169100e+03],
       [3.5077100e+03, 6.9000000e+01, 5.8210000e+03, 5.6000000e-01],
       [3.0427000e+03, 3.1000000e+01, 3.5000000e+03, 3.0000000e-01],
       [2.1800000e+00, 2.3000000e+01, 5.7240000e+03, 7.9790000e+01],
       [6.8864000e+03, 2.0000000e+01, 7.1080000e+03, 7.5645300e+03],
       [5.5438000e+02, 4.7000000e+01, 2.4380000e+03, 3.3000000e-01],
       [4.5484800e+03, 3.0300000e+02, 5.7030000e+03, 6.1000000e-01],
```

[2.5962100e+03, 4.7000000e+01, 7.5400000e+02, 6.0000000e-01],
[2.0273430e+04, 2.0000000e+01, 2.6200000e+03, 7.8300000e+00],
[7.1112900e+03, 9.0000000e+00, 1.3910000e+03, 1.4326000e+02],
[6.4244600e+03, 9.0000000e+00, 4.1750000e+03, 6.3900000e+01],
[9.7257000e+02, 2.7000000e+01, 6.0060000e+03, 1.8598440e+04],
[1.0701320e+04, 3.6000000e+01, 2.9630000e+03, 1.6000000e-01],
[7.6136100e+03, 1.2500000e+02, 2.6840000e+03, 1.9000000e-01],
[2.2690000e+02, 5.0000000e+00, 5.8030000e+03, 3.7471690e+04],
[1.4367100e+03, 7.7000000e+01, 5.5790000e+03, 4.4000000e-01],
[5.5759500e+03, 1.0000000e+01, 2.3500000e+03, 3.5780000e+02],
[3.2951700e+03, 9.7000000e+01, 4.7500000e+03, 4.3000000e-01],
[1.3148580e+04, 3.0000000e+00, 6.8340000e+03, 4.2347000e+02],
[7.6136100e+03, 1.2500000e+02, 2.6840000e+03, 1.9000000e-01],
[2.2690000e+02, 5.0000000e+00, 5.8030000e+03, 3.7471690e+04],
[5.7171300e+03, 1.6000000e+02, 9.3700000e+02, 1.0000000e-01],
[3.8544400e+03, 1.4000000e+01, 3.4280000e+03, 1.4287600e+03],
[3.5856200e+03, 7.0000000e+00, 1.7760000e+03, 3.2607100e+03],
[4.4743800e+03, 9.5000000e+01, 2.7010000e+03, 5.1000000e-01],
[1.4439500e+03, 1.7000000e+01, 1.9160000e+03, 3.2886000e+02],
[2.1252860e+04, 3.0000000e+00, 2.2920000e+03, 7.8248000e+02],
[8.9472000e+02, 2.0000000e+01, 4.8430000e+03, 4.8746000e+02],
[9.1470000e+01, 0.0000000e+00, 7.3400000e+02, 9.5780000e+02],
[3.3651600e+03, 7.0000000e+00, 2.6220000e+03, 1.4292700e+03],
[3.3732100e+03, 1.1600000e+02, 4.9950000e+03, 5.4000000e-01],
[4.0916600e+03, 7.6000000e+01, 1.0370000e+03, 2.0000000e-01],
[1.2039770e+04, 1.1000000e+01, 4.8700000e+03, 3.4291000e+02],
[6.0369000e+03, 1.8000000e+01, 7.0400000e+02, 9.4769000e+02],
[1.5782100e+03, 2.8000000e+01, 5.0960000e+03, 4.1060000e+01],
[1.0503000e+03, 2.0000000e+01, 5.5500000e+03, 1.4989900e+03],
[5.0652900e+03, 2.5000000e+01, 2.7090000e+03, 6.5800000e+01],
[1.5942780e+04, 2.5000000e+01, 3.9520000e+03, 6.0496000e+02],
[7.1514600e+03, 1.7300000e+02, 1.0430000e+03, 4.0000000e-01],
[2.7970630e+04, 5.0000000e+00, 4.3400000e+02, 5.9708900e+03],
[4.3167000e+02, 4.6000000e+01, 7.6100000e+02, 3.7000000e-01],
[1.1902100e+04, 7.0000000e+00, 5.6210000e+03, 9.4907100e+03],
[2.6622100e+03, 2.5000000e+01, 1.3900000e+03, 1.4346000e+02],
[5.4686700e+04, 0.0000000e+00, 6.2440000e+03, 5.3551680e+04],
[6.2093400e+03, 1.2000000e+01, 1.6720000e+03, 2.9860000e+02],
[3.9462270e+04, 6.0000000e+00, 4.2370000e+03, 6.9047000e+03],
[4.5872800e+03, 5.0000000e+00, 2.0530000e+03, 6.0199800e+03],
[2.3350500e+03, 1.8000000e+01, 4.6300000e+03, 1.4297000e+02],
[9.9313400e+03, 1.3800000e+02, 7.6200000e+02, 4.0000000e-01],
[1.1636850e+04, 2.0000000e+01, 3.4220000e+03, 2.4266000e+02],
[4.8352000e+02, 1.2600000e+02, 1.1060000e+03, 3.0000000e-01],
[1.0088960e+04, 6.0000000e+00, 6.0360000e+03, 1.6407400e+03],
[3.5371600e+03, 2.0000000e+01, 8.4400000e+02, 4.7197000e+02],
[1.2913080e+04, 4.9000000e+01, 1.3950000e+03, 1.6000000e-01],
[3.1445600e+03, 6.9000000e+01, 4.6960000e+03, 1.0000000e-02],
[6.7856000e+03, 4.5000000e+01, 6.1630000e+03, 3.0000000e-01],
[3.1222700e+03, 7.5000000e+01, 2.9640000e+03, 4.7000000e-01],

[9.0135200e+03, 2.1900000e+02, 1.6440000e+03, 1.7000000e-01],
[2.2273700e+03, 7.0000000e+01, 2.8390000e+03, 2.7000000e-01],
[2.0741220e+04, 6.0000000e+00, 8.4590000e+03, 2.7801100e+03],
[1.4542400e+03, 3.0000000e+01, 2.6290000e+03, 3.4000000e-01],
[2.4291800e+03, 1.8000000e+02, 4.6300000e+02, 1.4000000e-01],
[2.2437570e+04, 3.9000000e+01, 1.8560000e+03, 3.9000000e-01],
[1.0152970e+04, 0.0000000e+00, 3.1420000e+03, 1.1928660e+04],
[2.6178700e+03, 0.0000000e+00, 4.8780000e+03, 5.5489000e+02],
[5.0368000e+02, 2.8000000e+01, 1.6430000e+03, 4.5716600e+03],
[1.5553700e+03, 5.2000000e+01, 5.5010000e+03, 6.0000000e-01],
[8.1913500e+03, 2.8000000e+01, 6.8250000e+03, 1.2291500e+04],
[2.8598600e+03, 0.0000000e+00, 3.1910000e+03, 9.2146100e+03],
[2.5977700e+03, 1.8800000e+02, 4.1980000e+03, 1.7000000e-01],
[1.6948400e+03, 9.5000000e+01, 6.9520000e+03, 5.6000000e-01],
[2.4887700e+03, 8.1000000e+01, 8.3700000e+02, 6.6000000e-01],
[9.5724300e+03, 1.7000000e+01, 4.1290000e+03, 1.3660000e+01],
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[5.8990100e+03, 4.9000000e+01, 2.3010000e+03, 1.1000000e-01],
[8.4446000e+02, 9.6000000e+01, 1.9640000e+03, 7.0000000e-02],
[2.4094900e+03, 1.4000000e+01, 9.9200000e+02, 1.2203000e+02],
[5.1827200e+03, 3.0000000e+01, 2.6580000e+03, 4.1000000e-01],
[6.6851600e+03, 7.0000000e+00, 5.6910000e+03, 2.2015400e+03],
[9.4740900e+03, 2.6000000e+01, 1.7030000e+03, 6.4290100e+03],
[2.1890300e+03, 6.0000000e+00, 5.2900000e+03, 1.0381000e+03],
[1.0725600e+03, 1.0200000e+02, 1.4760000e+03, 2.1000000e-01],
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[2.7979000e+02, 1.0000000e+01, 5.4100000e+02, 6.2010000e+01],
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[3.7257300e+03, 1.4000000e+01, 1.3950000e+03, 1.8577000e+02],
[7.6348700e+03, 2.3100000e+02, 6.9200000e+02, 1.6000000e-01],
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[8.8362800e+03, 0.0000000e+00, 4.0020000e+03, 6.2323100e+03],

```
[1.4712000e+03, 4.8000000e+01, 2.4680000e+03, 5.3000000e-01],
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[1.7569400e+03, 1.1000000e+01, 3.3940000e+03, 6.7164000e+02],
[1.4332100e+03, 2.1000000e+01, 3.0050000e+03, 2.8574000e+03],
[2.0768100e+03, 0.0000000e+00, 3.1430000e+03, 2.8706400e+03],
[3.7312000e+03, 3.0000000e+00, 1.1400000e+03, 2.8630000e+02]])
```

```
X = np.vstack((churn['vintage'].head(1000),
churn['days_since_last_transaction'].head(1000))).T
```

X

```
array([[3135., 224.],
       [2531., 58.],
       [ 263., 60.],
       ...,
       [ 766., 27.],
       [2993., 0.],
       [1766., 339.]])
```

y

```
array([0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 0, 1,
1,
       0, 0, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1,
0,
       1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1,
```

1,	1, 0, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 0, 0, 0,
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0,	1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 1,
0,	0, 0, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 0,
0,	0, 1, 1, 0, 1, 0, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 0, 1,
0,	1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 0,
1,	1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 0, 1,
0,	0, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 0, 1, 1, 1, 0, 0,
0,	1, 1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0,
0,	0, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1,
1,	1, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 0, 0, 1,
1,	0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0,
1,	0, 0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 1, 1,
1,	0, 0, 0, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 0, 0, 1, 1, 0,
0,	0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 1,
0,	1, 1, 0, 0, 1, 1, 1, 0, 1, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1,
0,	1, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0, 1,
1,	0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 1, 1,
0,	0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0,
1,	0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1, 0,
0,	1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0, 0, 1, 1, 0, 1,
0,	1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 0,
0,	1, 0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 1,
1,	1, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 1, 1,
1,	1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 0, 1, 0, 1, 1,

```

0,      0, 1, 0, 1, 1, 0, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0,
0,      0, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1,
0,      1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 0, 0, 1,
1,      0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 1,
0,      1, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0,
0,      1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 0,
1,      0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 0, 1, 0, 1, 1, 0, 1, 0, 0,
1,      1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1,
0,      0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 0, 0, 1, 1, 1, 0, 1, 0, 1, 0,
0,      0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0,
1,      1, 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 0,
1,      1, 0, 0, 1, 1, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1,
0,      1, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0,
1,      0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 1, 1,
1,      0, 1, 0, 0, 1, 0, 1, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1,
0,      0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 1,
1,      0, 1, 0, 0, 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 0,
1,      1, 1, 0, 1, 0, 0, 0, 0, 1, 0])

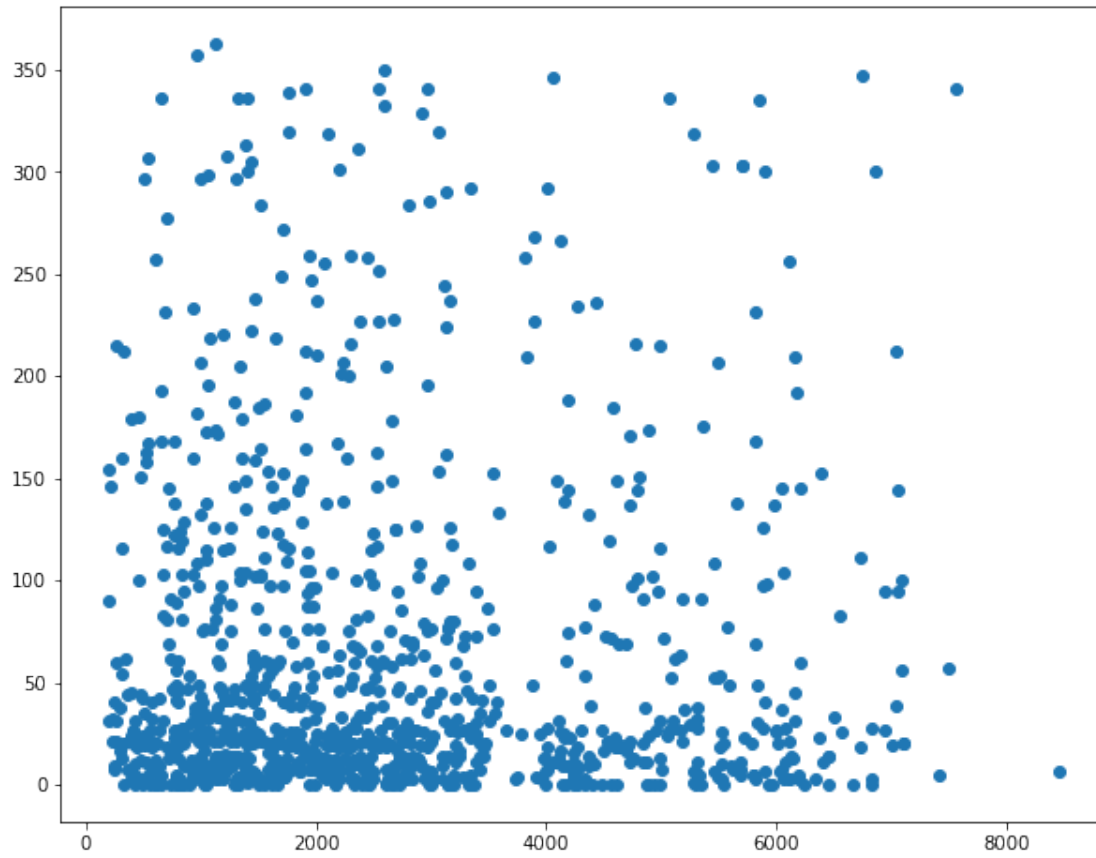
```

```
plt.figure(figsize=(10,8))
```

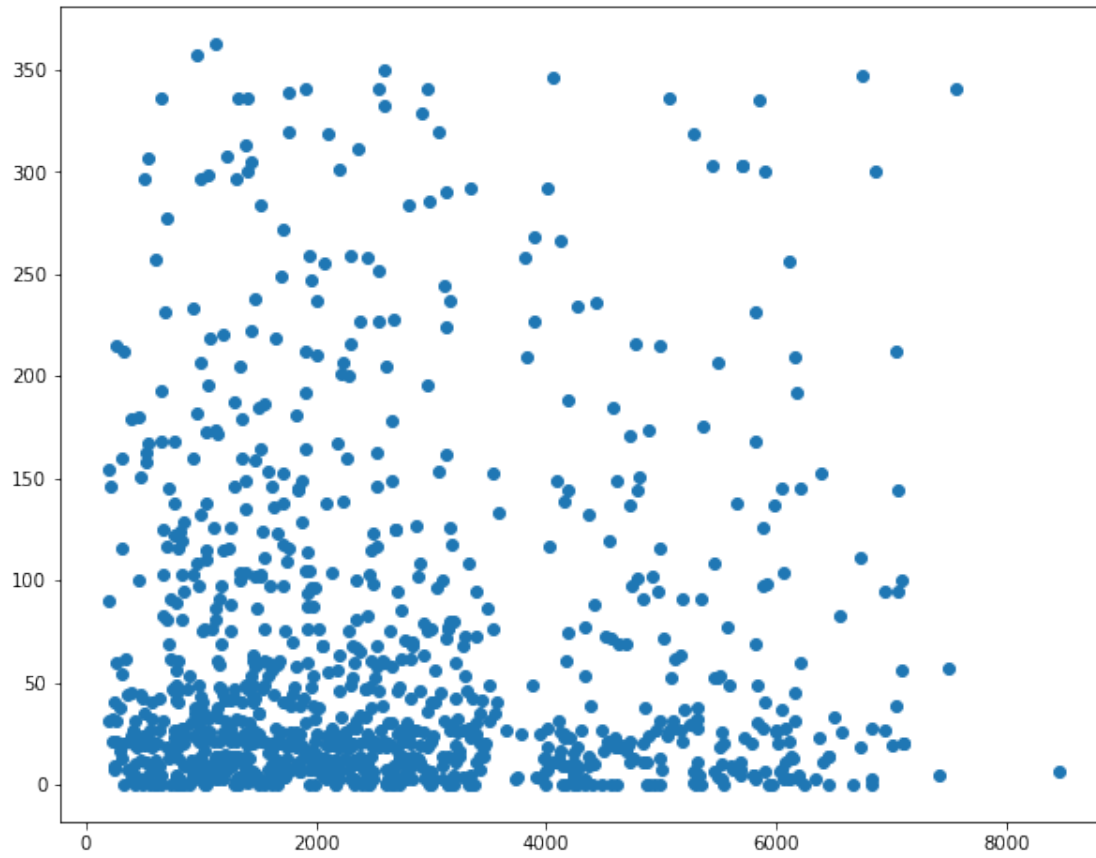
```

y=make_blobs(n_samples=1000, n_features=2,centers=2,random_state=10)
plt.scatter(X[:,0],X[:,1]);

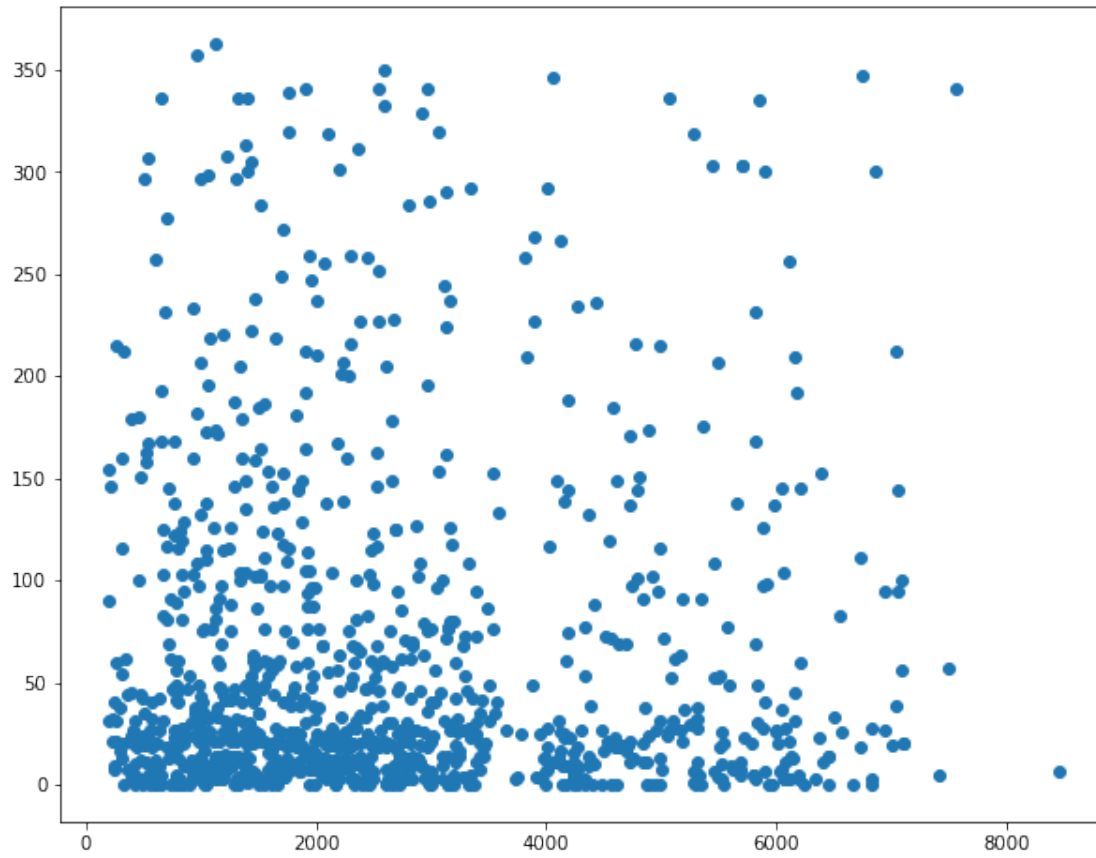
```



```
plt.figure(figsize=(10,8))  
  
y=make_blobs(n_samples=1000, n_features=2,centers=3,random_state=10)  
plt.scatter(X[:,0],X[:,1]);
```



```
plt.figure(figsize=(10,8))  
  
y=make_blobs(n_samples=1000, n_features=2,centers=4,random_state=10)  
plt.scatter(X[:,0],X[:,1]);
```

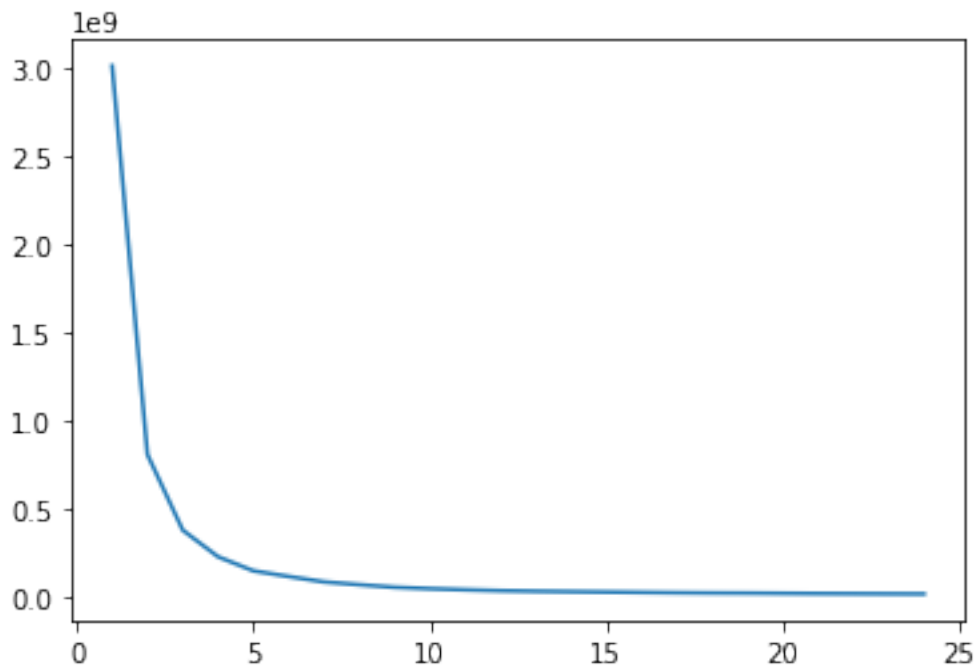
Implementing K Means on this dataset

Elbow method for finding k

```
from sklearn.cluster import KMeans
```

```
SSD=[]
for k in range(1,25):
    kmeans=KMeans(n_clusters=k,random_state=10)
    kmeans.fit(X)
    SSD.append(kmeans.inertia_)
plt.plot(range(1,25),SSD);
```

```
C:\Users\hp\anaconda3\lib\site-packages\sklearn\cluster\
_kmeans.py:1036: UserWarning: KMeans is known to have a memory leak on
Windows with MKL, when there are less chunks than available threads.
You can avoid it by setting the environment variable
OMP_NUM_THREADS=4.
  warnings.warn(
```

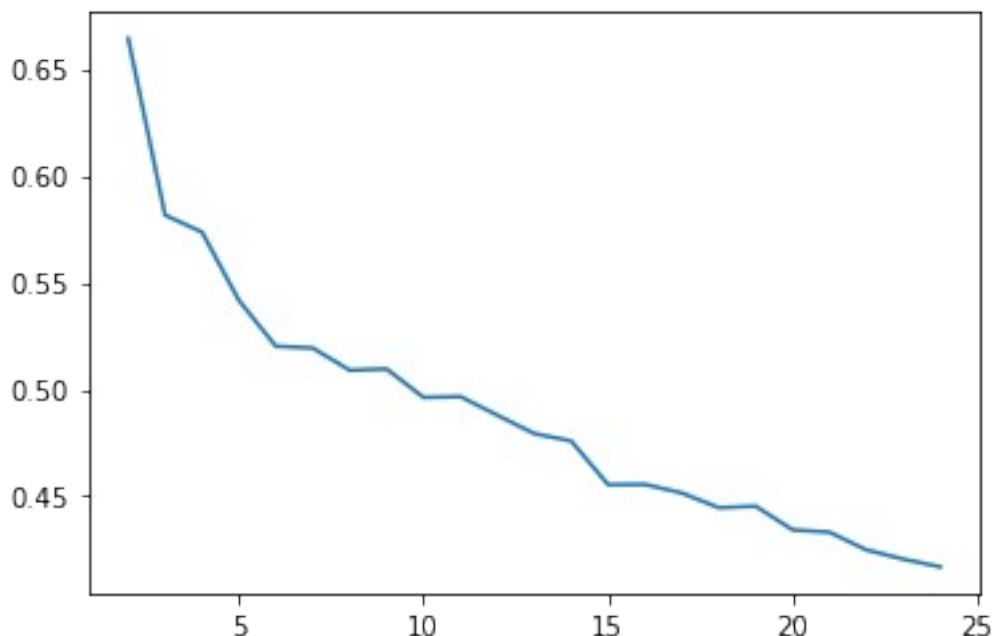


X

```
array([[3135., 224.],
       [2531., 58.],
       [ 263., 60.],
       ...,
       [ 766., 27.],
       [2993., 0.],
       [1766., 339.]])
```

Silhouette method

```
from sklearn.metrics import silhouette_score
SS=[]
for k in range(2,25):
    kmeans=KMeans(n_clusters=k, random_state=10)
    kmeans.fit(X)
    SS.append(silhouette_score(X,kmeans.predict(X)))
plt.plot(range(2,25),SS);
```



The best value of =2, the highest peak

Building the best model

```
k_best=KMeans(n_clusters=2,random_state=10)
```

```
k_best.fit(X)
```

```
clust_pred=k_best.predict(X)
```

```
clust_pred
```

```
array([1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 1,
1,
      1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1,
0,
      1, 0, 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 0,
1,
      1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0,
0,
      1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1,
1,
      1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 0,
1,
      1, 1, 1, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1,
1,
      0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1, 1,
0,
      1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 1,
0,
      1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0,
1,
      1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0,
1,
```

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1,	1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 1,
0,	0, 0, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1,
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0,	1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0,
1,	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0,
1,	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1,
0,	1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 1,
1,	0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1,
1,	1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1,
0,	1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 0, 0,
1,	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1, 0,
1,	1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1,
1,	1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1,
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1,	1, 1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0,
0,	0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 1,
1,	0, 1, 0, 1, 0, 0, 1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 0, 1, 0, 0, 1,
1,	1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1,
1,	1, 1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1,
1,	0, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1,
0,	1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1,

```

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1,      1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1,
1,      1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1,      1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1,
0,      1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1,
0,      0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1,
1,      1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 0,
1,      1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1,
1,      1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1,
      1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1])

```

```

k_best.cluster_centers_

```

```

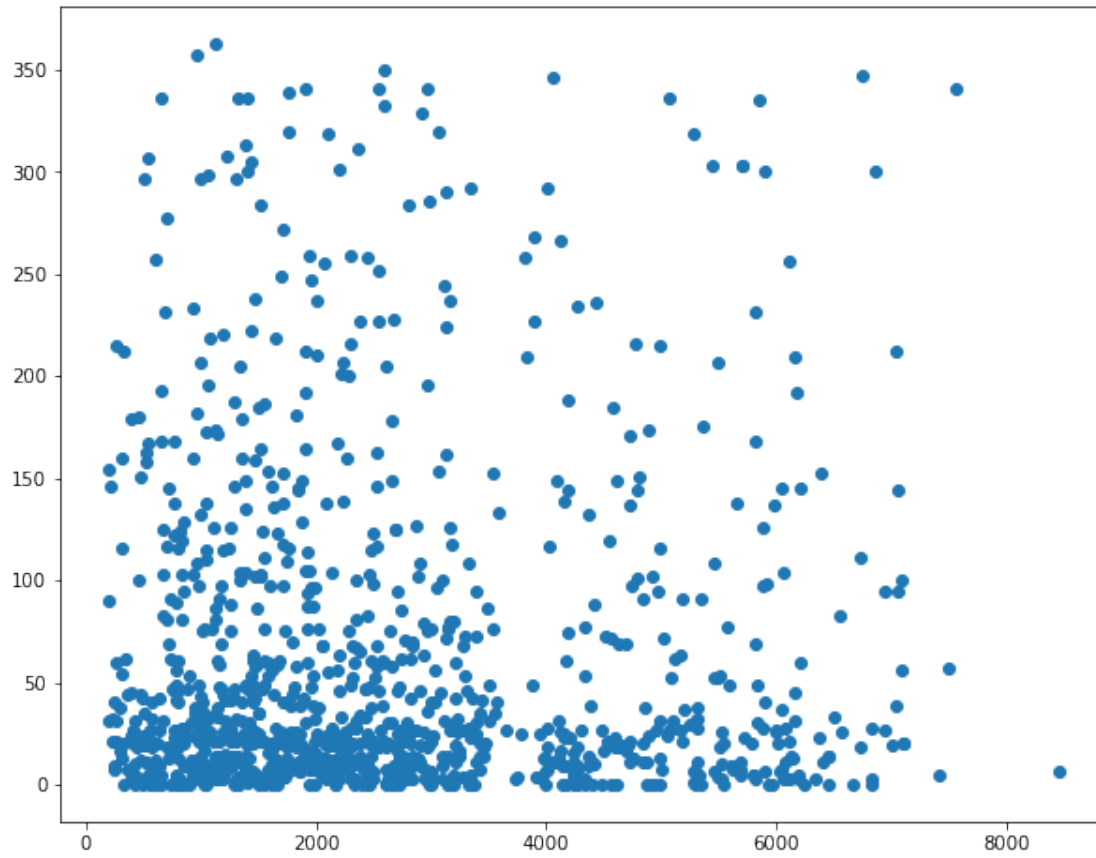
array([[5184.35658915,   65.          ],
       [1785.61590296,   65.03369272]])

```

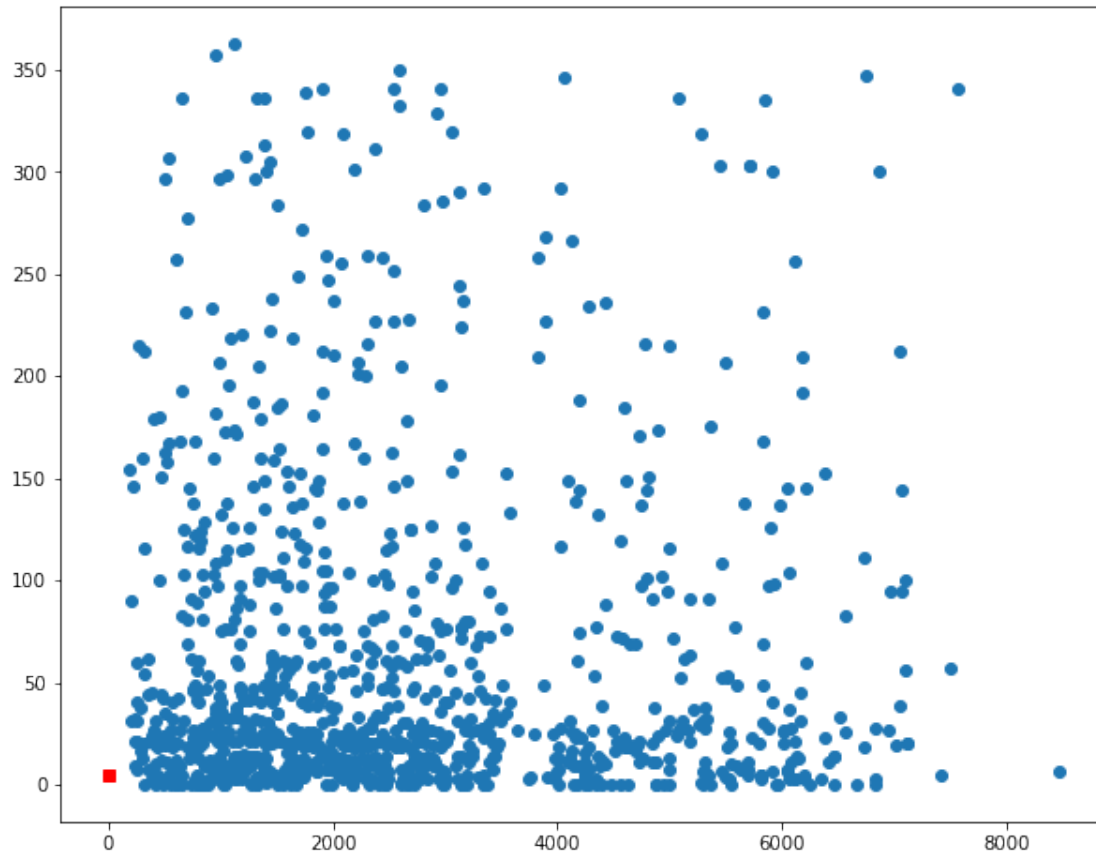
```

plt.figure(figsize=(10,8))
plt.scatter(X[:,0],X[:,1]);

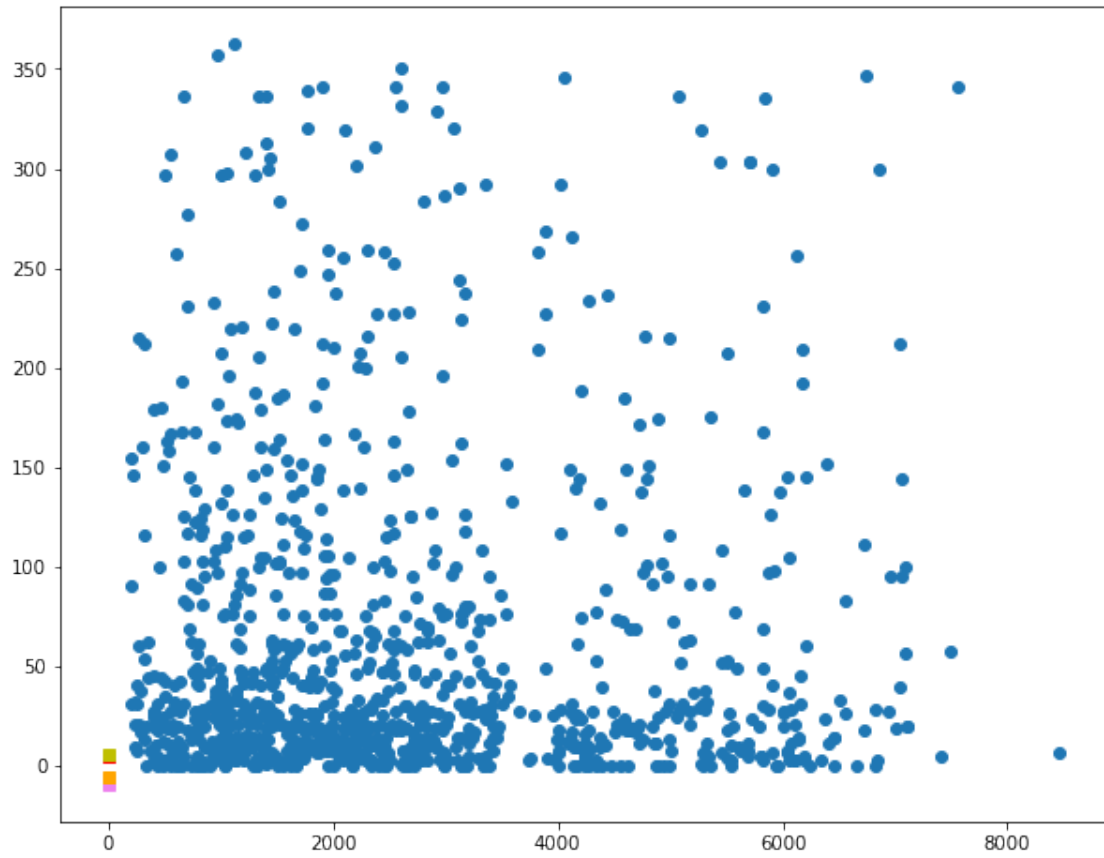
```



```
plt.figure(figsize=(10,8))
plt.scatter(X[:,0],X[:,1])
plt.plot(2.57427374, 4.9551547, c='r',marker='s');
```



```
plt.figure(figsize=(10,8))
plt.scatter(X[:,0],X[:,1])
plt.plot(2.57427374, 4.9551547, c='r',marker='s')
plt.plot(5.54690135, -9.62123904,c='violet',marker='s')
plt.plot(-6.10307996, 5.14422118,c='y',marker='s')
plt.plot(-0.03749354, -5.43011018,c='orange',marker='s');
```



END