FeatureSelection

March 26, 2023

[307]:
```
%matplotlib inline

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

import warnings
warnings.filterwarnings('ignore')
pd.options.display.max_columns = None

from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import StratifiedKFold
from sklearn.feature_selection import RFECV

from numpy import mean
from numpy import std
from sklearn.datasets import make_classification
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import RepeatedKFold
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestRegressor
from sklearn.pipeline import Pipeline
from sklearn import preprocessing
from sklearn.preprocessing import MinMaxScaler


from sklearn.metrics import accuracy_score
from sklearn.model_selection import cross_val_predict, KFold
from sklearn.preprocessing import StandardScaler

from sklearn.pipeline import Pipeline

from sklearn.feature_selection import RFE
from sklearn.linear_model import LogisticRegression
```

[308]:
```
#read dataset
```

```
data = pd.read_csv("/content/drive/MyDrive/CIND 820 Capstone Project/
 ↪merged_completedata.csv")
```

[309]:
```
#checking dimensions of data
data.head()
```

[309]:

	RecordID	X	Y	FID	BusinessID	\
0	1	-79.689829	43.644181	1	1055	
1	2	-79.689419	43.644988	2	1057	
2	3	-79.689419	43.644988	3	1058	
3	4	-79.689419	43.644988	4	1060	
4	5	-79.690664	43.645493	5	1061	

	Name	Address	StreetNo	\
0	Golf Trends Inc.	300 Ambassador Dr	300	
1	Apex Graphics Inc.	320 Ambassador Dr	320	
2	Sands, John & Associates Limited	320 Ambassador Dr	320	
3	Printmedia-Tackaberry Times	320 Ambassador Dr	320	
4	S W R Industries Ltd.	321 Ambassador Dr	321	

	StreetName	BldgNo	UnitNo	PostalCode	Location	Ward	NAICSCode	\
0	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	41	
1	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	32	
2	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	32	
3	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	32	
4	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	41	

	NAICSCat	NAICSDescr	Phone	\
0	Wholesale Trade	Amusement and Sporting Goods Wholesaler-Distri…	Yes	
1	Manufacturing	Support Activities for Printing	Yes	
2	Manufacturing	Support Activities for Printing	Yes	
3	Manufacturing	Other Printing	Yes	
4	Wholesale Trade	Industrial Machinery, Equipment and Supplies W…	Yes	

	Fax	TollFree	EMail	WebAddress	EmplRange	CENT_X	CENT_Y	Year	\
0	Yes	Yes	Yes	Yes	3	605668.2538	4.833187e+06	2016	
1	Yes	No	Yes	Yes	4	605699.9370	4.833277e+06	2016	
2	Yes	No	No	No	5	605699.9370	4.833277e+06	2016	
3	Yes	No	Yes	Yes	1	605699.9370	4.833277e+06	2016	
4	Yes	No	Yes	Yes	2	605598.6442	4.833332e+06	2016	

	Age	isnew	Closed
0	1	No	No
1	1	No	No
2	1	No	No
3	1	No	No
4	1	No	No

[310]:
```
#decribe categorical data
data.describe(include='O')
```

[310]:

	Name	Address	StreetName	BldgNo	UnitNo	PostalCode	\
count	78032	78032	78032	78032	78032	78032	
unique	22710	6618	669	2	2	37	
top	Subway	100 City Centre Dr	Dundas St E	No	Yes	L4W	
freq	212	953	3202	73798	53665	12410	

	Location	NAICSCat	NAICSDescr	\
count	78032	78032	78032	
unique	56	19	1039	
top	Northeast EA (West)	Retail Trade	Limited-service eating places	
freq	21104	11071	3647	

	Phone	Fax	TollFree	EMail	WebAddress	isnew	Closed
count	78032	78032	78032	78032	78032	78032	78032
unique	2	2	2	2	2	2	2
top	Yes	Yes	No	Yes	Yes	No	No
freq	77399	50803	66596	47406	56765	71148	71617

[311]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 78032 entries, 0 to 78031
Data columns (total 29 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   RecordID    78032 non-null  int64
 1   X           78032 non-null  float64
 2   Y           78032 non-null  float64
 3   FID         78032 non-null  int64
 4   BusinessID  78032 non-null  int64
 5   Name        78032 non-null  object
 6   Address     78032 non-null  object
 7   StreetNo    78032 non-null  int64
 8   StreetName  78032 non-null  object
 9   BldgNo      78032 non-null  object
 10  UnitNo      78032 non-null  object
 11  PostalCode  78032 non-null  object
 12  Location    78032 non-null  object
 13  Ward        78032 non-null  int64
 14  NAICSCode   78032 non-null  int64
 15  NAICSCat    78032 non-null  object
 16  NAICSDescr  78032 non-null  object
 17  Phone       78032 non-null  object
 18  Fax         78032 non-null  object
```

```
 19  TollFree    78032 non-null  object
 20  EMail       78032 non-null  object
 21  WebAddress  78032 non-null  object
 22  EmplRange   78032 non-null  int64
 23  CENT_X      78032 non-null  float64
 24  CENT_Y      78032 non-null  float64
 25  Year        78032 non-null  int64
 26  Age         78032 non-null  int64
 27  isnew       78032 non-null  object
 28  Closed      78032 non-null  object
dtypes: float64(4), int64(9), object(16)
memory usage: 17.3+ MB
```

[312]:
```
#NAICSCode back to object
data['NAICSCode'] = data['NAICSCode'].astype(str)
```

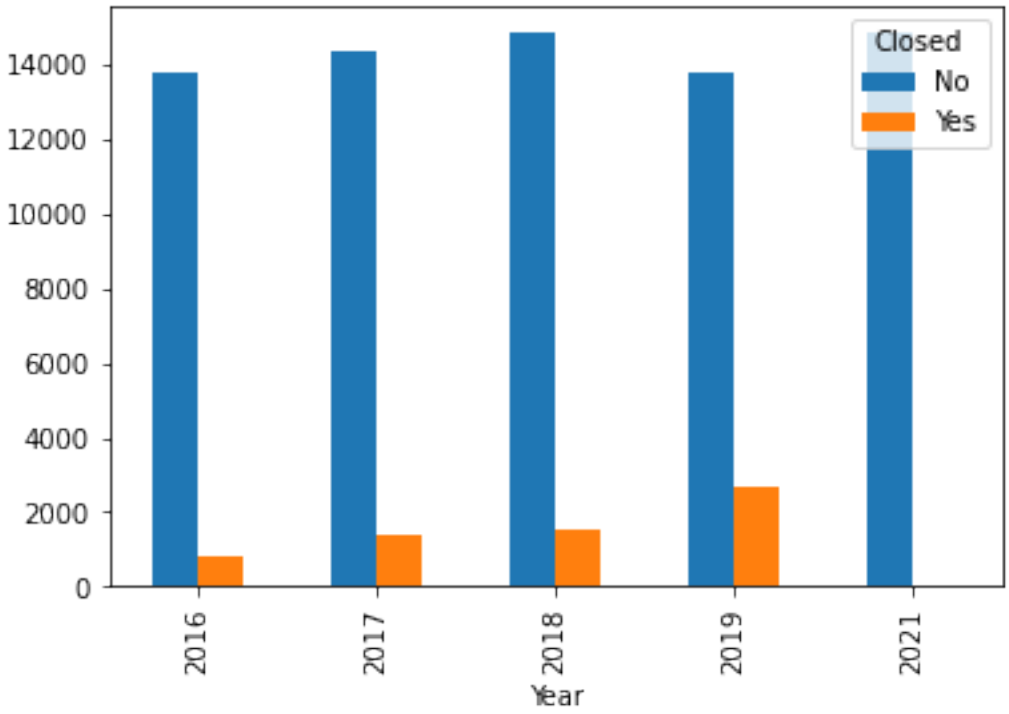
[313]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 78032 entries, 0 to 78031
Data columns (total 29 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   RecordID    78032 non-null  int64
 1   X           78032 non-null  float64
 2   Y           78032 non-null  float64
 3   FID         78032 non-null  int64
 4   BusinessID  78032 non-null  int64
 5   Name        78032 non-null  object
 6   Address     78032 non-null  object
 7   StreetNo    78032 non-null  int64
 8   StreetName  78032 non-null  object
 9   BldgNo      78032 non-null  object
 10  UnitNo      78032 non-null  object
 11  PostalCode  78032 non-null  object
 12  Location    78032 non-null  object
 13  Ward        78032 non-null  int64
 14  NAICSCode   78032 non-null  object
 15  NAICSCat    78032 non-null  object
 16  NAICSDescr  78032 non-null  object
 17  Phone       78032 non-null  object
 18  Fax         78032 non-null  object
 19  TollFree    78032 non-null  object
 20  EMail       78032 non-null  object
 21  WebAddress  78032 non-null  object
 22  EmplRange   78032 non-null  int64
 23  CENT_X      78032 non-null  float64
 24  CENT_Y      78032 non-null  float64
```

```
 25  Year         78032 non-null  int64
 26  Age          78032 non-null  int64
 27  isnew        78032 non-null  object
 28  Closed       78032 non-null  object
dtypes: float64(4), int64(8), object(17)
memory usage: 17.3+ MB
```

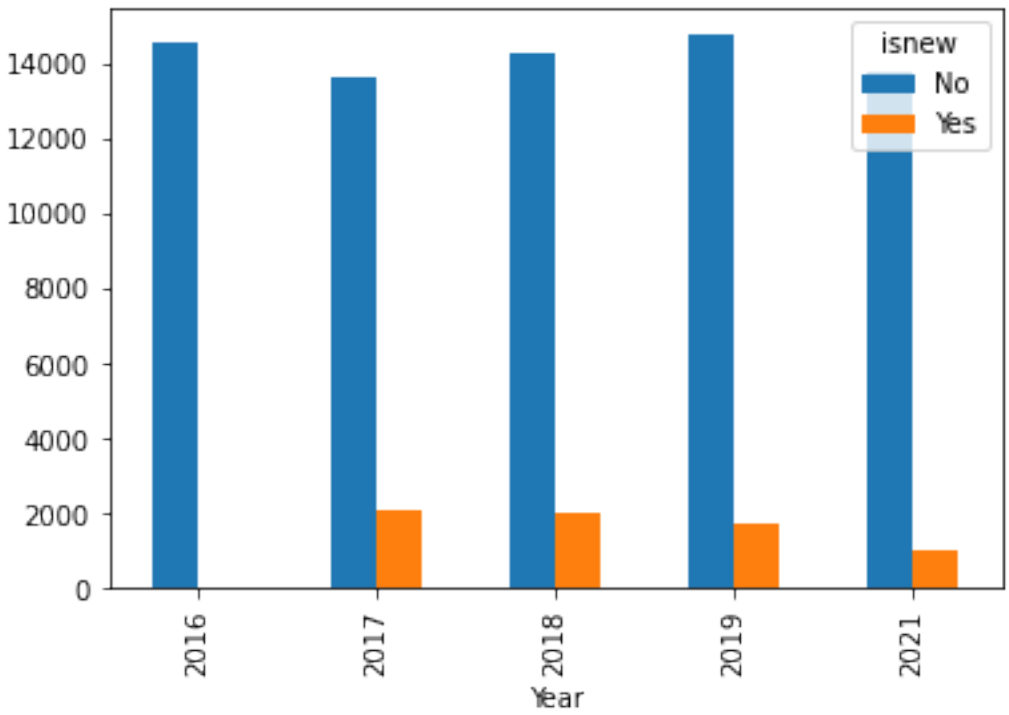
[314]:
```
df_gb_openclosed = data.groupby(['Year', 'Closed']).size().unstack(level=1)
df_gb_openclosed.plot(kind = 'bar')
```

[314]: <Axes: xlabel='Year'>



[315]:
```
df_gb_openclosed = data.groupby(['Year', 'isnew']).size().unstack(level=1)
df_gb_openclosed.plot(kind = 'bar')
```

[315]: <Axes: xlabel='Year'>



[316]:
```
data.head()
```

[316]:

	RecordID	X	Y	FID	BusinessID	Name	Address	StreetNo	StreetName	BldgNo	UnitNo	PostalCode	Location	Ward	NAICSCode
0	1	-79.689829	43.644181	1	1055	Golf Trends Inc.	300 Ambassador Dr	300	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	41
1	2	-79.689419	43.644988	2	1057	Apex Graphics Inc.	320 Ambassador Dr	320	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	32
2	3	-79.689419	43.644988	3	1058	Sands, John & Associates Limited	320 Ambassador Dr	320	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	32
3	4	-79.689419	43.644988	4	1060	Printmedia-Tackaberry Times	320 Ambassador Dr	320	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	32
4	5	-79.690664	43.645493	5	1061	S W R Industries Ltd.	321 Ambassador Dr	321	Ambassador Dr	No	No	L5T	Gateway EA (East)	5	41

```
          NAICSCat                                          NAICSDescr Phone  \
0  Wholesale Trade  Amusement and Sporting Goods Wholesaler-Distri…   Yes
1    Manufacturing                    Support Activities for Printing   Yes
2    Manufacturing                    Support Activities for Printing   Yes
3    Manufacturing                                      Other Printing   Yes
4  Wholesale Trade  Industrial Machinery, Equipment and Supplies W…   Yes

   Fax TollFree EMail WebAddress  EmplRange       CENT_X        CENT_Y  Year  \
0  Yes      Yes   Yes        Yes          3  605668.2538  4.833187e+06  2016
1  Yes       No   Yes        Yes          4  605699.9370  4.833277e+06  2016
2  Yes       No    No         No          5  605699.9370  4.833277e+06  2016
3  Yes       No   Yes        Yes          1  605699.9370  4.833277e+06  2016
4  Yes       No   Yes        Yes          2  605598.6442  4.833332e+06  2016

   Age isnew Closed
0    1    No     No
1    1    No     No
2    1    No     No
3    1    No     No
4    1    No     No
```

[317]:
```
#decribe categorical data
data.describe(include='O')
```

[317]:
```
           Name             Address   StreetName BldgNo UnitNo PostalCode  \
count     78032               78032        78032  78032  78032      78032
unique    22710                6618          669      2      2         37
top      Subway  100 City Centre Dr  Dundas St E     No    Yes        L4W
freq       212                 953         3202  73798  53665      12410

                   Location NAICSCode      NAICSCat  \
count                 78032     78032         78032
unique                   56        24            19
top     Northeast EA (West)        81  Retail Trade
freq                  21104      9052         11071

                           NAICSDescr  Phone    Fax TollFree  EMail  \
count                           78032  78032  78032    78032  78032
unique                           1039      2      2        2      2
top     Limited-service eating places    Yes    Yes       No    Yes
freq                             3647  77399  50803    66596  47406

       WebAddress  isnew Closed
count       78032  78032  78032
unique          2      2      2
top           Yes     No     No
freq        56765  71148  71617
```

[318]:
```
#drop columns that have unique values and categorical
data.drop(['FID','BusinessID','RecordID', 'Name','StreetNo','Address',␣
 ↪'NAICSCat',␣
 ↪'StreetName','Location','Phone','Fax','NAICSDescr','EMail','PostalCode','BldgNo','UnitNo','
 ↪'NAICSCode'], axis=1, inplace=True)
```

[319]:
```
data = data[data['Year'] == 2019]
```

[320]:
```
data.head()
```

[320]:

	X	Y	Ward	EmplRange	CENT_X	CENT_Y	Year	\
46689	-79.665386	43.684736	5	1	607567.2334	4.837723e+06	2019	
46690	-79.642760	43.593515	4	2	609556.5032	4.827621e+06	2019	
46691	-79.667311	43.682752	5	3	607415.6044	4.837500e+06	2019	
46692	-79.629235	43.698932	4	2	610454.8654	4.839347e+06	2019	
46693	-79.629235	43.698932	4	4	610454.8654	4.839347e+06	2019	

	Age	Closed
46689	4	No
46690	2	No
46691	4	No
46692	1	No
46693	1	No

[59]:
```
#data = data[data['Closed'] == 0]
#use this for when taking 2021 and is new!!!
```

[ ]:
```
#data.head()
```

[321]:
```
df2 = data.mean(axis=0)
print(df2)
```

```
X           -7.965769e+01
Y            4.360136e+01
Ward         5.372927e+00
EmplRange    2.183981e+00
CENT_X       6.088039e+05
CENT_Y       4.828662e+06
Year         2.019000e+03
Age          3.364451e+00
dtype: float64
```

[322]:
```
correlated_features= set()
correlation_matrix = data.drop('Closed', axis=1).corr()

for i in range(len(correlation_matrix.columns)):
  for j in range(i):
```

```
    if abs(correlation_matrix.iloc[i,j]) > 0.8:
      colname = correlation_matrix.columns[i]
      correlated_features.add(colname)
```

[323]:
```
correlated_features
```

[323]:
```
{'CENT_X', 'CENT_Y'}
```

[324]:
```
data.drop(['CENT_X', 'CENT_Y'], axis=1, inplace=True)
#use for closed analysys
```

[325]:
```
#checking dimensions of data
data.head()
```

[325]:

	X	Y	Ward	EmplRange	Year	Age	Closed
46689	-79.665386	43.684736	5	1	2019	4	No
46690	-79.642760	43.593515	4	2	2019	2	No
46691	-79.667311	43.682752	5	3	2019	4	No
46692	-79.629235	43.698932	4	2	2019	1	No
46693	-79.629235	43.698932	4	4	2019	1	No

[326]:
```
data.dtypes
```

[326]:
```
X            float64
Y            float64
Ward           int64
EmplRange      int64
Year           int64
Age            int64
Closed        object
dtype: object
```

[327]:
```
X = data.drop('Closed', axis=1)
target = data['Closed']

rfc = RandomForestClassifier(random_state=101)
rfecv = RFECV(estimator=rfc, step=1, cv=StratifiedKFold(10), scoring='accuracy')
rfecv_data = rfecv.fit(X, target)
#Recursive feature elimination
#Takes around 2-3 minutes to run. Not as effecient for feature selection.
```

[328]:
```
print('Optimal number of features: {}'.format(rfecv.n_features_))
```

```
Optimal number of features: 4
```

[329]:
```
print(np.where(rfecv.support_ == False)[0])
```

```
X.drop(X.columns[np.where(rfecv.support_ == False)[0]], axis=1, inplace=True)
```

```
[4 5]
```

[330]:
```
rfecv.estimator_.feature_importances_
```

[330]:
```
array([0.40950297, 0.42049184, 0.05850092, 0.11150427])
```

[331]:
```
ranking_features = rfecv.ranking_
print (ranking_features)
```

```
[1 1 1 1 3 2]
```

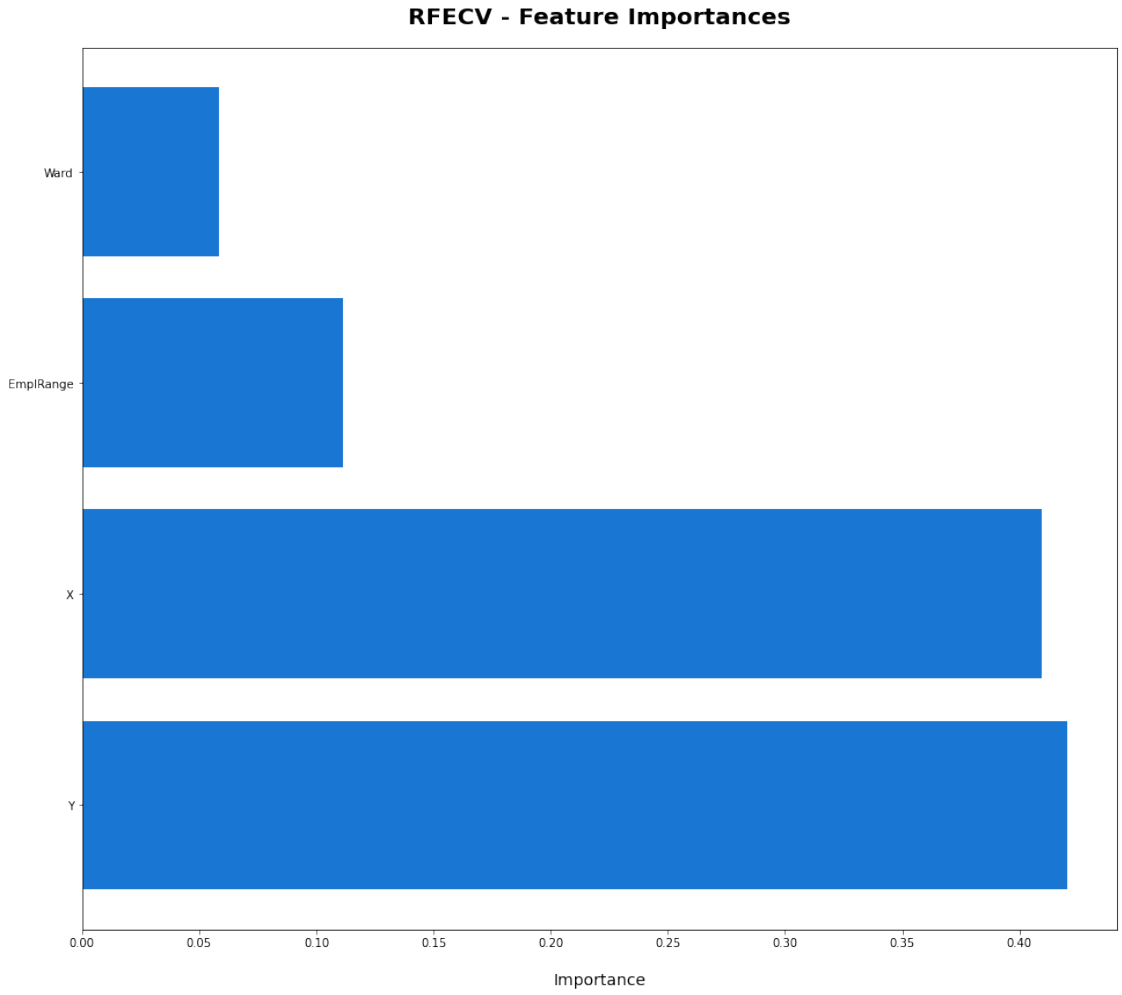
[332]:
```
ranking_scores = rfecv.cv_results_
print(ranking_scores)
```

```
{'mean_test_score': array([0.7111346 , 0.71924598, 0.73729562, 0.73808445,
0.73420456,
       0.73341738]), 'std_test_score': array([0.18339097, 0.18618487, 0.1262046
, 0.1199649 , 0.14775102,
       0.14623285]), 'split0_test_score': array([0.80811138, 0.82566586,
0.81053269, 0.80992736, 0.81416465,
       0.81355932]), 'split1_test_score': array([0.78692494, 0.80145278,
0.80932203, 0.81113801, 0.81355932,
       0.80932203]), 'split2_test_score': array([0.75060533, 0.75544794,
0.74455206, 0.72336562, 0.74818402,
       0.74576271]), 'split3_test_score': array([0.76150121, 0.76997579,
0.76089588, 0.75484262, 0.75847458,
       0.76815981]), 'split4_test_score': array([0.73365617, 0.74939467,
0.77360775, 0.76876513, 0.77058111,
       0.76937046]), 'split5_test_score': array([0.76392252, 0.77542373,
0.78631961, 0.79116223, 0.79358354,
       0.79116223]), 'split6_test_score': array([0.77905569, 0.78389831,
0.78813559, 0.78631961, 0.78934625,
       0.78692494]), 'split7_test_score': array([0.78389831, 0.78753027,
0.77602906, 0.78026634, 0.79479419,
       0.79479419]), 'split8_test_score': array([0.77952756, 0.77952756,
0.76014537, 0.76923077, 0.76377953,
       0.75590551]), 'split9_test_score': array([0.16414294, 0.16414294,
0.36341611, 0.38582677, 0.29557844,
       0.2992126 ])}
```

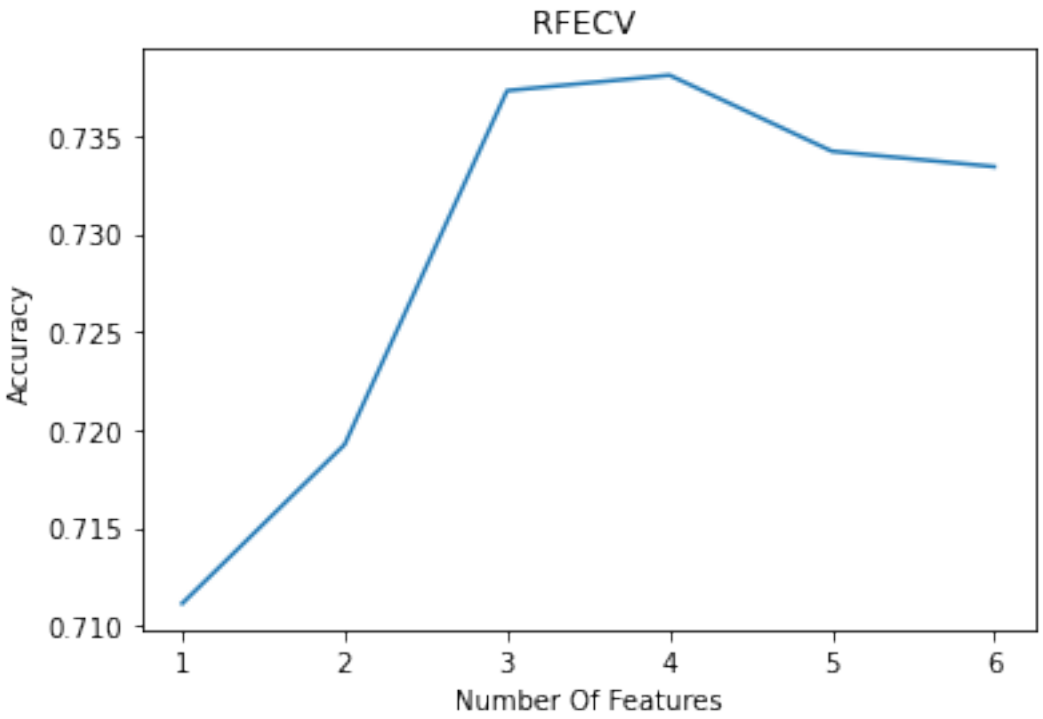
[333]:
```
dset = pd.DataFrame()
dset['attr'] = X.columns
dset['importance'] = rfecv.estimator_.feature_importances_

dset = dset.sort_values(by='importance', ascending=False)
```

```
plt.figure(figsize=(16, 14))
plt.barh(y=dset['attr'], width=dset['importance'], color='#1976D2')
plt.title('RFECV - Feature Importances', fontsize=20, fontweight='bold', pad=20)
plt.xlabel('Importance', fontsize=14, labelpad=20)
#plt.show()
```

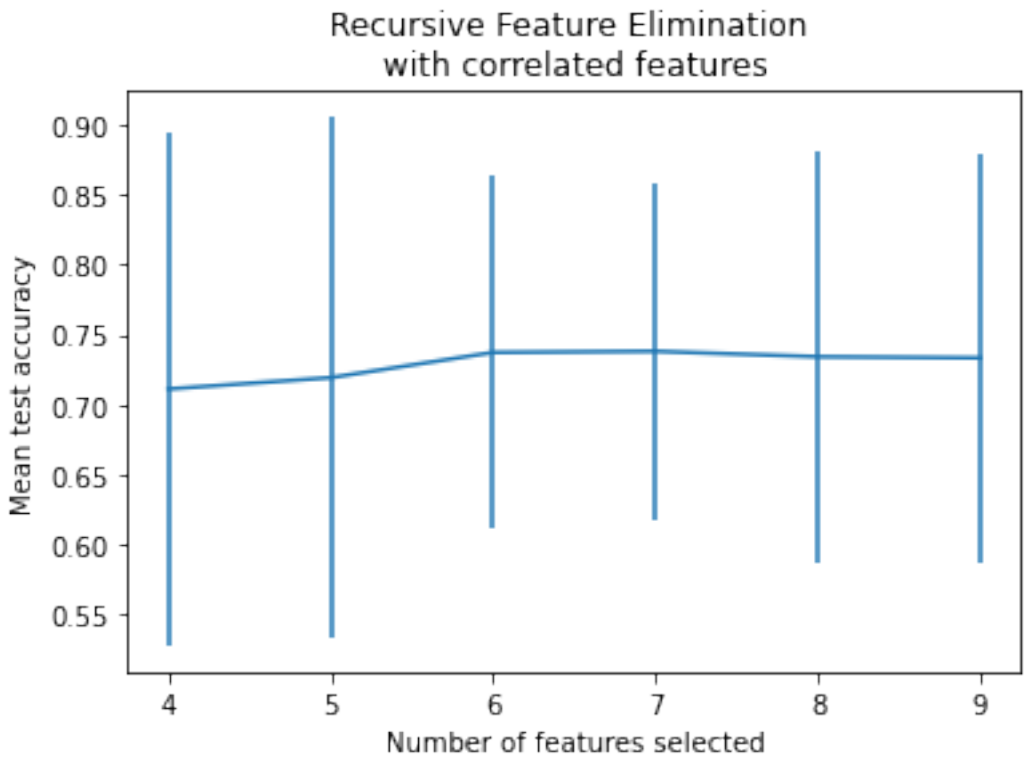
[333]: Text(0.5, 0, 'Importance')



[334]:
```
plt.title("RFECV ")
plt.xlabel("Number Of Features")
plt.ylabel("Accuracy")
plt.plot(range(1, len(rfecv.cv_results_['mean_test_score']) + 1), rfecv.
 ↪cv_results_['mean_test_score'])
plt.show()
```



[335]:
```
n_scores = len(rfecv.cv_results_["mean_test_score"])
plt.figure()
plt.xlabel("Number of features selected")
plt.ylabel("Mean test accuracy")
plt.errorbar(
    range(min_features_to_select, n_scores + min_features_to_select),
    rfecv.cv_results_["mean_test_score"],
    yerr=rfecv.cv_results_["std_test_score"],
)
plt.title("Recursive Feature Elimination \nwith correlated features")
plt.show()
```



[336]:
```
df_features = pd.DataFrame(columns = ['feature', 'support', 'ranking'])

for i in range(X.shape[1]):
    row = {'feature': i, 'support': rfecv_data.support_[i], 'ranking':␣
 ↪rfecv_data.ranking_[i]}
    df_features = df_features.append(row, ignore_index=True)

df_features.sort_values(by='ranking').head(10)
```

[336]:

	feature	support	ranking
0	0	True	1
1	1	True	1
2	2	True	1
3	3	True	1

[337]:
```
df_features[df_features['support']==True]
```

[337]:

	feature	support	ranking
0	0	True	1
1	1	True	1
2	2	True	1
3	3	True	1

[79]:
```
#Use the selected features as the X values in your models
```