Housing Tenure Prediction Analysis

April 29, 2024

0.1 Housing Tenure Prediction Analysis

0.1.1 Libraries requires for this project

[1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from matplotlib.pyplot import subplots, cm
import matplotlib.pyplot as plt
from mlxtend.plotting import plot_decision_regions
from sklearn import svm
from sklearn.svm import SVC
import sklearn.model_selection as skm
from sklearn.model_selection import train_test_split, GridSearchCV, KFold
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.metrics import classification_report, confusion_matrix,␣
↪accuracy_score
from sklearn.metrics import RocCurveDisplay
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import GridSearchCV
from ISLP import load_data, confusion_table
from ISLP.svm import plot as plot_svm
from sklearn.inspection import permutation_importance
```

0.1.2 Loading the 'Housing Data'

[2]:
```
Housing_Data = pd.read_csv("Housing.csv")
Housing_Data
```

[2]:
```
        SERIAL  DENSITY  OWNERSHP  OWNERSHPD  COSTELEC  COSTGAS  COSTWATR  \
0      1371772    920.0         1         13      9990     9993       360
1      1371773   3640.9         2         22      1080     9993      1800
2      1371773   3640.9         2         22      1080     9993      1800
3      1371774     22.5         1         13       600     9993      9993
4      1371775   3710.4         2         22      3600     9993      9997
…          …        …        …          …        …       …         …
75383  1402573   2754.9         2         22      9990     7200       960
```

```
75384  1402573   2754.9          2          22        9990      7200         960
75385  1402573   2754.9          2          22        9990      7200         960
75386  1402573   2754.9          2          22        9990      7200         960
75387  1402573   2754.9          2          22        9990      7200         960

       COSTFUEL  HHINCOME   VALUEH  …  NFAMS  NCOUPLES  PERNUM  PERWT  AGE  \
0          9993     75000   700000  …      1         0       1     14   52
1          9993     13600  9999999  …      2         0       1     83   22
2          9993     13600  9999999  …      2         0       2    106   22
3          9993      7000   800000  …      1         0       1     33   62
4          9993     50500  9999999  …      1         0       1    297   50
…           …         …       …  …    …         …      …     …  …
75383      9993     86700  9999999  …      1         2       1    229   30
75384      9993     86700  9999999  …      1         2       2    331   30
75385      9993     86700  9999999  …      1         2       3    331    5
75386      9993     86700  9999999  …      1         2       4    157   64
75387      9993     86700  9999999  …      1         2       5    225   60

       MARST  BIRTHYR  EDUC  EDUCD   INCTOT
0          6     1969     7     71    75000
1          6     1999    10    101     5600
2          6     1999     7     71     8000
3          4     1959     6     63     7000
4          3     1971     7     71    16000
…       …       …    …     …      …
75383      1     1991     6     63    35000
75384      1     1991     6     64    50000
75385      6     2016     0      2  9999999
75386      1     1957     6     63     1700
75387      1     1961     7     71        0

[75388 rows x 24 columns]
```

[3]:
```python
# Now let's see the columns in our data set
Housing_Data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 75388 entries, 0 to 75387
Data columns (total 24 columns):
 #   Column     Non-Null Count  Dtype
---  ------     --------------  -----
 0   SERIAL     75388 non-null  int64
 1   DENSITY    75388 non-null  float64
 2   OWNERSHP   75388 non-null  int64
 3   OWNERSHPD  75388 non-null  int64
 4   COSTELEC   75388 non-null  int64
 5   COSTGAS    75388 non-null  int64
 6   COSTWATR   75388 non-null  int64
```

```
 7   COSTFUEL   75388 non-null  int64
 8   HHINCOME   75388 non-null  int64
 9   VALUEH     75388 non-null  int64
 10  ROOMS      75388 non-null  int64
 11  BUILTYR2   75388 non-null  int64
 12  BEDROOMS   75388 non-null  int64
 13  VEHICLES   75388 non-null  int64
 14  NFAMS      75388 non-null  int64
 15  NCOUPLES   75388 non-null  int64
 16  PERNUM     75388 non-null  int64
 17  PERWT      75388 non-null  int64
 18  AGE        75388 non-null  int64
 19  MARST      75388 non-null  int64
 20  BIRTHYR    75388 non-null  int64
 21  EDUC       75388 non-null  int64
 22  EDUCD      75388 non-null  int64
 23  INCTOT     75388 non-null  int64
dtypes: float64(1), int64(23)
memory usage: 13.8 MB
```

[4]:
```
# Let's check the shape of our dataset
Housing_Data.shape
```

[4]: (75388, 24)

[5]:
```
# Lets calculate the summary statistics for our dataset for imputation
Housing_Data.describe()
```

[5]:

	SERIAL	DENSITY	OWNERSHP	OWNERSHPD	COSTELEC
count	7.538800e+04	75388.000000	75388.000000	75388.000000	75388.000000
mean	1.387234e+06	2423.430017	1.266050	15.152146	2155.588184
std	8.903828e+03	2526.581859	0.441894	4.114694	1918.598151
min	1.371772e+06	22.500000	1.000000	12.000000	48.000000
25%	1.379509e+06	448.200000	1.000000	13.000000	1080.000000
50%	1.387292e+06	1667.900000	1.000000	13.000000	1680.000000
75%	1.394971e+06	3843.300000	2.000000	22.000000	2400.000000
max	1.402573e+06	13284.600000	2.000000	22.000000	9997.000000

	COSTGAS	COSTWATR	COSTFUEL	HHINCOME	VALUEH
count	75388.000000	75388.000000	75388.000000	7.538800e+04	7.538800e+04
mean	6532.804850	3282.154680	9132.200363	1.325857e+05	3.115290e+06
std	4379.021441	3968.876334	2704.300467	1.300609e+05	4.178808e+06
min	48.000000	4.000000	4.000000	-7.100000e+03	1.000000e+03
25%	1200.000000	500.000000	9993.000000	5.500000e+04	4.000000e+05
50%	9992.000000	1200.000000	9993.000000	1.000000e+05	6.500000e+05
75%	9993.000000	9993.000000	9993.000000	1.640000e+05	9.999999e+06
max	9997.000000	9997.000000	9997.000000	1.674500e+06	9.999999e+06

```
       …          NFAMS       NCOUPLES         PERNUM          PERWT  \
count  …   75388.000000   75388.000000   75388.000000   75388.000000
mean   …       1.120138       0.772722       2.133072     100.746644
std    …       0.520437       0.466072       1.347956      79.428151
min    …       1.000000       0.000000       1.000000       2.000000
25%    …       1.000000       1.000000       1.000000      54.000000
50%    …       1.000000       1.000000       2.000000      80.000000
75%    …       1.000000       1.000000       3.000000     117.000000
max    …      13.000000       3.000000      16.000000    1113.000000

                AGE         MARST       BIRTHYR          EDUC         EDUCD  \
count  75388.000000  75388.000000  75388.000000  75388.000000  75388.000000
mean      41.737040      3.466599   1979.262960      6.553802     67.954754
std       23.497059      2.323782     23.497059      3.368158     33.507170
min        0.000000      1.000000   1928.000000      0.000000      1.000000
25%       22.000000      1.000000   1960.000000      6.000000     61.000000
50%       42.000000      4.000000   1979.000000      7.000000     71.000000
75%       61.000000      6.000000   1999.000000     10.000000    101.000000
max       93.000000      6.000000   2021.000000     11.000000    116.000000

             INCTOT
count  7.538800e+04
mean   1.741325e+06
std    3.730804e+06
min   -8.700000e+03
25%    1.560000e+04
50%    4.800000e+04
75%    1.250000e+05
max    9.999999e+06

[8 rows x 24 columns]
```

0.1.3 Data Cleaning and Preprocessing

For our analysis, we will be looking for owners/renters whose age falls between the range 18 years to 80 years

[6]:
```
# So, lets filter our data accordingly to condition
Housing_Data = Housing_Data[(Housing_Data['AGE'] >= 18) & (Housing_Data['AGE']␣
↪<= 80)]
```

After that, We will be considering the education of owners/renters to who have education attainment from 12th grade to 5+ years of college. There are some missing values in our data (code 99 means missing). So handling that and also getting rid of the column 'EDUCD' which means education attainment [detailed version] to handle redundancy.

[7]:
```
# Filtering the data accordingly
```

```
Housing_Data = Housing_Data[(Housing_Data['EDUC'] >= 6) & (Housing_Data['EDUC']␣
↪<= 11) & Housing_Data['EDUC'] != 99]

# Removing the 'EDUCD' column
Housing_Data.drop('EDUCD', axis=1, inplace=True)
```

[8]:
```
# Removing the 'DENSITY' column
Housing_Data.drop('DENSITY', axis=1, inplace=True)
```

[9]:
```
# Looking for properties built from the year 2000 to 2021
# So, Filtering our datase accordingly
Housing_Data = Housing_Data[(Housing_Data['BUILTYR2'] >= 9) &␣
↪(Housing_Data['BUILTYR2'] <= 26)]
```

[10]:
```
# Removing the 'PERWT' column
Housing_Data.drop('PERWT', axis=1, inplace=True)
```

[11]:
```
# Removing the 'BIRTHYR' column
Housing_Data.drop('BIRTHYR', axis=1, inplace=True)
```

[12]:
```
# Removing the 'OWNERSHPD' column
Housing_Data.drop('OWNERSHPD', axis=1, inplace=True)
```

[13]:
```
# Removing the 'INCTOT' column
Housing_Data.drop('INCTOT', axis=1, inplace=True)
```

[14]:
```
# Removing the 'NFAMS' column
Housing_Data.drop('NFAMS', axis=1, inplace=True)
```

[15]:
```
# Removing the 'NCOUPLES' column
Housing_Data.drop('NCOUPLES', axis=1, inplace=True)
```

[16]:
```
# REmoving the 'PERNUM' column
Housing_Data.drop('PERNUM', axis=1, inplace=True)
```

[17]:
```
Housing_Data.head(10)
```

[17]:

	SERIAL	OWNERSHP	COSTELEC	COSTGAS	COSTWATR	COSTFUEL	HHINCOME \
20	1371783	1	1920	1440	50	9993	30000
21	1371783	1	1920	1440	50	9993	30000
32	1371786	2	1800	9993	1400	9993	62000
33	1371786	2	1800	9993	1400	9993	62000
34	1371787	1	960	360	5000	9993	507500
35	1371787	1	960	360	5000	9993	507500
38	1371788	1	1200	9997	110	9993	115600
39	1371788	1	1200	9997	110	9993	115600
79	1371802	1	1560	9993	9993	9993	12000

```
81  1371803          2       3600      9993       9993       9993      45800

      VALUEH  ROOMS  BUILTYR2  BEDROOMS  VEHICLES  AGE  MARST  EDUC
20     15000      3        15         3         4   40      6     6
21     15000      3        15         3         4   32      6     6
32   9999999      4         9         3         2   28      6    11
33   9999999      4         9         3         2   26      6    10
34   5279000     10        15         6         2   37      1    10
35   5279000     10        15         6         2   36      1    10
38    375000      5         9         4         2   71      1    10
39    375000      5         9         4         2   71      1     7
79    550000      7        15         4         2   67      5    10
81   9999999      9         9         5         2   44      4     6
```

[18]:

```python
# Group by 'SERIAL' and aggregating the data
# Serial number of household members are associated with different variables so␣
 ↪grouping them with it
Housing_Data = Housing_Data.groupby('SERIAL').agg({
    'OWNERSHP': 'first',
    'COSTELEC': 'first',
    'COSTGAS': 'first',
    'COSTWATR': 'first',
    'COSTFUEL': 'first',
    'HHINCOME': 'first',
    'VALUEH': 'first',
    'ROOMS': 'first',
    'BUILTYR2': 'first',
    'BEDROOMS': 'first',
    'VEHICLES': 'first',
    'MARST': 'first',
    'AGE' : 'max',   # Taking the highest age of household member assuming that␣
 ↪he is earning the highest among the others
    'EDUC': 'max'    # Highest education attainment of that household member
}).reset_index()
```

[19]:

```python
# Final housing data set after cleaning and prefrocessing
Housing_Data.head(10)
```

[19]:

```
    SERIAL  OWNERSHP  COSTELEC  COSTGAS  COSTWATR  COSTFUEL  HHINCOME  \
0  1371783         1      1920     1440        50      9993     30000
1  1371786         2      1800     9993      1400      9993     62000
2  1371787         1       960      360      5000      9993    507500
3  1371788         1      1200     9997       110      9993    115600
4  1371802         1      1560     9993      9993      9993     12000
5  1371803         2      3600     9993      9993      9993     45800
6  1371804         1      2400     1800        40      9993    775000
7  1371807         1      1320      360      2200        50     95500
```

```
8  1371810          1       1800      1200       1800       9993     172500
9  1371811          1        480       600        110       9993      84000

    VALUEH  ROOMS  BUILTYR2  BEDROOMS  VEHICLES  MARST  AGE  EDUC
0    15000      3        15         3         4      6   40     6
1  9999999      4         9         3         2      6   28    11
2  5279000     10        15         6         2      1   37    10
3   375000      5         9         4         2      1   71    10
4   550000      7        15         4         2      5   67    10
5  9999999      9         9         5         2      4   60     7
6   950000      8         9         5         3      1   51    11
7   285000      6         9         4         2      1   80    10
8   950000      9         9         6         2      1   41    10
9   750000      6        25         4         2      1   35     7
```

0.1.4 Encoding the categorical variables

[20]:
```
# Converting 'MARST' and 'EDUC' to categorical using the label-Encoder
le = LabelEncoder()
Housing_Data['MARST'] = le.fit_transform(Housing_Data['MARST'])
Housing_Data['EDUC'] = le.fit_transform(Housing_Data['EDUC'])
```

[21]:
```
# Scaling our data to improve the perfomance of models
# We will be using standard scaler function
scaler = StandardScaler()

# This will not consider ownership as one of the feature
# Also, it is our target variable
features = Housing_Data.columns.difference(['OWNERSHP'])

# Fit the scaler to your data
Housing_Data[features] = scaler.fit_transform(Housing_Data[features])
```

0.1.5 Splitting the dataset into Training and Testing set

[22]:
```
# Splitting the dataset (70 - 30 ratio)
Housing_train_set, Housing_test_set = train_test_split(Housing_Data, test_size␣
 ↪= 0.3, random_state = 1)
```

0.1.6 Models

- SVM Model with linear kernel

[23]:
```
# Support Vector Machine model with linear kernel and using cost value = 1
# I used max_iterations as the model was taking time to execute
svm_linear_model = svm.SVC(kernel = 'linear', C = 1, max_iter = 10000)
```

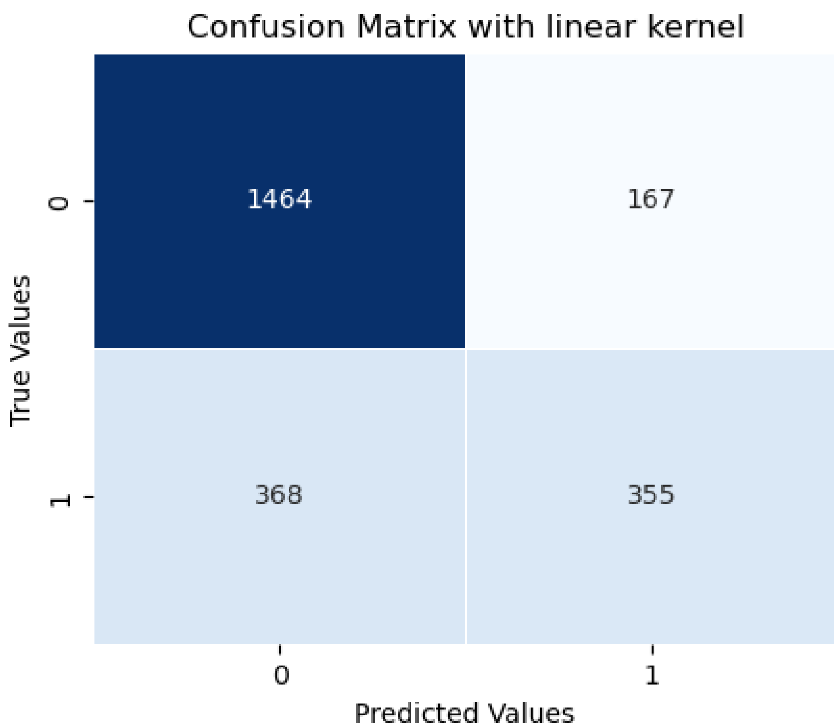
```
svm_linear_model.fit(Housing_train_set[['AGE', 'HHINCOME']],␣
 ↪Housing_train_set['OWNERSHP'])
```

[23]: SVC(C=1, kernel='linear', max_iter=10000)

[24]:
```
# Predicting the ownership status on the test set
lin_model_predicts = svm_linear_model.predict(Housing_test_set[['AGE',␣
 ↪'HHINCOME']])

# Evaluating the model
print(classification_report(Housing_test_set['OWNERSHP'], lin_model_predicts))
print("Accuracy:", round(accuracy_score(Housing_test_set['OWNERSHP'],␣
 ↪lin_model_predicts), 4))
```

```
              precision    recall  f1-score   support

           1       0.80      0.90      0.85      1631
           2       0.68      0.49      0.57       723

    accuracy                           0.77      2354
   macro avg       0.74      0.69      0.71      2354
weighted avg       0.76      0.77      0.76      2354

Accuracy: 0.7727
```

[25]:
```
# Lets construct a confusion matrix for our predictions
linear_matrix = confusion_matrix(Housing_test_set['OWNERSHP'],␣
 ↪lin_model_predicts)

# Plotting the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(linear_matrix, annot=True, fmt="d", linewidths=.5, cmap="Blues",␣
 ↪cbar=False)
plt.xlabel('Predicted Values')
plt.ylabel('True Values')
plt.title('Confusion Matrix with linear kernel')
plt.show()
```



So, with the linear kernel and default cost value, our model was poorly performing with the accuracy around 72.38%.

Now, we apply cross validation using skm.GridSearchCV() to select the best C value for our SVM model with a linear kernel.

[26]:
```
# Defining the KFold cross-validation for 5 folds
kfold = skm.KFold(5, random_state = 1, shuffle=True)

# Let's set up a grid for our cost value
c_values = {'C':[0.01, 0.1, 1, 10, 100]}

# Lets apply 5 fold cross validation using GridSearchCV() to get the best␣
↪c-value for our model
# we will be using the above model for cross-validation
grid = skm.GridSearchCV(svm_linear_model, c_values, cv = kfold, scoring =␣
↪'accuracy');

# refitting the model after cross-validation
grid.fit(Housing_train_set[['AGE', 'HHINCOME']], Housing_train_set['OWNERSHP'])
grid.best_params_
```

```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
```

```
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

[26]:
```
{'C': 0.01}
```

Now, lets refit the model with this c-value and check if ourt accuracy has been improved or not.

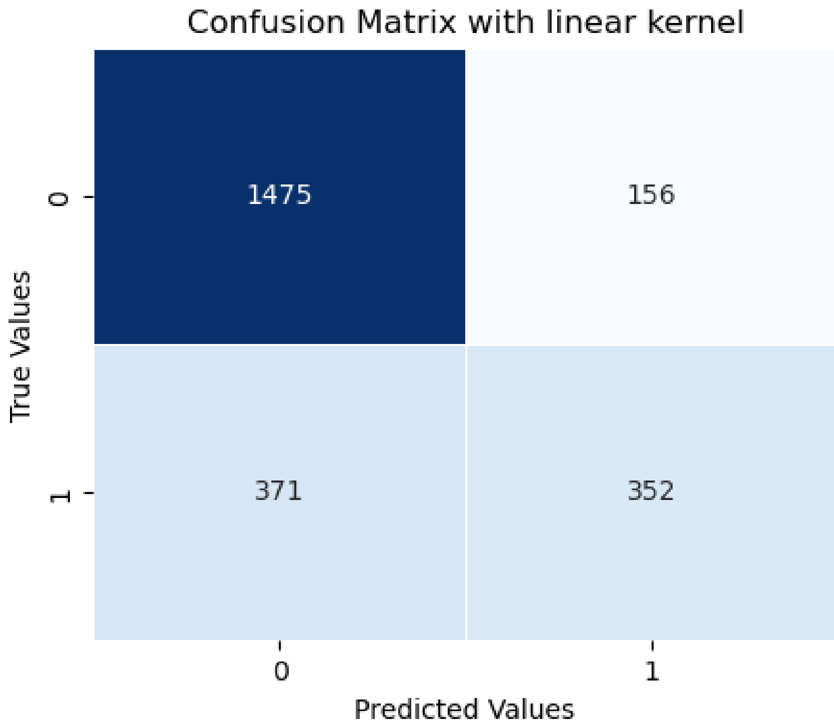
[27]:
```python
best_linear_model = grid.best_estimator_

# Predicting the ownership status on the test set
lin_model_predictsCV = best_linear_model.predict(Housing_test_set[['AGE',
    'HHINCOME']])
```

```
# Evaluating the model
print(classification_report(Housing_test_set['OWNERSHP'], lin_model_predictsCV))
print("Accuracy:", round(accuracy_score(Housing_test_set['OWNERSHP'],␣
 ↪lin_model_predictsCV), 4))
```

```
              precision    recall  f1-score   support

           1       0.80      0.90      0.85      1631
           2       0.69      0.49      0.57       723

    accuracy                           0.78      2354
   macro avg       0.75      0.70      0.71      2354
weighted avg       0.77      0.78      0.76      2354

Accuracy: 0.7761
```

So after cross-validation, the SVM linear kernel model with best cost value of 100 slighty decreased the accuracy around 72.25%.

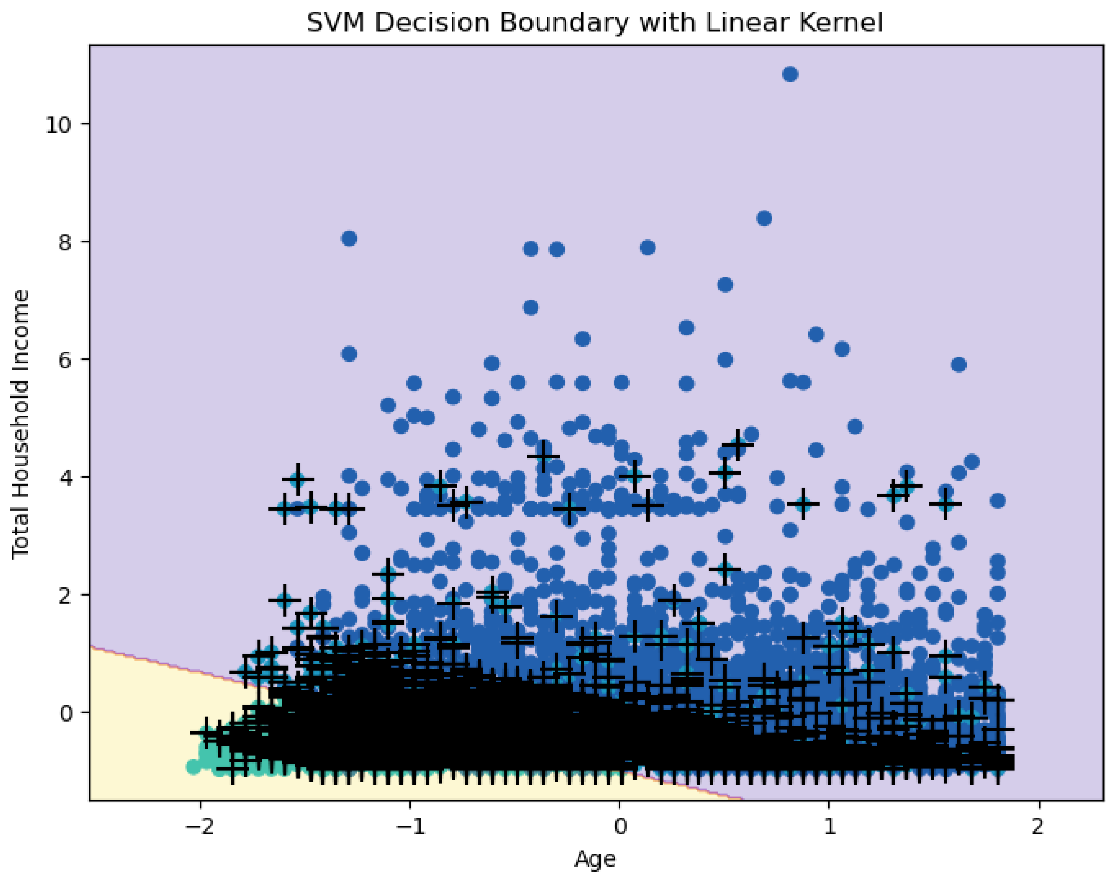
[28]:
```
# Lets construct a confusion matrix for our predictions
linear_matrixCV = confusion_matrix(Housing_test_set['OWNERSHP'],␣
 ↪lin_model_predictsCV)

# Plotting the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(linear_matrixCV, annot=True, fmt="d", linewidths=.5, cmap="Blues",␣
 ↪cbar=False)
plt.xlabel('Predicted Values')
plt.ylabel('True Values')
plt.title('Confusion Matrix with linear kernel')
plt.show()
```



Let's construct a plot to get the decision boundry about the ownership based on age and total household income

[29]:
```
# Extracting the features values (Age and total house income values) and target␣
↪variable (ownership values) used in the SVM
X_train = Housing_train_set[['AGE', 'HHINCOME']].values
y_train = Housing_train_set['OWNERSHP'].values

fig, ax = subplots(figsize=(8,6))
plot_svm(X_train,
         y_train,
         best_linear_model,
         ax=ax)
ax.set_xlabel('Age')
ax.set_ylabel('Total Household Income')
ax.set_title('SVM Decision Boundary with Linear Kernel')
plt.show()
```

```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\base.py:493:
UserWarning: X does not have valid feature names, but SVC was fitted with
feature names
  warnings.warn(
```



- SVM Model with polynomial kernel

[30]:
```
# Support Vector Machine model with polynomial kernel and using cost value = 1␣
↪and degree = 2
svm_poly_model = svm.SVC(kernel = 'poly', C = 1, degree = 2, max_iter = 10000)
svm_poly_model.fit(Housing_train_set[['AGE', 'MARST','HHINCOME']],␣
↪Housing_train_set['OWNERSHP'])
```

[30]:
```
SVC(C=1, degree=2, kernel='poly', max_iter=10000)
```

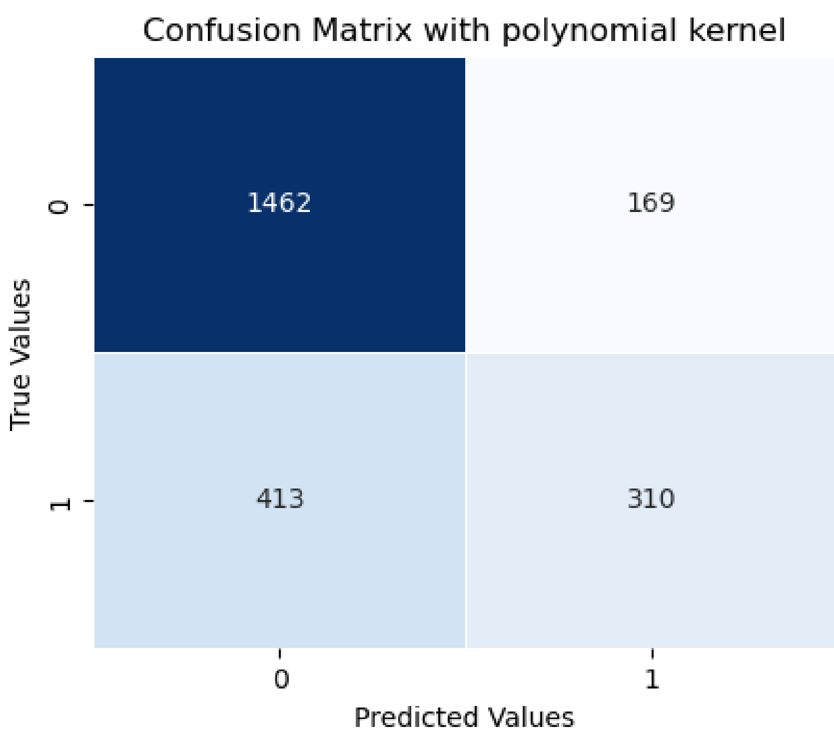
[31]:
```
# Predicting the ownership status on the test set
poly_model_predicts = svm_poly_model.predict(Housing_test_set[['AGE', 'MARST',␣
↪'HHINCOME']])

# Evaluating the model
print(classification_report(Housing_test_set['OWNERSHP'], poly_model_predicts))
print("Accuracy:", round(accuracy_score(Housing_test_set['OWNERSHP'],␣
↪poly_model_predicts), 4))
```

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

```
           1       0.78      0.90      0.83      1631
           2       0.65      0.43      0.52       723

    accuracy                           0.75      2354
   macro avg       0.71      0.66      0.67      2354
weighted avg       0.74      0.75      0.74      2354

Accuracy: 0.7528
```

[32]:

```python
# Lets construct a confusion matrix for our predictions
poly_matrix = confusion_matrix(Housing_test_set['OWNERSHP'],␣
 ↪poly_model_predicts)

# Plotting the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(poly_matrix, annot=True, fmt="d", linewidths=.5, cmap="Blues",␣
 ↪cbar=False)
plt.xlabel('Predicted Values')
plt.ylabel('True Values')
plt.title('Confusion Matrix with polynomial kernel')
plt.show()
```



[33]:
```python
# Defining the KFold cross-validation for 5 folds
kfold = skm.KFold(5, random_state = 1, shuffle=True)

# Let's set up a grid for our cost value and degree values
para_values = {'C':[0.01, 0.1, 1, 10, 100], 'degree':[2,3,4,5]}

# Lets apply 5 fold cross validation using GridSearchCV() to get the best␣
↪c-value for our model
# we will be using the above model for cross-validation
grid = skm.GridSearchCV(svm_poly_model, para_values, cv = kfold, scoring =␣
↪'accuracy');

# refitting the model after cross-validation
grid.fit(Housing_train_set[['AGE', 'MARST', 'HHINCOME']],␣
↪Housing_train_set['OWNERSHP'])
grid.best_params_
```

```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
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processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

[33]:
```
{'C': 0.1, 'degree': 5}
```

[34]:
```python
# Support Vector Machine model with polynomial kernel and using cost value = 0.
↪1 and degree = 5 after cross validation
svm_poly_modelCV = svm.SVC(kernel = 'poly', C = 0.1, degree = 5, max_iter =␣
↪10000)
svm_poly_modelCV.fit(Housing_train_set[['AGE', 'MARST','HHINCOME']],␣
↪Housing_train_set['OWNERSHP'])
```

```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

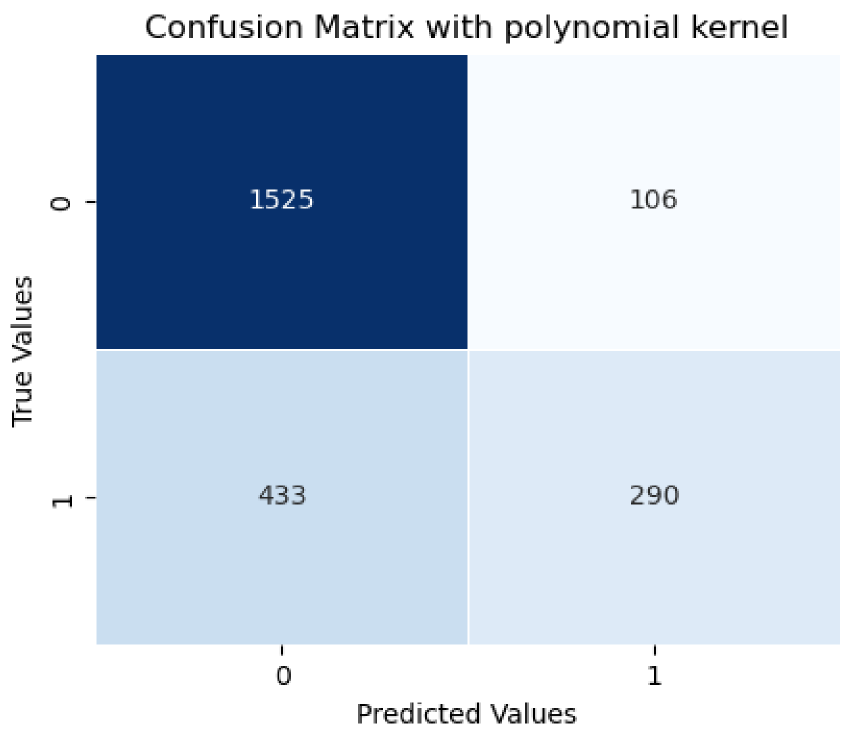
[34]:
```
SVC(C=0.1, degree=5, kernel='poly', max_iter=10000)
```

[35]:
```python
# Predicting the ownership status on the test set
poly_model_predictsCV = svm_poly_modelCV.predict(Housing_test_set[['AGE',␣
↪'MARST', 'HHINCOME']])

# Evaluating the model
print(classification_report(Housing_test_set['OWNERSHP'],␣
↪poly_model_predictsCV))
print("Accuracy:", round(accuracy_score(Housing_test_set['OWNERSHP'],␣
↪poly_model_predictsCV), 4))
```

```
              precision    recall  f1-score   support

           1       0.78      0.94      0.85      1631
           2       0.73      0.40      0.52       723

    accuracy                           0.77      2354
   macro avg       0.76      0.67      0.68      2354
weighted avg       0.76      0.77      0.75      2354

Accuracy: 0.771
```

[36]:
```python
# Lets construct a confusion matrix for our predictions
poly_matrixCV = confusion_matrix(Housing_test_set['OWNERSHP'],␣
↪poly_model_predictsCV)
```

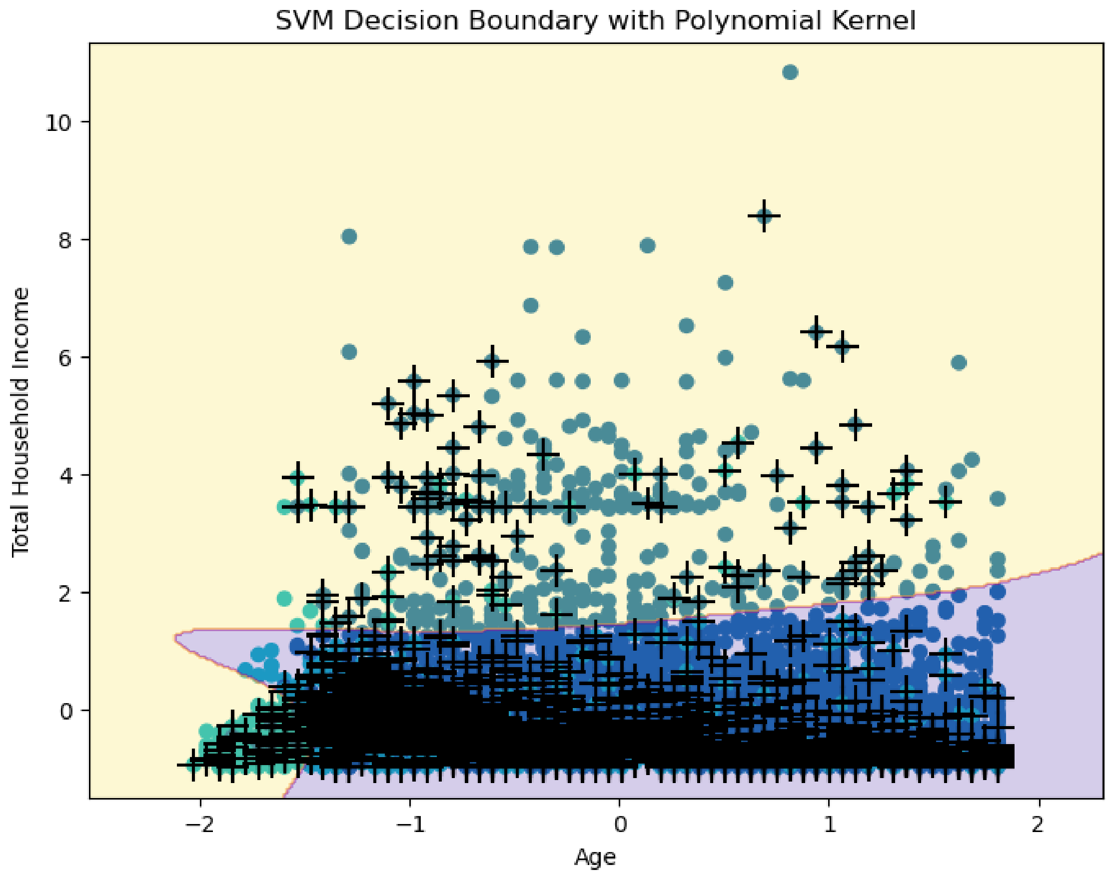
```
# Plotting the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(poly_matrixCV, annot=True, fmt="d", linewidths=.5, cmap="Blues",␣
 ↪cbar=False)
plt.xlabel('Predicted Values')
plt.ylabel('True Values')
plt.title('Confusion Matrix with polynomial kernel')
plt.show()
```



[37]:
```
# Decision Boundary Plot for polynomial kernel

# Assuming a mode value for the MARST (marital status)
mode_MARST = Housing_train_set['MARST'].mode()

# Creating a meshgrid for plotting based on the mode values from MARST variable
X = np.c_[X_train[:, :2], np.full(len(X_train), fill_value=mode_MARST)]

# Plotting the decision boundary graph
fig, ax = plt.subplots(figsize=(8, 6))
plot_svm(X, y_train, svm_poly_modelCV, ax=ax)
ax.set_xlabel('Age')
ax.set_ylabel('Total Household Income')
ax.set_title('SVM Decision Boundary with Polynomial Kernel')
```

```
plt.show()
```

```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\base.py:493:
UserWarning: X does not have valid feature names, but SVC was fitted with
feature names
  warnings.warn(
```



- SVM Model with radial basis function (rbf) kernel

[38]:
```
# Support Vector Machine model with rbf kernel and using cost value = 1 and␣
↪degree = 2 and gamma = 1
svm_rbf_model = svm.SVC(kernel = 'rbf', C = 1, degree = 2, gamma = 1, max_iter␣
↪= 10000)
svm_rbf_model.fit(Housing_train_set[['AGE','HHINCOME',␣
↪'COSTWATR','COSTELEC','EDUC']], Housing_train_set['OWNERSHP'])
```

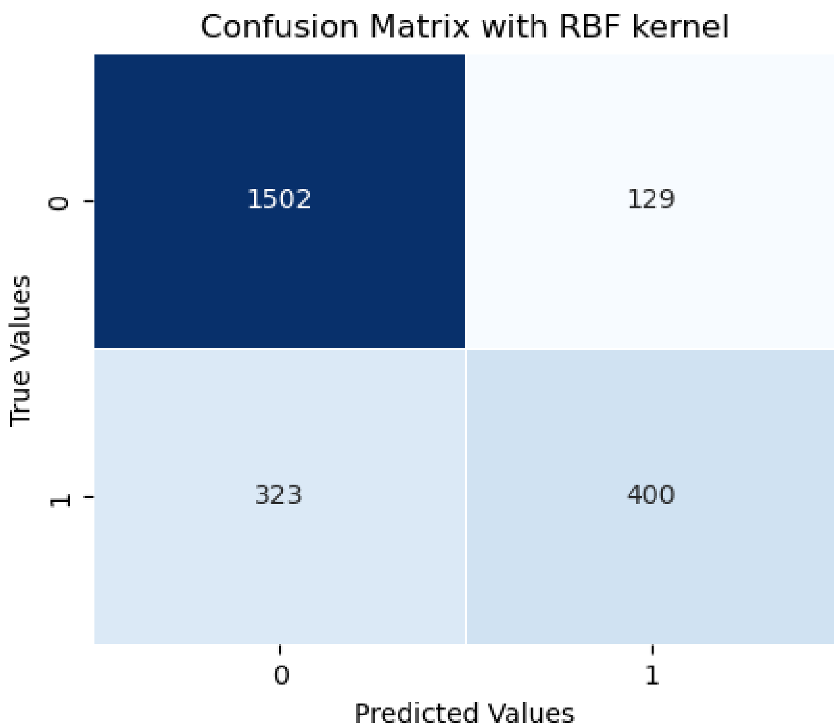
```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\svm\_base.py:297:
ConvergenceWarning: Solver terminated early (max_iter=10000).  Consider pre-
processing your data with StandardScaler or MinMaxScaler.
  warnings.warn(
```

[38]: SVC(C=1, degree=2, gamma=1, max_iter=10000)

[39]:
```
# Predicting the ownership status on the test set
rbf_model_predicts = svm_rbf_model.predict(Housing_test_set[['AGE', 'HHINCOME',␣
↪'COSTWATR','COSTELEC','EDUC']])

# Evaluating the model
print(classification_report(Housing_test_set['OWNERSHP'], rbf_model_predicts))
print("Accuracy:", round(accuracy_score(Housing_test_set['OWNERSHP'],␣
↪rbf_model_predicts), 4))
```

```
              precision    recall  f1-score   support

           1       0.82      0.92      0.87      1631
           2       0.76      0.55      0.64       723

    accuracy                           0.81      2354
   macro avg       0.79      0.74      0.75      2354
weighted avg       0.80      0.81      0.80      2354

Accuracy: 0.808
```

[40]:
```
# Lets construct a confusion matrix for our predictions
rbf_matrix = confusion_matrix(Housing_test_set['OWNERSHP'], rbf_model_predicts)

# Plotting the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(rbf_matrix, annot=True, fmt="d", linewidths=.5, cmap="Blues",␣
↪cbar=False)
plt.xlabel('Predicted Values')
plt.ylabel('True Values')
plt.title('Confusion Matrix with RBF kernel')
plt.show()
```



[41]:
```
# Defining the KFold cross-validation for 5 folds
kfold = skm.KFold(5, random_state = 1, shuffle=True)

# Let's set up a grid for our cost value and degree values
para_values = {'C':[0.01, 0.1, 1, 10, 100], 'degree':[3,4,5], 'gamma':[3,4]}

# Lets apply 5 fold cross validation using GridSearchCV() to get the best␣
↪c-value for our model
# we will be using the above model for cross-validation
grid = skm.GridSearchCV(svm_rbf_model, para_values, cv = kfold, scoring =␣
↪'accuracy');

# refitting the model after cross-validation
grid.fit(Housing_train_set[['AGE', 'HHINCOME', 'COSTELEC', 'COSTWATR',␣
↪'EDUC']], Housing_train_set['OWNERSHP'])
grid.best_params_
```

```
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  warnings.warn(
```

[41]:
```
{'C': 1, 'degree': 3, 'gamma': 3}
```

[42]:
```
# Support Vector Machine model with rbf kernel and using cost value = 1 and
↪degree = 3 and gamma = 3 after cross validation
```

```
svm_rbf_modelCV = svm.SVC(kernel = 'rbf', C = 1, degree = 3, gamma = 3,␣
↪max_iter = 10000)
svm_rbf_modelCV.fit(Housing_train_set[['AGE','HHINCOME', 'COSTELEC',␣
↪'COSTWATR', 'EDUC']], Housing_train_set['OWNERSHP'])
```

[42]:

```
SVC(C=1, gamma=3, max_iter=10000)
```

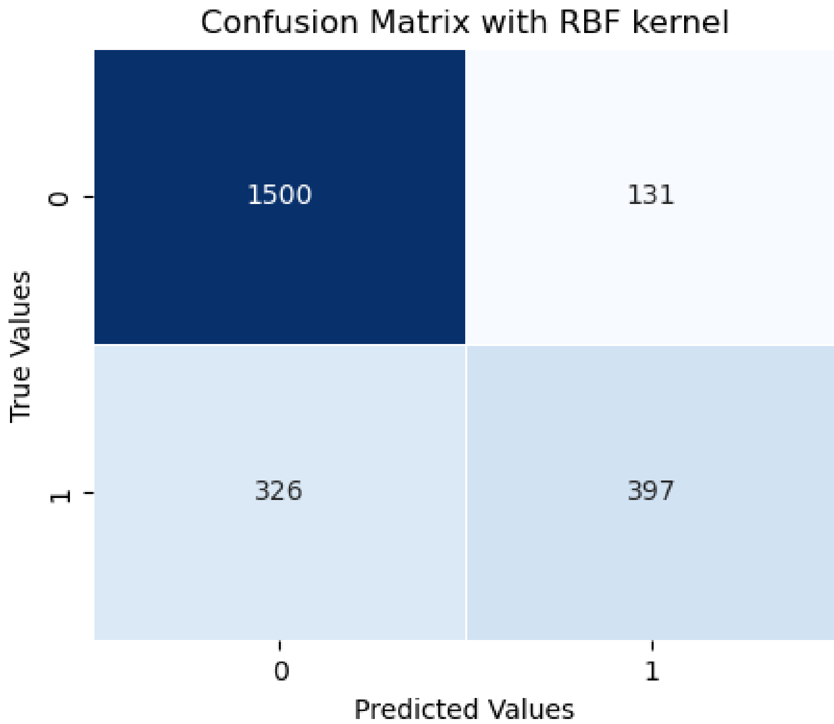
[43]:

```
# Predicting the ownership status on the test set
rbf_model_predictsCV = svm_rbf_modelCV.predict(Housing_test_set[['AGE',␣
↪'HHINCOME', 'COSTELEC', 'COSTWATR','EDUC']])

# Evaluating the model
print(classification_report(Housing_test_set['OWNERSHP'], rbf_model_predictsCV))
print("Accuracy:", round(accuracy_score(Housing_test_set['OWNERSHP'],␣
↪rbf_model_predictsCV), 4))
```

```
              precision    recall  f1-score   support

           1       0.82      0.92      0.87      1631
           2       0.75      0.55      0.63       723

    accuracy                           0.81      2354
   macro avg       0.79      0.73      0.75      2354
weighted avg       0.80      0.81      0.80      2354

Accuracy: 0.8059
```

[44]:

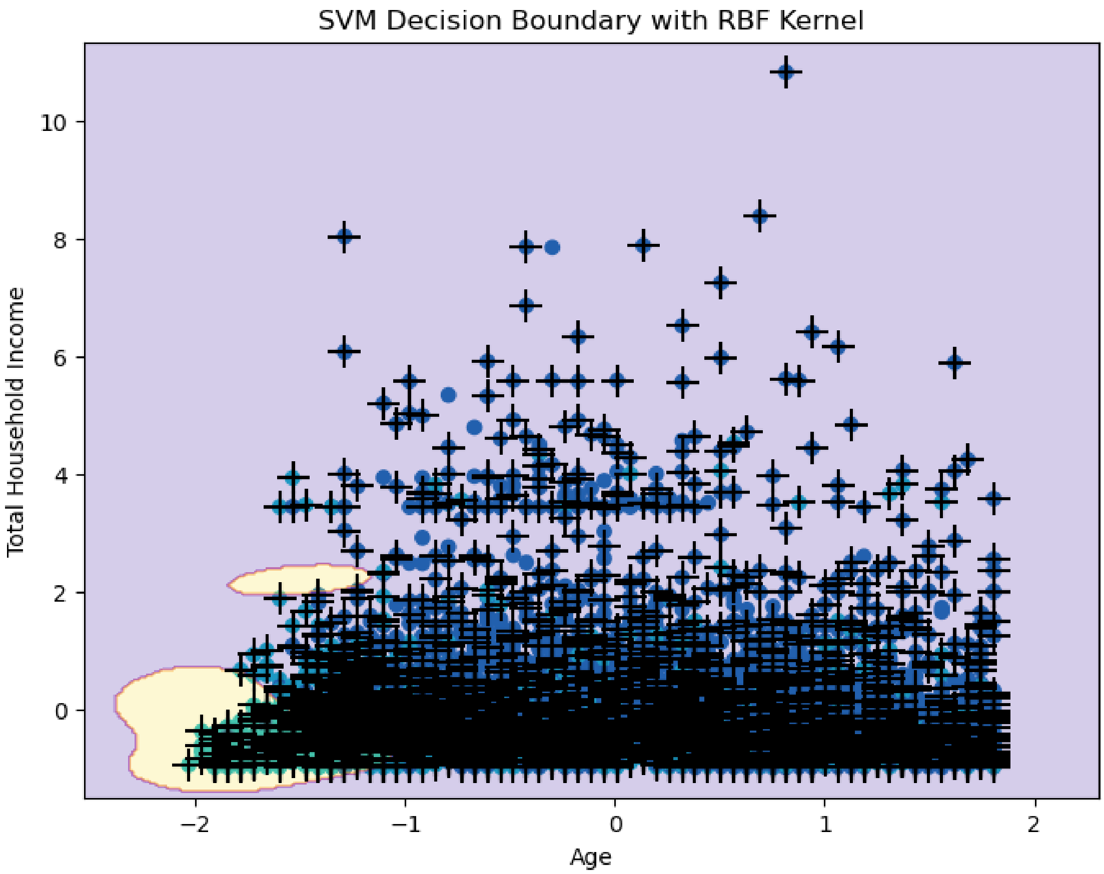
```
# Lets construct a confusion matrix for our predictions
rbf_matrixCV = confusion_matrix(Housing_test_set['OWNERSHP'],␣
↪rbf_model_predictsCV)

# Plotting the confusion matrix
plt.figure(figsize=(5, 4))
sns.heatmap(rbf_matrixCV, annot=True, fmt="d", linewidths=.5, cmap="Blues",␣
↪cbar=False)
plt.xlabel('Predicted Values')
plt.ylabel('True Values')
plt.title('Confusion Matrix with RBF kernel')
plt.show()
```




```
[45]: # Decision Boundary Plot for rbf kernel

# Selecting median values for COSTWATR and COSTELEC to make them constant␣
↪values for the sake of the graph
median_COSTELEC = Housing_train_set['COSTELEC'].median()
median_COSTWATR = Housing_train_set['COSTWATR'].median()

# gettting the mode for EDUC as it is a categorical variable to make it␣
↪constant as well
mode_EDUC = Housing_train_set['EDUC'].mode()[0]

# Creating the feature grid for the fixed values
X = np.c_[X_train[:, 0:2],
          np.full(len(X_train), fill_value = median_COSTELEC),
          np.full(len(X_train), fill_value = median_COSTWATR),
          np.full(len(X_train), fill_value = mode_EDUC)]

# plotting the decision boundary graph for rbf kernel
fig, ax = plt.subplots(figsize=(8, 6))
plot_svm(X, y_train, svm_rbf_modelCV, ax=ax)
ax.set_xlabel('Age')
ax.set_ylabel('Total Household Income')
ax.set_title('SVM Decision Boundary with RBF Kernel')
```

```
plt.show()
```

```
C:\Users\hirshikesh\anaconda3\lib\site-packages\sklearn\base.py:493:
UserWarning: X does not have valid feature names, but SVC was fitted with
feature names
  warnings.warn(
```

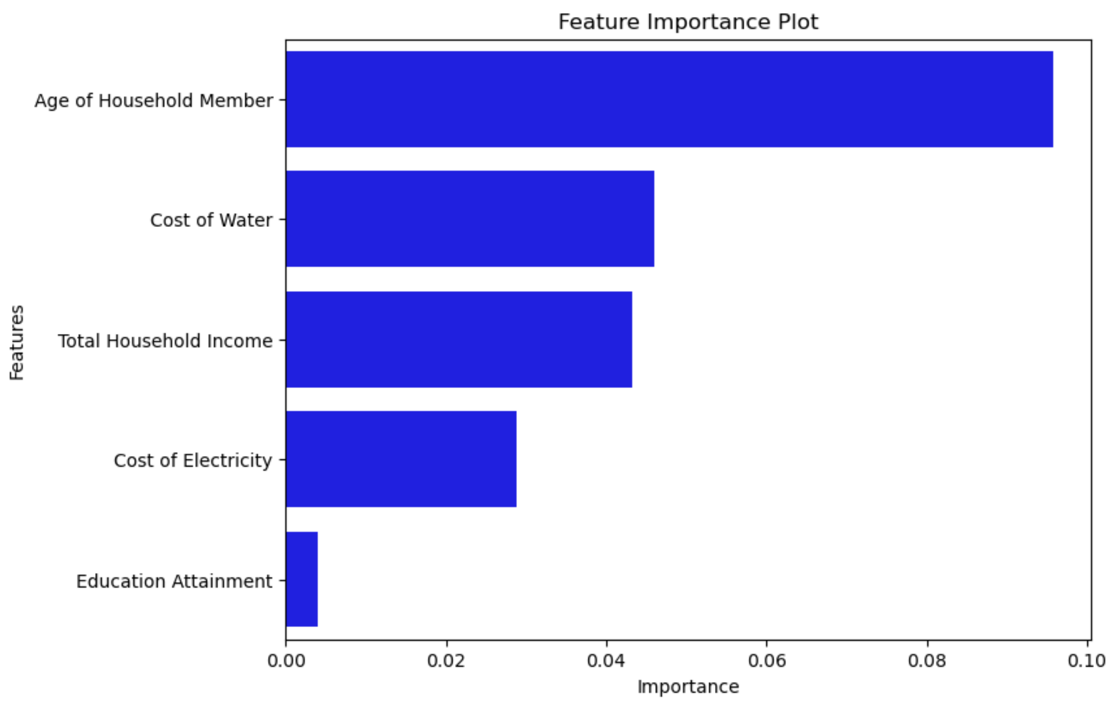


0.2 Getting the Strong Predictors

[46]:
```
# Computing the permutation importance for SVM models on the selected features
# permutation importance is used in observing the impact on model performance␣
↪for any SVM models with different kernels
# As our rbf model got the best accuracy, we will get the importance on this␣
↪model
# We will be using permutation_importance() function from the sklearn␣
↪inspections library
results = permutation_importance(svm_rbf_modelCV, Housing_test_set[['AGE',␣
↪'HHINCOME', 'COSTELEC', 'COSTWATR', 'EDUC']], Housing_test_set['OWNERSHP'],␣
↪n_repeats=10)
```

```
# Getting the feature names
names = ['Age of Household Member', 'Total Household Income', 'Cost of␣
↪Electricity', 'Cost of Water', 'Education Attainment']

# Now putting the results into a DataFrame and sorting them in descending order
imp_df = pd.DataFrame({'Feature': names, 'Importance': results.
↪importances_mean})
imp_df = imp_df.sort_values(by='Importance', ascending=False)
```

[47]:
```
# Feature Importance Plot
plt.figure(figsize=(8, 6))
sns.barplot(x='Importance', y='Feature', data=imp_df, color='blue')
plt.title('Feature Importance Plot')
plt.xlabel('Importance')
plt.ylabel('Features')
plt.show()
```



0.3 References

1) Ch9-1 and Ch9-2 python files
2) lecture notes
3) Python Documentation on scikit learn and other functions
    - https://scikit-learn.org/stable/modules/svm.html

- https://scikit-learn.org/stable/user_guide.html