Prediction of Online Shoppers' Purchasing Intention Using Ensemble (Bagging, Boosting, Stacking) Learning Methods

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I. INTRODUCTION

In most cases, the fate of an online business boils down to it's ability to improve the turnover rates of the shoppers that browse through their website into shoppers that end up making an eventual purchase. Key to improving this metric is the ability to predict which sessions are more likely to end up in a purchase and that is what this project aims to achieve. A couple of other techniques including traditional machine learning algorithms and neural networks (Sakar et al)[1] have been applied to predict shoppers' intention. This project however explores solving this binary classification problem using the three prevalent Ensemble learning methods namely: model bagging, model boosting and model stacking.

Ensemble Learning also known as Multiple Classifier Systems have been used extensively in the world of data science ever since Professor Leo Breiman of Berkeley popularized the term 'Bagging' in his 1994 paper[2]. The core idea of Ensemble Learning is to aggregate the results of several classifier models into a single model that performs better than any of the individual models that constitute it. Model Bagging achieves this by training several homogeneous weak learners in parallel and then averaging their results, Model Boosting trains several homogeneous weak learners sequentially before combining their results and Model Stacking combines together several heterogeneous models and makes use of of a meta-model to select the best predictions of each base model for each instance.

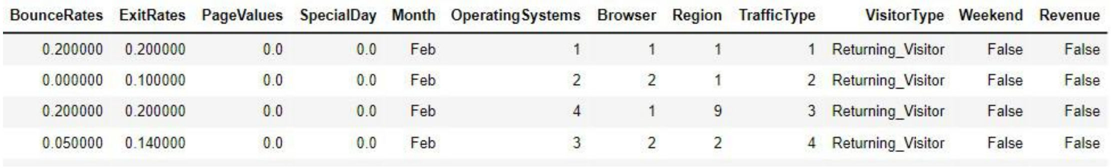
This report details the individual steps carried out in this project which was carried out entirely in Python 3 (using Jupyter Notebook) from the Objectives to the Methodology where the data pre-processing and transformation is discussed. After that, how each modelling method and algorithm implemented used is also shown and finally, a comparative analysis is conducted on the results of each of the three Ensemble methods used in order to demonstrate the limits of each approach. In its conclusion, other related work and possible areas of model accuracy improvement are discussed.

II. PROJECT OBJECTIVES

The goal of this project is two fold. First is to conduct binary classification of online shoppers sessions, using the three main Ensemble Learning methods (of bagging, boosting and stacking) into 2 categories. Secondly, is to carry out a comparative analysis of which Ensemble method performs better by producing the best level of Accuracy, F1 score , Precision and Recall on the Online shoppers' dataset.

Expected outcome example:

Input:



BounceRates	ExitRates	PageValues	SpecialDay	Month	OperatingSystems	Browser	Region	TrafficType	VisitorType	Weekend	Revenue
0.200000	0.200000	0.0	0.0	Feb	1	1	1	1	Returning_Visitor	False	False
0.000000	0.100000	0.0	0.0	Feb	2	2	1	2	Returning_Visitor	False	False
0.200000	0.200000	0.0	0.0	Feb	4	1	9	3	Returning_Visitor	False	False
0.050000	0.140000	0.0	0.0	Feb	3	2	2	4	Returning_Visitor	False	False

Output:

ID	Revenue
0	0
1	0
2	1
3	0

III. METHODOLOGY

The data used in this project was the Online shoppers' intention data by UCI's Machine Learning Library obtained on Kaggle[3]. The dataset is comprised of feature vectors that was obtained over the course of 12,330 sessions, where each session belongs to a different shopper in a 1 year period. Of the 12,330 sessions, 10,422 (84.5%) resulted in no purchase while 1,908 (15.5%) resulted in a purchase.

A. Exploratory Data Analysis

TABLE 1: Numerical features used in the Online Shoppers' Intention analysis model[4]

Feature name	Feature description	Min. value	Max. value	SD
Administrative	Number of pages visited by the visitor about account management	0	27	3.32
Administrative duration	Total amount of time (in seconds) spent by the visitor on account management related pages	0	3398	176.70
Informational	Number of pages visited by the visitor about Web site, communication and address information of the shopping site	0	24	1.26
Informational duration	Total amount of time (in seconds) spent by the visitor on informational pages	0	2549	140.64
Product related	Number of pages visited by visitor about product related pages	0	705	44.45
Product related duration	Total amount of time (in seconds) spent by the visitor on product related pages	0	63973	1912.25
Bounce rate	Average bounce rate value of the pages visited by the visitor	0	0.2	0.04
Exit rate	Average exit rate value of the pages visited by the visitor	0	0.2	0.05
Page value	Average page value of the pages visited by the visitor	0	361	18.55
Special day	Closeness of the site visiting time to a special day	0	1.0	0.19

The Table 1 above gives the statistical overview of all the numerical features present in the dataset, while Table 2 below gives the statistical overview of all the categorical features present in the dataset. Since the dataset was gathered by the Machine Learning Library of UCI, some preliminary data cleaning had already been carried out on it such that there were no missing or null values in the data points or columns.

The tables also give a brief explanation as to what summary of what each column feature means with respect to the online shopping sessions.

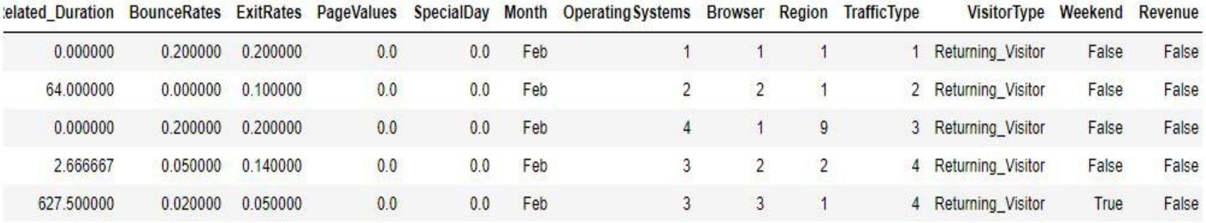
TABLE 2: Categorical features used in the Online Shoppers' Intention analysis model[4]

Feature name	Feature description	Number of categorical values
OperatingSystems	Operating system of the visitor	8
Browser	Browser of the visitor	13
Region	Geographic region from which the session has been started by the visitor	9
TrafficType	Traffic source by which the visitor has arrived at the Web site (e.g., banner, SMS, direct)	20
VisitorType	Visitor type as ''New Visitor,'' ''Returning Visitor,'' and ''Other'	3
Weekend	Boolean value indicating whether the date of the visit is weekend	2
Month	Month value of the visit date	12
Revenue	Class label indicating whether the visit has been finalized with a transaction	2

B. Data Transformation and Standardization

The next step in the data processing is the encoding of all the categorical features listed in Table 2 into numerical features. This is because none of the models we are going to be working with would be able to process data that is not entirely in numerical form. To achieve this, LabelEncoder was imported from Scikit-learn and used to one-hot encode each categorical variable.

TABLE 3: Raw features before label encoding



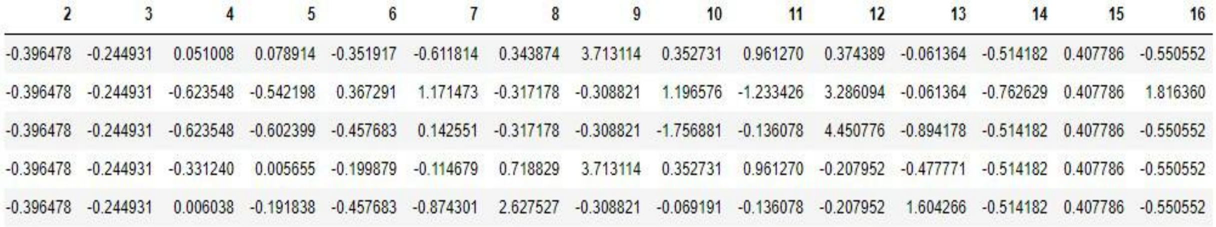
elated_Duration	BounceRates	ExitRates	PageValues	SpecialDay	Month	OperatingSystems	Browser	Region	TrafficType	VisitorType	Weekend	Revenue
0.000000	0.200000	0.200000	0.0	0.0	Feb	1	1	1	1	Returning_Visitor	False	False
64.000000	0.000000	0.100000	0.0	0.0	Feb	2	2	1	2	Returning_Visitor	False	False
0.000000	0.200000	0.200000	0.0	0.0	Feb	4	1	9	3	Returning_Visitor	False	False
2.666667	0.050000	0.140000	0.0	0.0	Feb	3	2	2	4	Returning_Visitor	False	False
627.500000	0.020000	0.050000	0.0	0.0	Feb	3	3	1	4	Returning_Visitor	True	False

TABLE 4: Features after label encoding

luctRelated_Duration	BounceRates	ExitRates	PageValues	SpecialDay	Month	OperatingSystems	Browser	Region	TrafficType	VisitorType	Weekend	Revenue
0.000000	0.20	0.20	0.0	0	2	0	0	0	0	2	0	0
64.000000	0.00	0.10	0.0	0	2	1	1	0	1	2	0	0
0.000000	0.20	0.20	0.0	0	2	3	0	8	2	2	0	0
2.666667	0.05	0.14	0.0	0	2	2	1	1	3	2	0	0
627.500000	0.02	0.05	0.0	0	2	2	2	0	3	2	1	0

After the encoding, the target feature 'Revenue' was then removed from the dataset and the remaining features were transformed by using StandardScaler from Scikit-learn to scale them such that their mean becomes zero and the standard deviation 1. This is necessary so as to prevent data points from features with high numerical values from unfairly skewing the predictions in any particular way, therefore leading to more accurate predictions by the Ensemble models.

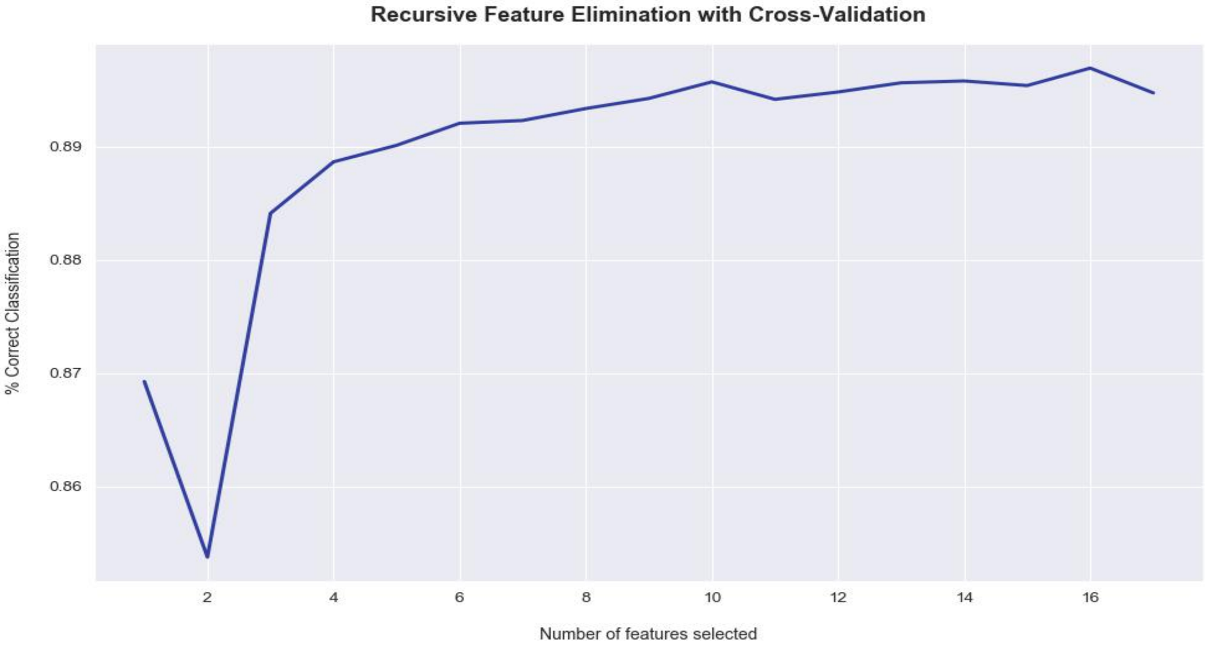
TABLE 5: Features after standardization (excluding Revenue feature)



2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
-0.396478	-0.244931	0.051008	0.078914	-0.351917	-0.611814	0.343874	3.713114	0.352731	0.961270	0.374389	-0.061364	-0.514182	0.407786	-0.550552
-0.396478	-0.244931	-0.623548	-0.542198	0.367291	1.171473	-0.317178	-0.308821	1.196576	-1.233426	3.286094	-0.061364	-0.762629	0.407786	1.816360
-0.396478	-0.244931	-0.623548	-0.602399	-0.457683	0.142551	-0.317178	-0.308821	-1.756881	-0.136078	4.450776	-0.894178	-0.514182	0.407786	-0.550552
-0.396478	-0.244931	-0.331240	0.005655	-0.199879	-0.114679	0.718829	3.713114	0.352731	0.961270	-0.207952	-0.477771	-0.514182	0.407786	-0.550552
-0.396478	-0.244931	0.006038	-0.191838	-0.457683	-0.874301	2.627527	-0.308821	-0.069191	-0.136078	-0.207952	1.604266	-0.514182	0.407786	-0.550552

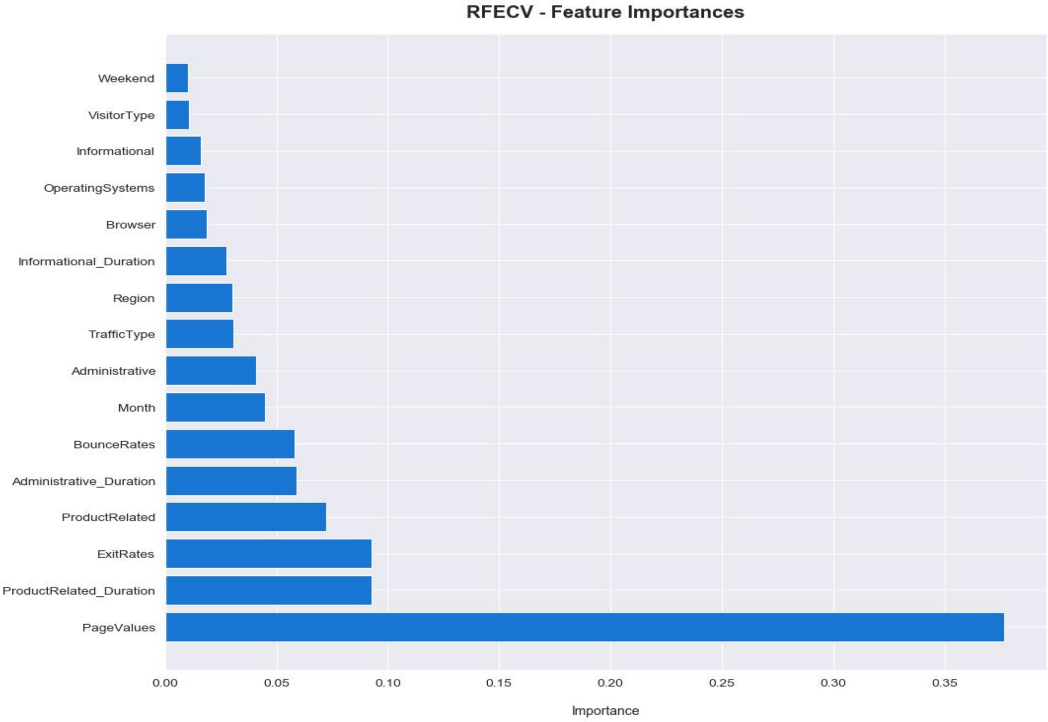
C. Feature Importance and Selection

In order to obtain a clearer view of the contribution of each feature to the overall prediction and in determining which features should be dropped, a Cross Validated Recursive Feature Elimination model (RFECV) from python feature_selection module is fitted to the entire dataset (excluding the target feature 'Revenue') using a Stratified K-fold in order to check which number of features produce the best level of accuracy for modelling.



Graph 1: Potential model performance for each number of features using RFECV

The results showed that 16 features would give the higher number of model prediction accuracy. Below is chart showing the percentage of importance of each of the selected 16 features contributes to overall model prediction accuracy.



Graph 2: Feature Importance in ascending order

IV. MODELLING

A. Data Splitting and Balancing

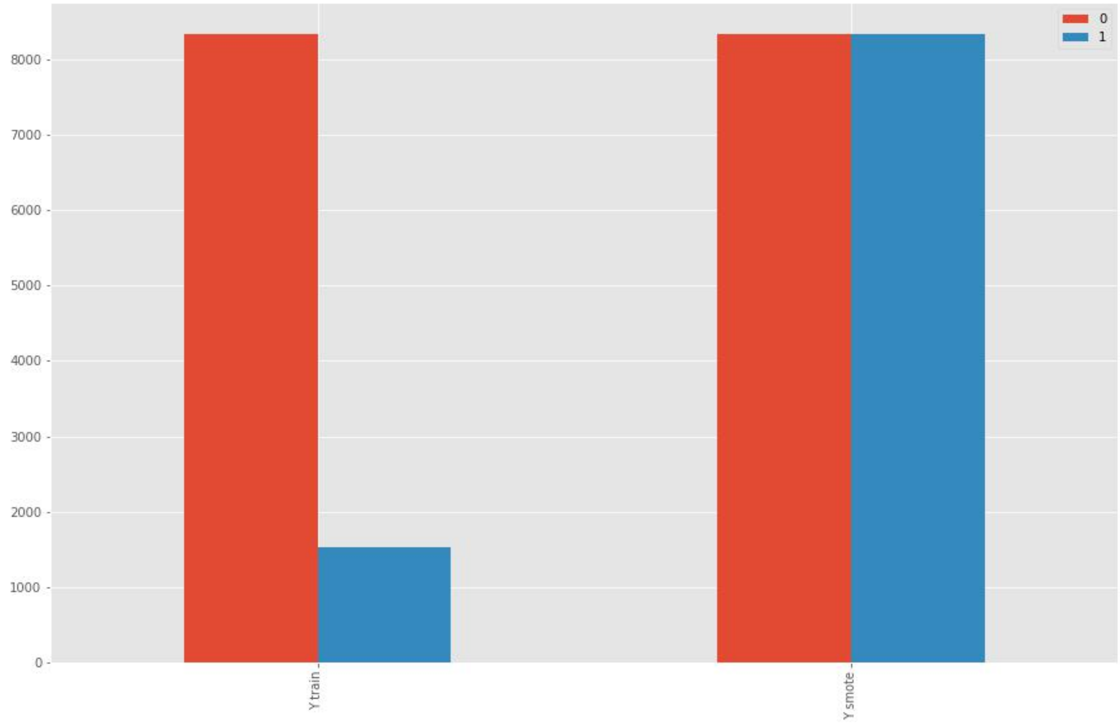
After the data was successfully pre-processed and transformed, we feed it into our models. But before doing that two key steps were carried out:

1. Data splitting

The data is split 80% train data and 20% using the Train-Test-Split function. The stratify parameter is also set on the target feature to ensure that the number of number of data points from each class in the target feature is proportionally split into the train and test sets. 80% of the data was for training used so as to maximize the prediction accuracy of the models especially on the data points that end in a purchase (i.e where Revenue = 1) as the data is imbalanced having more 70% more data points that do not end in a purchase (I.e where Revenue = 0)

2. Data balancing

To finally address the issue of data imbalance, the data points in the training set where Revenue = 1 are over-sampled using the SMOTE function from the Imbalanced-Learn python library to match the number of data points where Revenue = 0. This raises the total number of data points from 9864 to 16676, where the new dataset has 8338 data samples with Revenue class of 1 and also 8338 data samples with Revenue class of 0, therefore balancing the total number of positive and negative target class labels.



Graph 3: Data samples of the Target variable before and after SMOTE balancing

B. Base Model

To set the tone for the entire modelling exercise, a base level of performance has to be set in order to judge if there is a progression in the prediction capability of each successive model. For this project, the base model that was used was a K Nearest Neighbors (KNN) Classifier[5]. This was chosen due to its simplicity as KNN models work by aggregating the predictions of the data points nearest to the query data point. K was set to 8 and fit to the training data. A lot of emphasis would be placed on F1-scores because F1-score is the parameter that shows how well our precision and recall scores balance each other. Below is the performance of the base model on the test data

TABLE 6: Base Model Performance

Target Class Value	Precision	Recall	F1-score	Support
0	0.93	0.80	0.87	2084
1	0.40	0.66	0.50	382
Macro Avg	0.66	0.74	0.68	2466
Accuracy				0.79

From the performance of KNN, we obtained an average F1- score of 0.68 and an overall model accuracy of 0.79 which is okay for a benchmark performance. However, the F1-score for positive data points in the target class is low at 0.50 (which is no better than a random coin toss). therefore we expect future models to perform better at predicting the positive target class by having a much better F1-score.

C. Ensemble Method Models

1. Model Bagging

The first Ensemble method that was applied is Bagging. The core idea of Bagging (Breiman, 1996c) is to combine several homogeneous weak learner models, in this case several decision trees, which are learned independently of each other and averaged together into a single prediction. The specific type of Bagging model used in this project is the Random Forests model which is the most efficient as far as Bagging models go. The model is imported from Scikit-Learn and its parameters are tuned using a cross validation process. GridSearchCV function is used for this tuning, and after the tuning is completed the model is then fit on the training data.

2. Model Boosting

The second Ensemble model tested on the training data was the Boosting Ensemble. But here instead of using the regular adaptive boosting model or any of its variants, the Extreme Gradient Boosting (XGB) algorithm was used. Extreme Gradient Boosting like other Boosting[6] models (Freund & Schapire, 1996; Schapire, 1990) similarly uses a combination of several weak learners (decision trees), which are learned sequentially such that each tree builds upon the results of the previous one, and then it combines the prediction of each tree by using a number of hyper-parameters to ensure that no individual tree has an inordinate amount of influence on the final prediction. Here also, GridSearchCV is used to tune all the hyper-parameters to find the best combination for our provided dataset. Also very important to note here is that the parameters for maximum tree depth and number of estimators for the XGB model were set to 14 and 600 respectively to further strengthen it's performance.

3. Model Stacking

The third and final Ensemble model that was used to make predictions on the data was a stacked generalization. Unlike Bagging and Boosting, Stacking[7] (Wolpert, 1992) can combine several heterogeneous or dissimilar weak learner models together in order to make a prediction. It also differs from them such that it does not simply average the predictions of the weak models in order to make a final prediction, rather it fits a 'meta-model' on top of them, and the job of this meta-model is to learn when it is appropriate to use each of the meta-models to make predictions on the test data. This thereby results in a combination that uses the strengths of each model and an overall model that is better than any of its individual weak models.

For this project, the stacking model was kept simple by using only two models: The cross validated XGB model from the Bagging test, and a Logistic Regression model that has been tuned using GridSearchCV. Then a simple un-tuned Logistic Regression model was fitted as the meta-model to make the final predictions. The simple Logistic Regression was chosen as a meta-model because it is usually better to have a simpler model rather than a complex one to reduce the complications of choosing a final prediction.

V. RESULTS

A. Performance Metrics

The following are the performance metrics used in evaluating and comparing the performances of each model:

1. Accuracy: total number of correct predictions / total number of predictions
2. Precision: true positive/ (true positive + false positive)
3. Recall: true positive/ (true positive + false negative)
4. Support: This refers to the number of data samples used from each class
5. F1-score: This refers to the ratio of the product of Precision and Recall to their sum multiplied by two. This can be expressed mathematically as:

$$F_1 = \frac{2(\mathrm{Precision\ x\ Recall})}{(\mathrm{Precision} + \mathrm{Recall})}$$

The F1-score is very important in this project, especially the F1-score on positive class data samples since it is very important for online companies to know how to predict sessions that end up in Revenue more than they need to predict sessions that don't.

5.2 Results

TABLE 7: Bagging (Random Forest) Model Performance on Test Data

Target Class Value	Precision	Recall	F1-score	Support
0	0.94	0.92	0.93	2084
1	0.62	0.69	**0.65**	382
Macro Avg	0.78	0.81	**0.79**	2466
Accuracy				**0.89**

TABLE 8: Boosting (Extreme Gradient Boosting) Model Performance on Test Data

Target Class Value	Precision	Recall	F1-score	Support
0	0.94	0.94	0.94	2084
1	0.68	0.67	**0.67**	382
Macro Avg	0.81	0.81	**0.81**	2466
Accuracy				**0.90**

TABLE 9: Stacking (XGB + Logistic Regression) Model Performance on Test Data

Target Class Value	Precision	Recall	F1-score	Support
0	0.95	0.92	0.93	2084
1	0.61	0.73	**0.67**	382
Macro Avg	0.78	0.82	**0.80**	2466
Accuracy				**0.89**

TABLE 10: Stacking (XGB + Random Forest) Model Performance on Test Data

Target Class Value	Precision	Recall	F1-score	Support
0	0.94	0.93	0.93	2084
1	0.63	0.68	**0.65**	382
Macro Avg	0.78	0.80	**0.79**	2466
Accuracy				**0.89**

TABLE 11: Overall Model Performance Comparison on Test Data

Model	Avg Precision	Avg Recall	Avg F1-score	Accuracy	Rank
KNN	0.66	0.74	0.68	0.79	Base
Random Forest	0.78	0.81	0.79	0.89	3rd
XGB	**0.81**	0.81	**0.81**	**0.90**	1st
XGB + Logistic Regression stack	0.78	**0.82**	0.80	0.89	2nd
XGB + Random Forest stack	0.78	0.80	0.79	0.89	4th

The results at the end of modelling show the following:

1. All ensemble models used generally performed much better than the KNN model (which was used as the benchmark for performance) on all performance metrics.
2. The stacking ensemble of XGB and Random Forest comes in at fourth place, performing worse as an ensemble than either of its individual base models when used alone. It had an average precision of 0.78, an average Recall of 0.80 and an overall accuracy of 0.89
3. In third place was the bagging ensemble method, Random Forest. It had a decent level of overall accuracy at 0.89, but ranked lowest of the three ensemble models because it had the lowest F1-score in predicting the positive Revenue label (at 0.65) and also the lowest average F1-score of the three at 0.79
4. In terms of accuracy and F1-score (on positive class where Revenue = 1), the stacking ensemble of XGB and Logistic Regression performed better than Random Forest but less than the boosting ensemble model, putting it comfortably in second place. It had an overall accuracy score of 0.89 and an average F1-score of 0.80, but performed better at predicting positive Revenue classes with an F1-score of 0.67.

5. Finally the Boosting model emerged as the champion, but by a slight margin as it ties with the Stacked model with an F1-score of 0.67 in predicting positive Revenue classes. Where it does shine better than the other models is on its overall accuracy which is 0.90 and its average F1 score which is 0.81.

VI. RELATED WORK

In a study by Suchacka and Chodak[8], they categorized shoppers online behaviour using web server log data and then used association rule mining on the resulting log data to obtain potential knowledge about different customer profiles. Another study used Support Vector Machines (SVM) to classify online bookstore user data into browser and buyer sessions[9]. K-nearest neighbors classifier, which is one of the models that was used in this project, has also been used on the Online shoppers' dataset to classify the user sessions into those that generate Revenue and those that do not[10]. Finally, Sakar et al also work on this same online shoppers' dataset but instead classify each user session by implementing multi-layer and Long Short Term Memory (LSTM) recurrent neural networks

VII. LIMITS and EXTENSIONS

The scope of this work covers only the application of Ensemble learning methods to this binary classification problem of shopping data. As was shown, this method is limited first by the fact that not enough positive data samples for Revenue were available. Also is the fact that even though GridSearchCV was used to tune each model, a lot more time to could be dedicated to tuning the hyper-parameters using dedicated python libraries like: Ray-Tune, Optuna, Hyperopt, Mlmachine, Polyaxon, BayesianOptimization ,Talos, SHERPA.

Furthermore, more improvements in accuracy could be obtained by applying Neural networks and Multi-layer Perceptrons to model the data like Sakar et al[11] did in their paper

VIII. CONCLUSION

In conclusion, we have been able to successfully classify the test data of online shoppers' user intention into the sessions that generate revenue and the ones that do not, with an overall accuracy of 0.90. This was achieved using the ensemble boosting model called Extreme Gradient Boosting (XGB), which emerged the winner out of a collection of four different ensemble learning models. In second place was the stacking ensemble of XGB and Logistic regression which produced an overall accuracy of 0.89 and coming in close at third place was the bagging ensemble model of Random forests which also had an overall accuracy of 0.89, but lower average precision, recall and F1-score values.

Although this makes it to appear as that model boosting was the best ensemble learning method of them all, it is very important to note that an ensemble learning method's performance is highly dependent on the type of data being used. On a different data type like text data or image data, it might get outperformed by other types of ensemble models. Also, model accuracy can be improved if more positive Revenue class data samples can be obtained to balance the data instead of having to create artificial data samples using SMOTE or other oversampling techniques. Additionally, other modelling approaches like Neural networks and Deep learning have generally shown themselves to be superior to ensemble learning methods and might be a better option for real-world use case scenarios.

IX. REFERENCES

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APPENDIX
Code and Experimental Results

```
In [2]: import numpy as np
        import pandas as pd
        import seaborn as sns
        import matplotlib.pyplot as plt
        import sklearn.metrics as metrics
        from numpy import mean
        from numpy import std
        from pandas import read_csv
        from sklearn.model_selection import cross_val_score
        from sklearn.metrics import accuracy_score
        from sklearn.model_selection import RepeatedStratifiedKFold
        from sklearn.neighbors import KNeighborsClassifier
        from sklearn.linear_model import LogisticRegression
        from xgboost import XGBClassifier
        from sklearn.ensemble import StackingClassifier
        from sklearn.svm import SVC
        from sklearn.model_selection import RandomizedSearchCV
        from sklearn.preprocessing import StandardScaler
        from sklearn.pipeline import Pipeline
        from sklearn.model_selection import train_test_split, GridSearchCV, StratifiedKFold
        from imblearn.over_sampling import RandomOverSampler, SMOTE
        from sklearn.model_selection import GridSearchCV
        from sklearn.datasets import make_classification
        from sklearn.ensemble import RandomForestClassifier
        from sklearn.preprocessing import StandardScaler
        from sklearn.decomposition import PCA
```

Data Pre-processing, EDA and Cleaning

```
In [3]: # importing the online shopping data file
        df = pd.read_csv('online_shoppers_intention.csv')
        df.head(20)
```

Out[3]:

	Administrative	Administrative_Duration	Informational	Informational_Duration	ProductRelated	ProductRelated_Duration	BounceRates
0	0	0.0	0	0.0	1	0.000000	0.200000
1	0	0.0	0	0.0	2	64.000000	0.000000
2	0	0.0	0	0.0	1	0.000000	0.200000
3	0	0.0	0	0.0	2	2.666667	0.050000
4	0	0.0	0	0.0	10	627.500000	0.020000
5	0	0.0	0	0.0	19	154.216667	0.015789
6	0	0.0	0	0.0	1	0.000000	0.200000
7	1	0.0	0	0.0	0	0.000000	0.200000
8	0	0.0	0	0.0	2	37.000000	0.000000
9	0	0.0	0	0.0	3	738.000000	0.000000
10	0	0.0	0	0.0	3	395.000000	0.000000
11	0	0.0	0	0.0	16	407.750000	0.018750
12	0	0.0	0	0.0	7	280.500000	0.000000
13	0	0.0	0	0.0	6	98.000000	0.000000
14	0	0.0	0	0.0	2	68.000000	0.000000
15	2	53.0	0	0.0	23	1668.285119	0.008333
16	0	0.0	0	0.0	1	0.000000	0.200000
17	0	0.0	0	0.0	13	334.966667	0.000000
18	0	0.0	0	0.0	2	32.000000	0.000000
19	0	0.0	0	0.0	20	2981.166667	0.000000

```
In [4]: df.shape

Out[4]: (12330, 18)
```

```
In [5]: # defining a function to carry out exploratory data analysis on the null, unique, duplicate and missing
         values in the data
        def info(data_fr):
            for col in data_fr.columns:
                print(col ,'value_counts: ',data_fr[col].value_counts())
                print(col ,'total values: ',len(data_fr[col]))
                print(col ,'null values: ',data_fr[col].isna().sum())
                print(col ,'non-null values: ',data_fr[col].notnull().sum())
                print('is unique: ', data_fr[col].nunique()/len(data_fr[col]))
                print(col ,'duplicate values: ', (len(data_fr[col]) - data_fr[col].nunique()))
                print('\n')
```

```
In [7]: info(df)

        Administrative value_counts:  0     5768
        1     1354
        2     1114
        3      915
        4      765
        5      575
        6      432
        7      338
        8      287
        9      225
        10     153
        11     105
        12      86
        13      56
        14      44
        15      38
        16      24
        17      16
        18      12
        19       6
        24       4
        22       4
        23       3
        20       2
        21       2
        26       1
        27       1
        Name: Administrative, dtype: int64
        Administrative total values:  12330
        Administrative null values:  0
        Administrative non-null values:  12330
        is unique:  0.0021897810218978104
        Administrative duplicate values:  12303


        Administrative_Duration value_counts:  0.000000      5903
        4.000000        56
        5.000000        53
        7.000000        45
        11.000000       42
                      ...
        294.070513       1
        90.875000        1
        97.333333        1
        53.166667        1
        247.083333       1
        Name: Administrative_Duration, Length: 3335, dtype: int64
        Administrative_Duration total values:  12330
        Administrative_Duration null values:  0
        Administrative_Duration non-null values:  12330
        is unique:  0.2704785077047851
        Administrative_Duration duplicate values:  8995


        Informational value_counts:  0     9699
        1     1041
        2      728
        3      380
        4      222
        5       99
        6       78
        7       36
        9       15
        8       14
        10       7
        12       5
        14       2
        11       1
        13       1
        24       1
        16       1
        Name: Informational, dtype: int64
        Informational total values:  12330
        Informational null values:  0
        Informational non-null values:  12330
        is unique:  0.00137875101378751
        Informational duplicate values:  12313


        Informational_Duration value_counts:  0.0      9925
        9.0        33
        6.0        26
        10.0       26
        7.0        26
                 ...
        291.5       1
        43.2        1
        338.4       1
        86.6        1
        145.6       1
        Name: Informational_Duration, Length: 1258, dtype: int64
        Informational_Duration total values:  12330
        Informational_Duration null values:  0
        Informational_Duration non-null values:  12330
        is unique:  0.10202757502027575
        Informational_Duration duplicate values:  11072


        ProductRelated value_counts:  1      622
        2      465
        3      458
        4      404
        6      396
              ...
        377      1
        385      1
        292      1
        409      1
        339      1
        Name: ProductRelated, Length: 311, dtype: int64
        ProductRelated total values:  12330
        ProductRelated null values:  0
        ProductRelated non-null values:  12330
        is unique:  0.025223033252230333
        ProductRelated duplicate values:  12019


        ProductRelated_Duration value_counts:  0.000000       755
        17.000000       21
        8.000000        17
        11.000000       17
        15.000000       16
                      ...
        6560.007540      1
        821.893333       1
        2004.500000      1
        266.500000       1
        1919.550000      1
        Name: ProductRelated_Duration, Length: 9551, dtype: int64
        ProductRelated_Duration total values:  12330
        ProductRelated_Duration null values:  0
        ProductRelated_Duration non-null values:  12330
        is unique:  0.7746147607461477
        ProductRelated_Duration duplicate values:  2779


        BounceRates value_counts:  0.000000    5518
        0.200000     700
        0.066667     134
        0.028571     115
        0.050000     113
                    ...
        0.023457       1
        0.003901       1
        0.005074       1
        0.016735       1
        0.007356       1
        Name: BounceRates, Length: 1872, dtype: int64
        BounceRates total values:  12330
        BounceRates null values:  0
        BounceRates non-null values:  12330
        is unique:  0.15182481751824817
        BounceRates duplicate values:  10458


        ExitRates value_counts:  0.200000    710
        0.100000    338
        0.050000    329
        0.033333    291
        0.066667    267
                   ...
        0.025325      1
        0.020586      1
        0.084444      1
        0.055882      1
        0.010710      1
        Name: ExitRates, Length: 4777, dtype: int64
        ExitRates total values:  12330
        ExitRates null values:  0
        ExitRates non-null values:  12330
        is unique:  0.38742903487429037
        ExitRates duplicate values:  7553


        PageValues value_counts:  0.000000     9600
        53.988000       6
        42.293068       3
        40.278152       2
        12.558857       2
                     ...
        1.625051        1
        20.157102       1
        8.191923        1
        12.587222       1
        30.203577       1
        Name: PageValues, Length: 2704, dtype: int64
        PageValues total values:  12330
        PageValues null values:  0
        PageValues non-null values:  12330
        is unique:  0.21930251419302516
        PageValues duplicate values:  9626


        SpecialDay value_counts:  0.0    11079
        0.6      351
        0.8      325
        0.4      243
        0.2      178
        1.0      154
        Name: SpecialDay, dtype: int64
        SpecialDay total values:  12330
        SpecialDay null values:  0
        SpecialDay non-null values:  12330
        is unique:  0.00048661800486618007
        SpecialDay duplicate values:  12324


        Month value_counts:  May     3364
        Nov     2998
        Mar     1907
        Dec     1727
        Oct      549
        Sep      448
        Aug      433
        Jul      432
        June     288
        Feb      184
        Name: Month, dtype: int64
        Month total values:  12330
        Month null values:  0
        Month non-null values:  12330
        is unique:  0.0008110300081103001
        Month duplicate values:  12320


        OperatingSystems value_counts:  2    6601
        1    2585
        3    2555
        4     478
        8      79
        6      19
        7       7
        5       6
        Name: OperatingSystems, dtype: int64
        OperatingSystems total values:  12330
        OperatingSystems null values:  0
        OperatingSystems non-null values:  12330
        is unique:  0.0006488240064882401
        OperatingSystems duplicate values:  12322


        Browser value_counts:  2     7961
        1     2462
        4      736
        5      467
        6      174
        10     163
        8      135
        3      105
        13      61
        7       49
        12      10
        11       6
        9        1
        Name: Browser, dtype: int64
        Browser total values:  12330
        Browser null values:  0
        Browser non-null values:  12330
        is unique:  0.00105433901054339
        Browser duplicate values:  12317


        Region value_counts:  1    4780
        3    2403
        4    1182
        2    1136
        6     805
        7     761
        9     511
        8     434
        5     318
        Name: Region, dtype: int64
        Region total values:  12330
        Region null values:  0
        Region non-null values:  12330
        is unique:  0.00072992700729927
        Region duplicate values:  12321


        TrafficType value_counts:  2     3913
        1     2451
        3     2052
        4     1069
        13     738
        10     450
        6      444
        8      343
        5      260
        11     247
        20     198
        9       42
        7       40
        15      38
        19      17
        14      13
        18      10
        16       3
        12       1
        17       1
        Name: TrafficType, dtype: int64
        TrafficType total values:  12330
        TrafficType null values:  0
        TrafficType non-null values:  12330
        is unique:  0.0016220600162206002
        TrafficType duplicate values:  12310


        VisitorType value_counts:  Returning_Visitor    10551
        New_Visitor           1694
        Other                   85
        Name: VisitorType, dtype: int64
        VisitorType total values:  12330
        VisitorType null values:  0
        VisitorType non-null values:  12330
        is unique:  0.00024330900243309004
        VisitorType duplicate values:  12327


        Weekend value_counts:  False    9462
        True     2868
        Name: Weekend, dtype: int64
        Weekend total values:  12330
        Weekend null values:  0
        Weekend non-null values:  12330
        is unique:  0.00016220600162206002
        Weekend duplicate values:  12328


        Revenue value_counts:  False    10422
        True      1908
        Name: Revenue, dtype: int64
        Revenue total values:  12330
        Revenue null values:  0
        Revenue non-null values:  12330
        is unique:  0.00016220600162206002
        Revenue duplicate values:  12328
```

```
In [6]: #dropping any row with missing values
        df = df.dropna()
        df.shape
        df.columns

Out[6]: Index(['Administrative', 'Administrative_Duration', 'Informational',
               'Informational_Duration', 'ProductRelated', 'ProductRelated_Duration',
               'BounceRates', 'ExitRates', 'PageValues', 'SpecialDay', 'Month',
               'OperatingSystems', 'Browser', 'Region', 'TrafficType', 'VisitorType',
               'Weekend', 'Revenue'],
              dtype='object')
```

```
In [7]: #using label encoder to encode all categorical input feature
        from sklearn.preprocessing import LabelEncoder

        label_enc = LabelEncoder()
        for feature in ['SpecialDay', 'Month', 'OperatingSystems', 'Browser', 'Region', 'TrafficType', 'Visitor
        Type', 'Weekend', 'Revenue']:
            df[feature] = label_enc.fit_transform(df[feature])
        df.head(5)
```

Out[7]:

	Administrative	Administrative_Duration	Informational	Informational_Duration	ProductRelated	ProductRelated_Duration	BounceRates
0	0	0.0	0	0.0	1	0.000000	0.20
1	0	0.0	0	0.0	2	64.000000	0.00
2	0	0.0	0	0.0	1	0.000000	0.20
3	0	0.0	0	0.0	2	2.666667	0.05
4	0	0.0	0	0.0	10	627.500000	0.02

```
In [8]: #make every column a float, but keeping revenue as a bool
        df = df.astype(float)
        df['Revenue'] = df['Revenue'].astype(int)
        df.dtypes
        df.head(5)
```

Out[8]:

	Administrative	Administrative_Duration	Informational	Informational_Duration	ProductRelated	ProductRelated_Duration	BounceRates
0	0.0	0.0	0.0	0.0	1.0	0.000000	0.20
1	0.0	0.0	0.0	0.0	2.0	64.000000	0.00
2	0.0	0.0	0.0	0.0	1.0	0.000000	0.20
3	0.0	0.0	0.0	0.0	2.0	2.666667	0.05
4	0.0	0.0	0.0	0.0	10.0	627.500000	0.02

Feature Scaling

```
In [113]: #In general it is a good idea to scale the data
          scaler = StandardScaler()
          scaler.fit(X)
          X = scaler.transform(X)
```

```
In [9]: #train test split
        X, y = df.drop(['Revenue'], axis=1), df['Revenue']

        #In general it is a good idea to scale the data
        scaler = StandardScaler()
        scaler.fit(X)
        X = scaler.transform(X)

        X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42, stratify=y)
        X_train.shape

Out[9]: (9864, 17)
```

Feature Selection

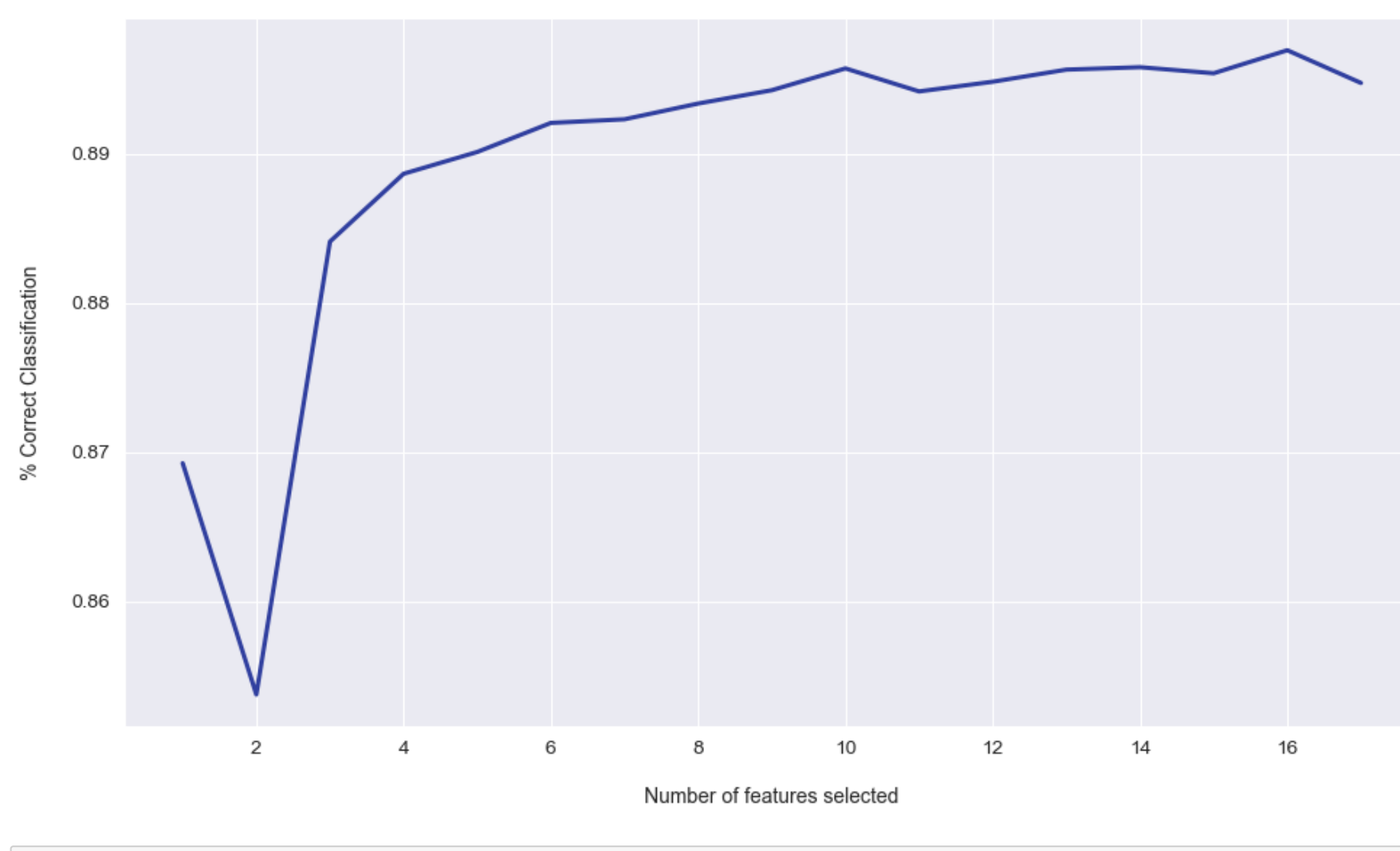
```
In [18]: # putting X_train into a dataframe for rfecv evaluation
         X_df = pd.DataFrame(X_train)
         X_df.head()
```

Out[18]:

	0	1	2	3	4	5	6	7	8	9	10	11	
0	1.711449	3.685152	-0.396478	-0.244931	0.051008	0.078914	-0.351917	-0.611814	0.343874	3.713114	0.352731	0.961270	0.37
1	-0.696993	-0.457191	-0.396478	-0.244931	-0.623548	-0.542198	0.367291	1.171473	-0.317178	-0.308821	1.196576	-1.233426	3.28
2	-0.696993	-0.457191	-0.396478	-0.244931	-0.623548	-0.602399	-0.457683	0.142551	-0.317178	-0.308821	-1.756881	-0.136078	4.45
3	-0.094882	1.454877	-0.396478	-0.244931	-0.331240	0.005655	-0.199879	-0.114679	0.718829	3.713114	0.352731	0.961270	-0.20
4	-0.696993	-0.457191	-0.396478	-0.244931	0.006038	-0.191838	-0.457683	-0.874301	2.627527	-0.308821	-0.069191	-0.136078	-0.20

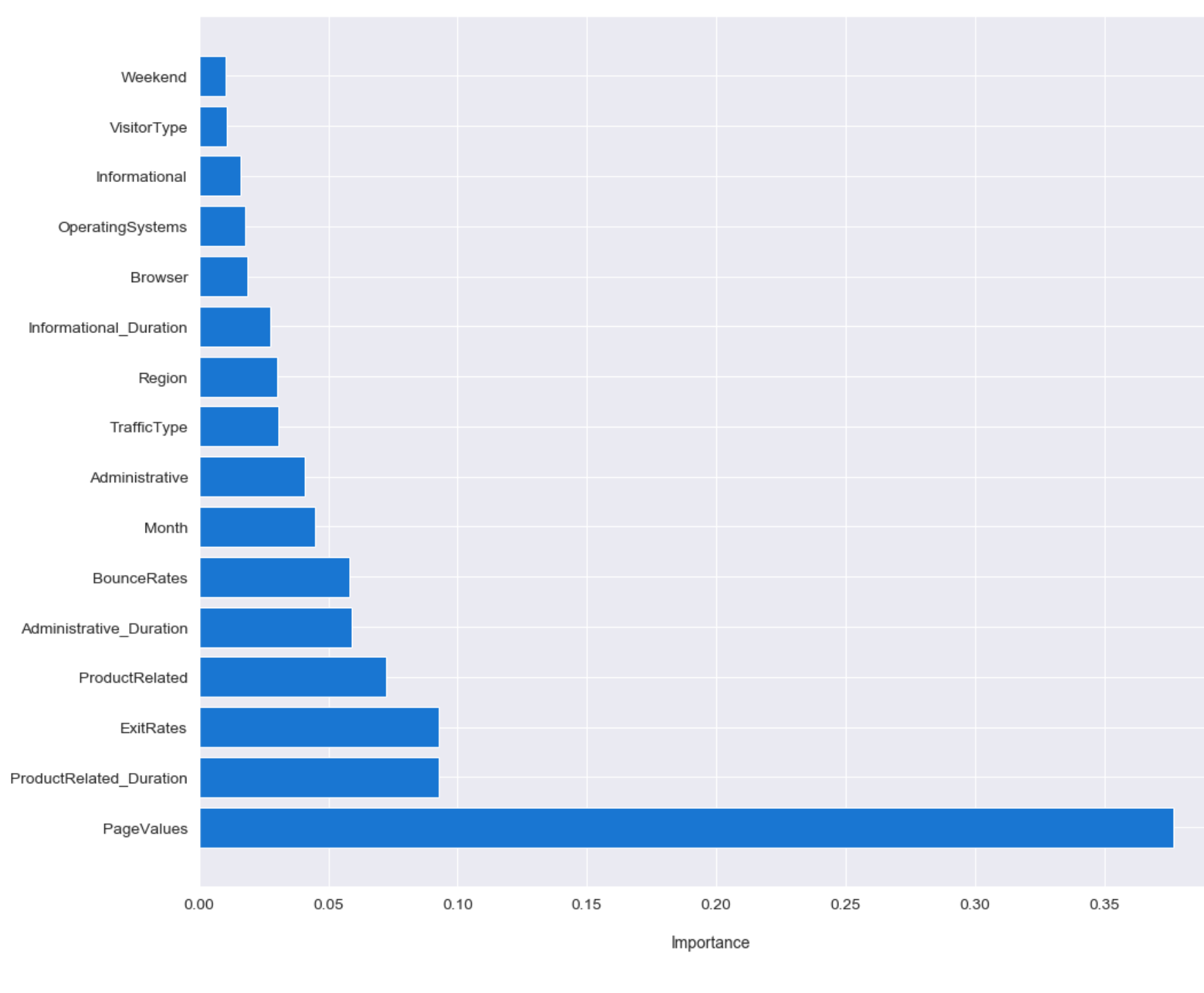
```
In [160]: from sklearn.model_selection import StratifiedKFold
          from sklearn.feature_selection import RFECV
          rfc = RandomForestClassifier(random_state=101)
          rfecv = RFECV(estimator=rfc, step=1, cv=StratifiedKFold(10), scoring='accuracy')
          rfecv.fit(X, y)

Out[160]: RFECV(cv=StratifiedKFold(n_splits=10, random_state=None, shuffle=False),
                estimator=RandomForestClassifier(random_state=101), scoring='accuracy')
```

```
In [161]: # plotting the rfecv chart for feature selection
          plt.figure(figsize=(16, 9))
          plt.title('Recursive Feature Elimination with Cross-Validation', fontsize=18, fontweight='bold', pad=2
          0)
          plt.xlabel('Number of features selected', fontsize=14, labelpad=20)
          plt.ylabel('% Correct Classification', fontsize=14, labelpad=20)
          plt.plot(range(1, len(rfecv.grid_scores_) + 1), rfecv.grid_scores_, color='#303F9F', linewidth=3)

          plt.show()
```



```
In [164]: df_x = pd.DataFrame(X, columns = ['Administrative', 'Administrative_Duration', 'Informational',
                 'Informational_Duration', 'ProductRelated', 'ProductRelated_Duration',
                 'BounceRates', 'ExitRates', 'PageValues', 'SpecialDay', 'Month',
                 'OperatingSystems', 'Browser', 'Region', 'TrafficType', 'VisitorType',
                 'Weekend'])

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

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

          [9]
```

```
In [165]: # plotting a bargraph of each selected feature according to their importance
          dset = pd.DataFrame()
          dset['attr'] = df_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()
```



Data Oversampling with SMOTE

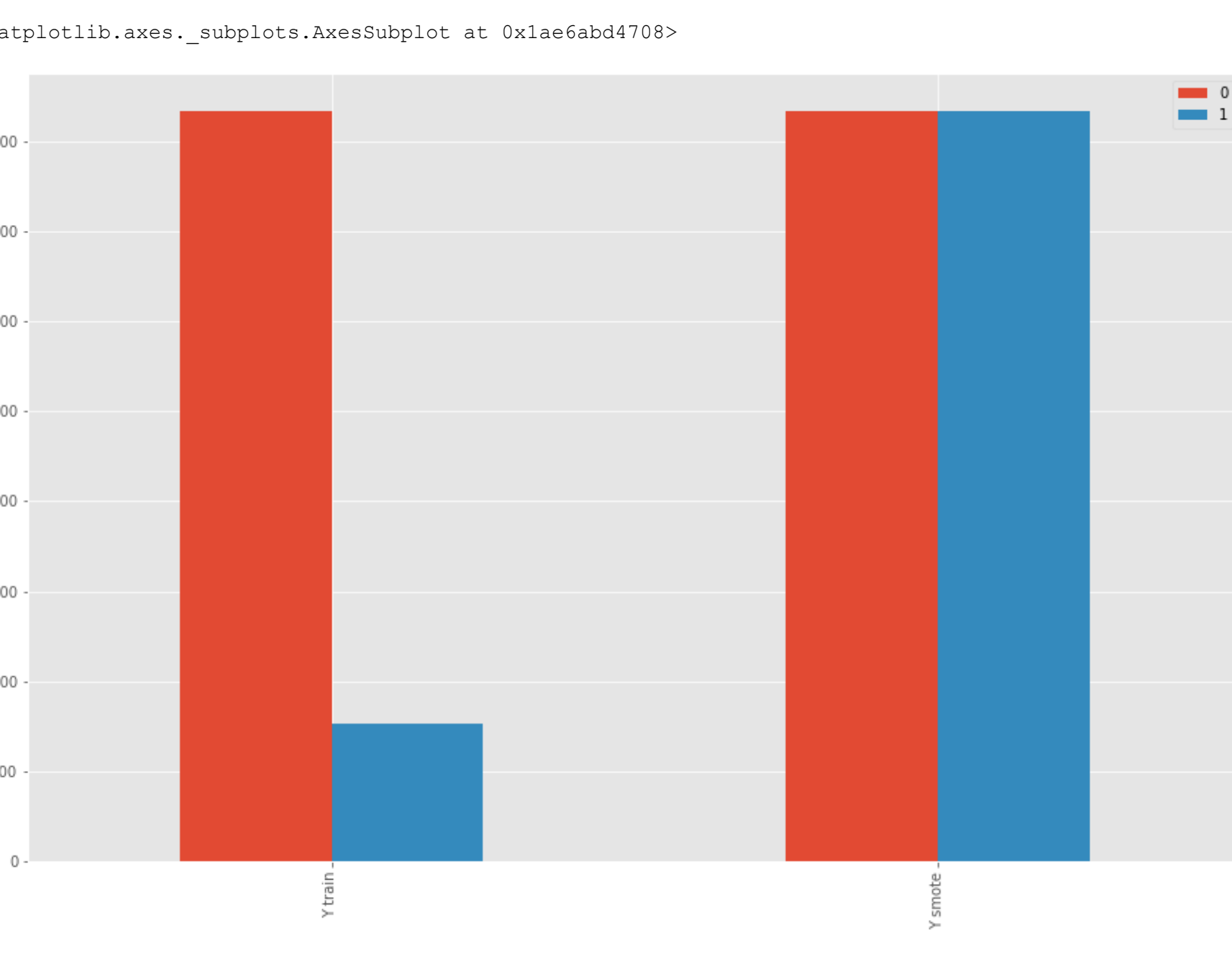
```
In [167]: # splitting the dataset beefore applying smote oversampling
          X_train, X_test, y_train, y_test = train_test_split(df_x, y, test_size=0.2, random_state=42, stratify=
          y)
          X_train.shape

Out[167]: (9864, 16)
```

```
In [10]: #applying smote oversampling to address data imbalance
         smote = SMOTE(random_state=1, k_neighbors=6)

         X_train_smote, y_smote = smote.fit_resample(X_train, y_train)
         print(X_train_smote.shape)

         (16676, 17)
```

```
In [24]: #converting y_train to a dataframe for plotting
         y_df = pd.DataFrame(y_train)
         print(y_df["Revenue"].value_counts())

         0    8338
         1    1526
         Name: Revenue, dtype: int64
```

```
In [23]: #converting y_smote to a dataframe for plotting
         y_sdf = pd.DataFrame(y_smote)
         print(y_sdf["Revenue"].value_counts())

         1    8338
         0    8338
         Name: Revenue, dtype: int64
```

```
In [31]: # plotting the dataset before and after smote oversampling
         import matplotlib.pyplot as plt
         from matplotlib import style
         import seaborn as sns
         y_dict = {'Y train': [8338, 1526], 'Y smote': [8338, 8338]}
         y_comb = pd.DataFrame(data=y_dict)
         print(y_comb)

         # plotting the rss values of each feature on the train and test data side by side as a multiple bargrap
         h
         style.use('ggplot')
         y_comb.T.plot(kind='bar',figsize=(15,10))

            Y train  Y smote
         0     8338     8338
         1     1526     8338

Out[31]: <matplotlib.axes._subplots.AxesSubplot at 0x1ae6abd4708>
```



Modelling

Base Model - KNN

```
In [178]: # creating a KNN model
          knn = KNeighborsClassifier(n_neighbors = 8)
          knn.fit(X_train_smote, y_smote)

Out[178]: KNeighborsClassifier(n_neighbors=8)
```

```
In [179]: # checking the accuracy, precision, recall and f1-score of the KNN model
          y_pred_knn = knn.predict(X_test)
          print (accuracy_score(y_test, y_pred_knn))
          print(metrics.classification_report(y_test, y_pred_knn))

          0.7923763179237632
                        precision    recall  f1-score   support

                     0       0.93      0.82      0.87      2084
                     1       0.40      0.66      0.50       382

              accuracy                           0.79      2466
             macro avg       0.66      0.74      0.68      2466
          weighted avg       0.85      0.79      0.81      2466
```

Model Bagging - Random Forest

```
In [135]: #Random Forest model
          rfc = RandomForestClassifier(n_jobs=-1,max_features= 'sqrt' ,n_estimators=50, oob_score = True)

          param_grid_rf = {
              'n_estimators': [200, 700],
              'max_features': ['auto', 'sqrt', 'log2']
          }

          rf_stack = GridSearchCV(estimator=rfc, param_grid=param_grid_rf, cv= 5)
          rf_stack.fit(X_train_smote, y_smote)

Out[135]: GridSearchCV(cv=5,
                       estimator=RandomForestClassifier(max_features='sqrt',
                                                        n_estimators=50, n_jobs=-1,
                                                        oob_score=True),
                       param_grid={'max_features': ['auto', 'sqrt', 'log2'],
                                   'n_estimators': [200, 700]})
```

```
In [136]: # checking the accuracy, precision, recall and f1-score of the Random forest model and
          y_pred = rf_stack.predict(X_test)
          print (accuracy_score(y_test, y_pred))
          print(metrics.classification_report(y_test, y_pred))

          0.8856447688564477
                        precision    recall  f1-score   support

                     0       0.94      0.92      0.93      2084
                     1       0.62      0.69      0.65       382

              accuracy                           0.89      2466
             macro avg       0.78      0.81      0.79      2466
          weighted avg       0.89      0.89      0.89      2466
```

Model Boosting - XGB

In [12]:

```
# creating a xgbclassifier model
xgb = XGBClassifier()
# xgb.fit(X_train_smote, y_smote)


xgb_stack = GridSearchCV(xgb,{'max_depth': [2,4,6,8, 10, 12, 14],
                    'n_estimators': [50,100,200, 300, 400, 500, 600]},
                    verbose=1,
                    scoring='neg_log_loss')

xgb_stack.fit(X_train_smote, y_smote)
```

```
Fitting 5 folds for each of 49 candidates, totalling 245 fits
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: divide by zero encountered in log
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: invalid value encountered in multiply
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: divide by zero encountered in log
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: divide by zero encountered in log
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: invalid value encountered in multiply
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
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C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: invalid value encountered in multiply
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: divide by zero encountered in log
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: invalid value encountered in multiply
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: divide by zero encountered in log
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
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g: invalid value encountered in multiply
  loss = -(transformed_labels * np.log(y_pred)).sum(axis=1)
[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed: 12.6min finished
```

Out[12]:

```
GridSearchCV(estimator=XGBClassifier(base_score=None, booster=None,
                                     colsample_bylevel=None,
                                     colsample_bynode=None,
                                     colsample_bytree=None, gamma=None,
                                     gpu_id=None, importance_type='gain',
                                     interaction_constraints=None,
                                     learning_rate=None, max_delta_step=None,
                                     max_depth=None, min_child_weight=None,
                                     missing=nan, monotone_constraints=None,
                                     n_estimators=100, n_jobs=None,
                                     num_parallel_tree=None, random_state=None,
                                     reg_alpha=None, reg_lambda=None,
                                     scale_pos_weight=None, subsample=None,
                                     tree_method=None, validate_parameters=None,
                                     verbosity=None),
             param_grid={'max_depth': [2, 4, 6, 8, 10, 12, 14],
                         'n_estimators': [50, 100, 200, 300, 400, 500, 600]},
             scoring='neg_log_loss', verbose=1)
```

In [139]:

```
# checking the accuracy, precision, recall and f1-score of the xgb_stack model tuned up to 14 md and 6
00 ne
y_pred_xgb = xgb_stack.predict(X_test)
print (accuracy_score(y_test, y_pred_xgb))
print(metrics.classification_report(y_test, y_pred_xgb))
```

```
0.8990267639902676
              precision    recall  f1-score   support

           0       0.94      0.94      0.94      2084
           1       0.68      0.67      0.67       382

    accuracy                           0.90      2466
   macro avg       0.81      0.81      0.81      2466
weighted avg       0.90      0.90      0.90      2466
```

Model Stacking

In [14]:

```
# defining the function to create a stacked model ensemble
def get_stacking():
    # define the base models
    level0 = list()
#     level0.append(('randomForest', rf_stack))
#     level0.append(('xgboost', xgb_stack))
#     level0.append(('lr', lr_stack))
    level0.append(('lr_b', lr))
    # define meta learner model
    level1 = LogisticRegression()
    # define the stacking ensemble
    model = StackingClassifier(estimators=level0, final_estimator=level1, cv=5)
    return model
```

In [15]:

```
stack_model_light = get_stacking()
stack_model_light.fit(X_train_smote, y_smote)
```

```
Fitting 5 folds for each of 49 candidates, totalling 245 fits
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
C:\Users\akinmade\Anaconda3\lib\site-packages\sklearn\metrics_classification.py:2240: RuntimeWarnin
g: divide by zero encountered in log
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[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed: 12.4min finished
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Fitting 5 folds for each of 49 candidates, totalling 245 fits
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[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
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[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed:  8.5min finished
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Fitting 5 folds for each of 49 candidates, totalling 245 fits
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[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
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[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed: 10.1min finished
```

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Fitting 5 folds for each of 49 candidates, totalling 245 fits
```

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[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
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[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed:  9.6min finished
```

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Fitting 5 folds for each of 49 candidates, totalling 245 fits
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[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
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[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed:  8.8min finished
```

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Fitting 5 folds for each of 49 candidates, totalling 245 fits
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[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
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[Parallel(n_jobs=1)]: Done 245 out of 245 | elapsed:  8.7min finished
```

```
Out[15]: StackingClassifier(cv=5,
                            estimators=[('xgboost',
                                         GridSearchCV(estimator=XGBClassifier(base_score=None,
                                                                              booster=None,
                                                                              colsample_bylevel=None,
                                                                              colsample_bynode=None,
                                                                              colsample_bytree=None,
                                                                              gamma=None,
                                                                              gpu_id=None,
                                                                              importance_type='gain',
                                                                              interaction_constraints=None,
                                                                              learning_rate=None,
                                                                              max_delta_step=None,
                                                                              max_depth=None,
                                                                              min_child_weight=None,
                                                                              missing=nan,
                                                                              monoton...
                                                                              num_parallel_tree=None,
                                                                              random_state=None,
                                                                              reg_alpha=None,
                                                                              reg_lambda=None,
                                                                              scale_pos_weight=None,
                                                                              subsample=None,
                                                                              tree_method=None,
                                                                              validate_parameters=None,
                                                                              verbosity=None),
                                                      param_grid={'max_depth': [2, 4, 6,
                                                                                8, 10,
                                                                                12, 14],
                                                                  'n_estimators': [50,
                                                                                   100,
                                                                                   200,
                                                                                   300,
                                                                                   400,
                                                                                   500,
                                                                                   600]},
                                                      scoring='neg_log_loss',
                                                      verbose=1)),
                                        ('lr_b', LogisticRegression())],
                            final_estimator=LogisticRegression())
```

using XGB + Random Forest at level 0 and Logistic Regression at level 1

```
In [188]: # checking the accuracy, precision, recall and f1-score of the normal stacked model using xgb_stack, r
          f_stack at lvl0 and LR at lvl1
          y_pred_stack = stack_model.predict(X_test)
          print (accuracy_score(y_test, y_pred_stack))
          print(metrics.classification_report(y_test, y_pred_stack))
```

```
0.8880778588807786
              precision    recall  f1-score   support

           0       0.94      0.93      0.93      2084
           1       0.63      0.68      0.65       382

    accuracy                           0.89      2466
   macro avg       0.78      0.80      0.79      2466
weighted avg       0.89      0.89      0.89      2466
```

using XGB + Logistic Regression at level 0 and Logistic Regression at level 1

```
In [155]: # checking the accuracy, precision, recall and f1-score of the normal stacked model lr, xgb_stack, dt
           lvl1: lr basic standardzd, 80%
          y_pred_stack = stack_model.predict(X_test)
          print (accuracy_score(y_test, y_pred_stack))
          print(metrics.classification_report(y_test, y_pred_stack))
```

```
0.8864557988645579
              precision    recall  f1-score   support

           0       0.95      0.92      0.93      2084
           1       0.61      0.73      0.67       382

    accuracy                           0.89      2466
   macro avg       0.78      0.82      0.80      2466
weighted avg       0.90      0.89      0.89      2466
```