

## Task 2 - Predictive Analysis

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### Part I - Research Question

**A1. Propose one relevant question and choose a classification method.**

■ *Which customers are most likely to churn?*

We will endeavor to answer the above question by using Random Forest.

**A2. Define one goal of the data analysis.**

The ultimate goal is to reduce operating costs. We will build a Random Forest model to predict which customers are likely to churn. The organization will benefit from knowing which customers are most likely to churn or discontinue service. This will inform the decisions of stakeholders in matters where customer retention is involved. For example, it takes a lot more money to acquire new customers than to retain existing ones. Knowing which customers are at a high risk of churn will provide the organization with advanced warnings to prevent churn. This will surely reduce the operating costs of the organization.

This goal is within the scope of the scenario and is represented in the available data.

### Part II - Method Justification

**B1. Explain how the classification method you chose analyzes the selected data set. Include expected outcomes.**

I chose the Random Forest method for classification because it's like a decision tree on steroids. It uses many decision trees and tally's the vote to decided on a class. "By combining the outputs of these trees, the random forest algorithm delivers a consolidated and more accurate result." (Sruthi, 2023).

I expect the model to show the relationship between the target variable "churn" its best predictors. I also expect a summary of the model's performance, such as accuracy, MSE, and AUC scores.

## **B2. Summarize one assumption of the chosen classification method.**

The core assumption of Random Forest is that its sampling is representative of the population. Since RF models are built on multiple decision trees, they are highly sensitive to imbalanced data. Any imbalance in the data needs to be dealt with first before trying to make a prediction.

## **B3. List the packages or libraries you have chosen for Python or R, and justify how each item on the list supports the analysis.**

The packages/libraries I've chosen are:

- sys: for running the executable file (d209\_task1.py)
- random: set random seed for reproducibility of the experiment
- pandas: for manipulating dataframes
- numpy: for performing mathematical computations
- matplotlib and seaborn: for visualizations
- Image: display image from a URL
- StandardScaler: to scale the data set
- train\_test\_split: to split the data into train and test sets
- SMOTE: to handle imbalanced data set
- RandomForestClassifier: random forest classifier
- roc\_curve, confusion\_matrix, mean\_squared\_error: display metrics
- GridSearchCV: to optimize the model

## **Part III - Data Preparation**

### **C1. Describe one data preprocessing goal relevant to the classification method from part A1.**

One preprocessing goal is to encode categorical variables with values using dummy variables. Most machine learning models require the use of numerical data. For binary columns, we will change "Yes" to 1 and "No" to 0. Similarly, we will convert True to 1 and False to 0. We will utilize the `get_dummies()` method to accomplish this goal.

## **C2. Identify the initial data set variables that you will use to analyze the classification question from part A1, and classify each variable as continuous or categorical.**

Independent Variables:

- Children, Continuous, Quantitative
- Age, Continuous, Quantitative
- Income, Continuous, Quantitative
- Marital, Categorical, Qualitative
- Gender, Categorical, Qualitative
- Outage\_sec\_perweek, Continuous, Quantitative
- Email, Continuous, Quantitative
- Contacts, Continuous, Quantitative
- Yearly\_equip\_failure, Categorical, Qualitative
- Techie, Categorical, Qualitative
- Contract, Categorical, Qualitative
- Port\_modem, Categorical, Qualitative
- Tablet, Categorical, Qualitative
- InternetService, Categorical, Qualitative
- Phone, Categorical, Qualitative
- Multiple, Categorical, Qualitative
- OnlineSecurity, Categorical, Qualitative
- OnlineBackup, Categorical, Qualitative
- DeviceProtection, Categorical, Qualitative
- TechSupport, Categorical, Qualitative
- StreamingTV, Categorical, Qualitative
- StreamingMovies, Categorical, Qualitative
- PaperlessBilling, Categorical, Qualitative
- PaymentMethod, Categorical, Qualitative
- Tenure, Continuous, Quantitative
- MonthlyCharge, Continuous, Quantitative
- Bandwidth\_GB\_Year, Continuous, Quantitative

Dependent/Target Variable:

- Churn, Categorical, Qualitative

## **C3. Explain each of the steps used to prepare the data for the analysis. Identify the code segment for each step.**

- Load and view the data
  - use pandas to read the csv use head or tail methods use info()
- Perform data cleaning
  - remove duplicates, missing values, outliers
- Remove irrelevant data for the analysis
  - use the drop method
- Pre-process data
  - encode categorical data, scale the features

```
In [1]: # setting the random seed for reproducibility
import random
random.seed(493)

# for manipulating dataframes
import pandas as pd
import numpy as np

# for visualizations
%matplotlib inline
import matplotlib.pyplot as plt
import seaborn as sns
sns.set(style="whitegrid")
from IPython.display import Image

# for modeling
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split
from imblearn.over_sampling import SMOTE
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import roc_curve
from sklearn.metrics import confusion_matrix
from sklearn.metrics import roc_auc_score
from sklearn.metrics import mean_squared_error
from sklearn.model_selection import GridSearchCV

# to print out all the outputs of the cell
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = "all"

# set display options
pd.set_option('display.max_columns', None)
pd.set_option('display.max_rows', None)
pd.set_option('display.max_colwidth', None)
```

```
In [2]: # read the csv file
df = pd.read_csv('churn_clean.csv')
```

```
df.info()  
df.head()
```

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

RangeIndex: 10000 entries, 0 to 9999

Data columns (total 50 columns):

#	Column	Non-Null	Count	Dtype
0	CaseOrder	10000	non-null	int64
1	Customer_id	10000	non-null	object
2	Interaction	10000	non-null	object
3	UID	10000	non-null	object
4	City	10000	non-null	object
5	State	10000	non-null	object
6	County	10000	non-null	object
7	Zip	10000	non-null	int64
8	Lat	10000	non-null	float64
9	Lng	10000	non-null	float64
10	Population	10000	non-null	int64
11	Area	10000	non-null	object
12	TimeZone	10000	non-null	object
13	Job	10000	non-null	object
14	Children	10000	non-null	int64
15	Age	10000	non-null	int64
16	Income	10000	non-null	float64
17	Marital	10000	non-null	object
18	Gender	10000	non-null	object
19	Churn	10000	non-null	object
20	Outage_sec_perweek	10000	non-null	float64
21	Email	10000	non-null	int64
22	Contacts	10000	non-null	int64
23	Yearly_equip_failure	10000	non-null	int64
24	Techie	10000	non-null	object
25	Contract	10000	non-null	object
26	Port_modem	10000	non-null	object
27	Tablet	10000	non-null	object
28	InternetService	7871	non-null	object
29	Phone	10000	non-null	object
30	Multiple	10000	non-null	object
31	OnlineSecurity	10000	non-null	object
32	OnlineBackup	10000	non-null	object
33	DeviceProtection	10000	non-null	object
34	TechSupport	10000	non-null	object
35	StreamingTV	10000	non-null	object
36	StreamingMovies	10000	non-null	object
37	PaperlessBilling	10000	non-null	object
38	PaymentMethod	10000	non-null	object
39	Tenure	10000	non-null	float64
40	MonthlyCharge	10000	non-null	float64
41	Bandwidth_GB_Year	10000	non-null	float64
42	Item1	10000	non-null	int64
43	Item2	10000	non-null	int64
44	Item3	10000	non-null	int64
45	Item4	10000	non-null	int64
46	Item5	10000	non-null	int64
47	Item6	10000	non-null	int64
48	Item7	10000	non-null	int64
49	Item8	10000	non-null	int64

dtypes: float64(7), int64(16), object(27)

memory usage: 3.8+ MB

Out[2]:

	CaseOrder	Customer_id	Interaction	UID	City	S
0	1	K409198	aa90260b-4141-4a24-8e36-b04ce1f4f77b	e885b299883d4f9fb18e39c75155d990	Point Baker	
1	2	S120509	fb76459f-c047-4a9d-8af9-e0f7d4ac2524	f2de8bef964785f41a2959829830fb8a	West Branch	
2	3	K191035	344d114c-3736-4be5-98f7-c72c281e2d35	f1784cfa9f6d92ae816197eb175d3c71	Yamhill	
3	4	D90850	abfa2b40-2d43-4994-b15a-989b8c79e311	dc8a365077241bb5cd5ccd305136b05e	Del Mar	
4	5	K662701	68a861fd-0d20-4e51-a587-8a90407ee574	aabb64a116e83fdc4befc1fbab1663f9	Needville	

In [3]: *# select rows that are duplicated based on all columns*  
`dup = df[df.duplicated()]`  
  
*# find out how many rows are duplicated*  
`dup.shape`

Out[3]: (0, 50)

In [4]: `def show_missing(df):`  
    *"""*  
    *Takes a dataframe and returns a dataframe with stats*  
    *on missing and null values with their percentages.*  
    *"""*  
    `null_count = df.isnull().sum()`  
    `null_percentage = (null_count / df.shape[0]) * 100`  
    `empty_count = pd.Series(((df == ' ') | (df == '')).sum())`  
    `empty_percentage = (empty_count / df.shape[0]) * 100`  
    `nan_count = pd.Series(((df == 'nan') | (df == 'NaN')).sum())`  
    `nan_percentage = (nan_count / df.shape[0]) * 100`  
    `dfx = pd.DataFrame({'num_missing': null_count, 'missing_percentage': null_perce`  
                            `'num_empty': empty_count, 'empty_percentage': empty_perce`  
                            `'nan_count': nan_count, 'nan_percentage': nan_percentage})`  
    `return dfx`  
  
    `show_missing(df)`

Out[4]:

	num_missing	missing_percentage	num_empty	empty_percentage	na
CaseOrder	0	0.00	0	0.0	
Customer_id	0	0.00	0	0.0	
Interaction	0	0.00	0	0.0	
UID	0	0.00	0	0.0	
City	0	0.00	0	0.0	
State	0	0.00	0	0.0	
County	0	0.00	0	0.0	
Zip	0	0.00	0	0.0	
Lat	0	0.00	0	0.0	
Lng	0	0.00	0	0.0	
Population	0	0.00	0	0.0	
Area	0	0.00	0	0.0	
TimeZone	0	0.00	0	0.0	
Job	0	0.00	0	0.0	
Children	0	0.00	0	0.0	
Age	0	0.00	0	0.0	
Income	0	0.00	0	0.0	
Marital	0	0.00	0	0.0	
Gender	0	0.00	0	0.0	
Churn	0	0.00	0	0.0	
Outage_sec_perweek	0	0.00	0	0.0	
Email	0	0.00	0	0.0	
Contacts	0	0.00	0	0.0	
Yearly_equip_failure	0	0.00	0	0.0	
Techie	0	0.00	0	0.0	
Contract	0	0.00	0	0.0	
Port_modem	0	0.00	0	0.0	
Tablet	0	0.00	0	0.0	
InternetService	2129	21.29	0	0.0	
Phone	0	0.00	0	0.0	



	num_missing	missing_percentage	num_empty	empty_percentage	na
<b>Multiple</b>	0	0.00	0	0.0	
<b>OnlineSecurity</b>	0	0.00	0	0.0	
<b>OnlineBackup</b>	0	0.00	0	0.0	
<b>DeviceProtection</b>	0	0.00	0	0.0	
<b>TechSupport</b>	0	0.00	0	0.0	
<b>StreamingTV</b>	0	0.00	0	0.0	
<b>StreamingMovies</b>	0	0.00	0	0.0	
<b>PaperlessBilling</b>	0	0.00	0	0.0	
<b>PaymentMethod</b>	0	0.00	0	0.0	
<b>Tenure</b>	0	0.00	0	0.0	
<b>MonthlyCharge</b>	0	0.00	0	0.0	
<b>Bandwidth_GB_Year</b>	0	0.00	0	0.0	
<b>Item1</b>	0	0.00	0	0.0	
<b>Item2</b>	0	0.00	0	0.0	
<b>Item3</b>	0	0.00	0	0.0	
<b>Item4</b>	0	0.00	0	0.0	
<b>Item5</b>	0	0.00	0	0.0	
<b>Item6</b>	0	0.00	0	0.0	
<b>Item7</b>	0	0.00	0	0.0	
<b>Item8</b>	0	0.00	0	0.0	

```
In [5]: # handle missing values
df['InternetService'].value_counts()
```

```
Out[5]: InternetService
Fiber Optic    4408
DSL            3463
Name: count, dtype: int64
```

```
In [6]: # fill missing values with None as in no service
df = df.fillna("None")

df['InternetService'].value_counts()
show_missing(df)
```

```
Out[6]: InternetService
        Fiber Optic    4408
        DSL            3463
        None           2129
        Name: count, dtype: int64
```

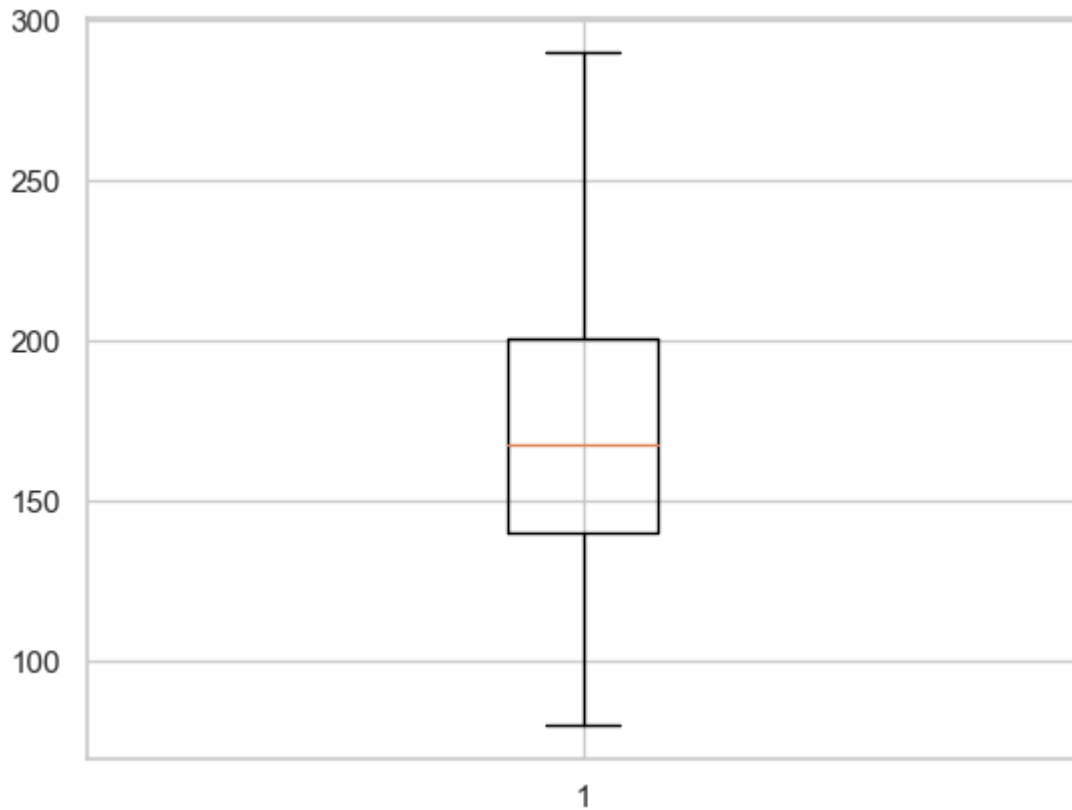
Out[6]:

	num_missing	missing_percentage	num_empty	empty_percentage	na
CaseOrder	0	0.0	0	0.0	
Customer_id	0	0.0	0	0.0	
Interaction	0	0.0	0	0.0	
UID	0	0.0	0	0.0	
City	0	0.0	0	0.0	
State	0	0.0	0	0.0	
County	0	0.0	0	0.0	
Zip	0	0.0	0	0.0	
Lat	0	0.0	0	0.0	
Lng	0	0.0	0	0.0	
Population	0	0.0	0	0.0	
Area	0	0.0	0	0.0	
TimeZone	0	0.0	0	0.0	
Job	0	0.0	0	0.0	
Children	0	0.0	0	0.0	
Age	0	0.0	0	0.0	
Income	0	0.0	0	0.0	
Marital	0	0.0	0	0.0	
Gender	0	0.0	0	0.0	
Churn	0	0.0	0	0.0	
Outage_sec_perweek	0	0.0	0	0.0	
Email	0	0.0	0	0.0	
Contacts	0	0.0	0	0.0	
Yearly_equip_failure	0	0.0	0	0.0	
Techie	0	0.0	0	0.0	
Contract	0	0.0	0	0.0	
Port_modem	0	0.0	0	0.0	
Tablet	0	0.0	0	0.0	
InternetService	0	0.0	0	0.0	
Phone	0	0.0	0	0.0	

	num_missing	missing_percentage	num_empty	empty_percentage	na
<b>Multiple</b>	0	0.0	0	0.0	
<b>OnlineSecurity</b>	0	0.0	0	0.0	
<b>OnlineBackup</b>	0	0.0	0	0.0	
<b>DeviceProtection</b>	0	0.0	0	0.0	
<b>TechSupport</b>	0	0.0	0	0.0	
<b>StreamingTV</b>	0	0.0	0	0.0	
<b>StreamingMovies</b>	0	0.0	0	0.0	
<b>PaperlessBilling</b>	0	0.0	0	0.0	
<b>PaymentMethod</b>	0	0.0	0	0.0	
<b>Tenure</b>	0	0.0	0	0.0	
<b>MonthlyCharge</b>	0	0.0	0	0.0	
<b>Bandwidth_GB_Year</b>	0	0.0	0	0.0	
<b>Item1</b>	0	0.0	0	0.0	
<b>Item2</b>	0	0.0	0	0.0	
<b>Item3</b>	0	0.0	0	0.0	
<b>Item4</b>	0	0.0	0	0.0	
<b>Item5</b>	0	0.0	0	0.0	
<b>Item6</b>	0	0.0	0	0.0	
<b>Item7</b>	0	0.0	0	0.0	
<b>Item8</b>	0	0.0	0	0.0	

```
In [7]: # remove outliers
plt.boxplot(df['MonthlyCharge'])
fig = plt.figure(figsize=(10, 7))
```

```
Out[7]: {'whiskers': [<matplotlib.lines.Line2D at 0x23cd2968b50>,
<matplotlib.lines.Line2D at 0x23cd2968df0>],
'caps': [<matplotlib.lines.Line2D at 0x23cd29850d0>,
<matplotlib.lines.Line2D at 0x23cd2985370>],
'boxes': [<matplotlib.lines.Line2D at 0x23cd29688b0>],
'medians': [<matplotlib.lines.Line2D at 0x23cd2985610>],
'fliers': [<matplotlib.lines.Line2D at 0x23cd29858b0>],
'means': []}
```



<Figure size 1000x700 with 0 Axes>

```
In [8]: # remove irrelevant data
df.drop(columns=['CaseOrder', 'Customer_id', 'Interaction', 'UID', 'City', 'State',
                'County', 'Zip', 'Lat', 'Lng', 'Population', 'Area', 'TimeZone', 'Job',
                'Item1', 'Item2', 'Item3', 'Item4', 'Item5', 'Item6', 'Item7', 'Item8'],
        inplace=True)
```

```
In [9]: # encode categorical data

# assemble list of categorical columns to generate dummy variables for
dummy_columns = ['Marital',
                 'Gender',
                 'Techie',
                 'Contract',
                 'Port_modem',
                 'Tablet',
                 'InternetService',
                 'Phone',
                 'Multiple',
                 'OnlineSecurity',
                 'OnlineBackup',
                 'DeviceProtection',
                 'TechSupport',
                 'StreamingTV',
                 'StreamingMovies',
                 'PaperlessBilling',
                 'PaymentMethod'
                ]
```

```
In [10]: def dummify(df, column):
        """
        Takes a dataframe and column to return a dataframe with
        dummy variables appended.
        """
        dummy = pd.get_dummies(df[column], prefix=column, prefix_sep='_')
        return pd.concat([df, dummy], axis=1)
```

```
In [11]: dummified = df.copy()

        # loop through all the columns to generate dummy for
        for col in dummy_columns:
            dummified = dummify(dummified, col)
```

```
In [12]: dummified.head()
```

```
Out[12]:
```

	Children	Age	Income	Marital	Gender	Churn	Outage_sec_perweek	Email	Contact
--	----------	-----	--------	---------	--------	-------	--------------------	-------	---------

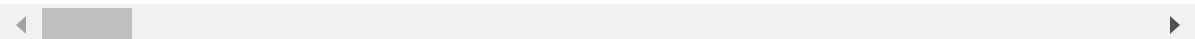
0	0	68	28561.99	Widowed	Male	No	7.978323	10	
---	---	----	----------	---------	------	----	----------	----	--

1	1	27	21704.77	Married	Female	Yes	11.699080	12	
---	---	----	----------	---------	--------	-----	-----------	----	--

2	4	50	9609.57	Widowed	Female	No	10.752800	9	
---	---	----	---------	---------	--------	----	-----------	---	--

3	1	48	18925.23	Married	Male	No	14.913540	15	
---	---	----	----------	---------	------	----	-----------	----	--

4	0	83	40074.19	Separated	Male	Yes	8.147417	16	
---	---	----	----------	-----------	------	-----	----------	----	--



```
In [13]: # drop original columns we generated dummies for
        dummified.drop(columns=dummy_columns, inplace=True)
        dummified.head()
```

```
Out[13]:
```

	Children	Age	Income	Churn	Outage_sec_perweek	Email	Contacts	Yearly equip_fail
--	----------	-----	--------	-------	--------------------	-------	----------	-------------------

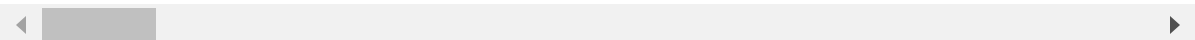
0	0	68	28561.99	No	7.978323	10	0
---	---	----	----------	----	----------	----	---

1	1	27	21704.77	Yes	11.699080	12	0
---	---	----	----------	-----	-----------	----	---

2	4	50	9609.57	No	10.752800	9	0
---	---	----	---------	----	-----------	---	---

3	1	48	18925.23	No	14.913540	15	2
---	---	----	----------	----	-----------	----	---

4	0	83	40074.19	Yes	8.147417	16	2
---	---	----	----------	-----	----------	----	---



```
In [14]: # move target variable at the end of the dataframe
df = dummified[['Children', 'Age', 'Income', 'Outage_sec_perweek', 'Email',
               'Contacts', 'Yearly equip_failure', 'Tenure', 'MonthlyCharge',
               'Bandwidth_GB_Year', 'Marital_Divorced', 'Marital_Married',
               'Marital_Never Married', 'Marital_Separated', 'Marital_Widowed',
               'Gender_Female', 'Gender_Male', 'Gender_Nonbinary', 'Techie_No',
               'Techie_Yes', 'Contract_Month-to-month', 'Contract_One year',
               'Contract_Two Year', 'Port_modem_No', 'Port_modem_Yes', 'Tablet_No',
               'Tablet_Yes', 'InternetService_DSL', 'InternetService_Fiber Optic',
               'InternetService_None', 'Phone_No', 'Phone_Yes', 'Multiple_No',
               'Multiple_Yes', 'OnlineSecurity_No', 'OnlineSecurity_Yes',
               'OnlineBackup_No', 'OnlineBackup_Yes', 'DeviceProtection_No',
               'DeviceProtection_Yes', 'TechSupport_No', 'TechSupport_Yes',
               'StreamingTV_No', 'StreamingTV_Yes', 'StreamingMovies_No',
               'StreamingMovies_Yes', 'PaperlessBilling_No', 'PaperlessBilling_Yes',
               'PaymentMethod_Bank Transfer(automatic)',
               'PaymentMethod_Credit Card (automatic)',
               'PaymentMethod_Electronic Check', 'PaymentMethod_Mailed Check', 'Churn']]
```

```
In [15]: # replace True with 1's and False with 0's
df = df.replace(True, 1)
df = df.replace(False, 0)

# replace 'Yes' with 1's and 'No' with 0's
df['Churn'] = df['Churn'].replace('Yes', 1)
df['Churn'] = df['Churn'].replace('No', 0)

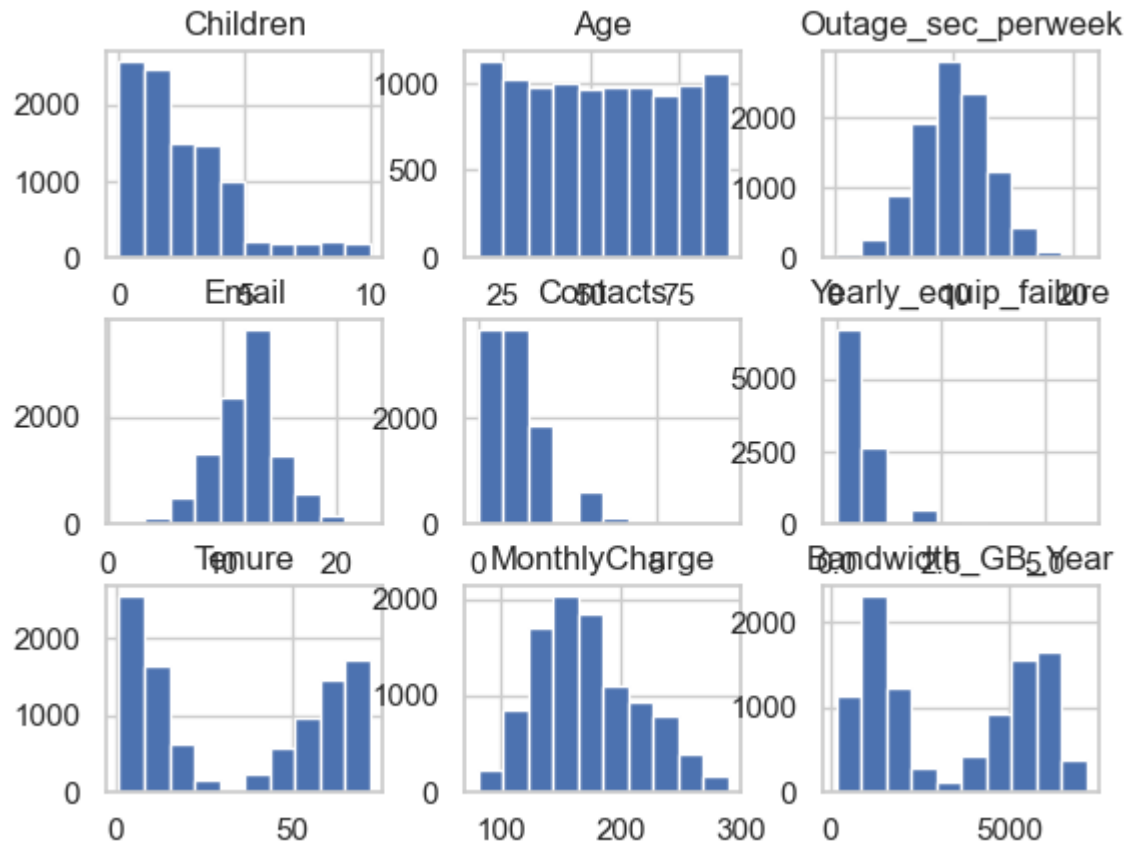
df.head()
```

```
Out[15]:
```

	Children	Age	Income	Outage_sec_perweek	Email	Contacts	Yearly equip_failure	
0	0	68	28561.99	7.978323	10	0	1	6.
1	1	27	21704.77	11.699080	12	0	1	1.
2	4	50	9609.57	10.752800	9	0	1	15.
3	1	48	18925.23	14.913540	15	2	0	17.
4	0	83	40074.19	8.147417	16	2	1	1.

```
In [16]: # make histograms and save the plot
df[['Children',
    'Age',
    'Outage_sec_perweek',
    'Email',
    'Contacts',
    'Yearly equip_failure',
    'Tenure',
    'MonthlyCharge',
    'Bandwidth_GB_Year'
]].hist()
```

```
Out[16]: array([[<Axes: title={'center': 'Children'}>,
<Axes: title={'center': 'Age'}>,
<Axes: title={'center': 'Outage_sec_perweek'}>],
[<Axes: title={'center': 'Email'}>,
<Axes: title={'center': 'Contacts'}>,
<Axes: title={'center': 'Yearly equip_failure'}>],
[<Axes: title={'center': 'Tenure'}>,
<Axes: title={'center': 'MonthlyCharge'}>,
<Axes: title={'center': 'Bandwidth_GB_Year'}>]], dtype=object)
```



```
In [17]: # scale the data
scaler = StandardScaler()

# apply scaler() to all the columns except the 'yes-no' and 'dummy' variables
num_vars = ['Children', 'Age', 'Outage_sec_perweek', 'Email', 'Contacts', 'Yearly_eq
df[num_vars] = scaler.fit_transform(df[num_vars])

df.head()
```



Out[17]:

	Children	Age	Income	Outage_sec_perweek	Email	Contacts	Yearly equip_f
0	-0.972338	0.720925	28561.99	-0.679978	-0.666282	-1.005852	0.9
1	-0.506592	-1.259957	21704.77	0.570331	-0.005288	-1.005852	0.9
2	0.890646	-0.148730	9609.57	0.252347	-0.996779	-1.005852	0.9
3	-0.506592	-0.245359	18925.23	1.650506	0.986203	1.017588	-0.6
4	-0.972338	1.445638	40074.19	-0.623156	1.316700	1.017588	0.9

## C4. Provide a copy of the cleaned data set.

```
In [18]: # save the prepared data set
df.to_csv('churn_prepared2.csv', index=False)
```

## Part IV - Analysis

### D1. Split the data into training and test data sets and provide the file(s).

```
In [19]: df.head()
```

Out[19]:

	Children	Age	Income	Outage_sec_perweek	Email	Contacts	Yearly equip_f
0	-0.972338	0.720925	28561.99	-0.679978	-0.666282	-1.005852	0.9
1	-0.506592	-1.259957	21704.77	0.570331	-0.005288	-1.005852	0.9
2	0.890646	-0.148730	9609.57	0.252347	-0.996779	-1.005852	0.9
3	-0.506592	-0.245359	18925.23	1.650506	0.986203	1.017588	-0.6
4	-0.972338	1.445638	40074.19	-0.623156	1.316700	1.017588	0.9

```
In [20]: # split the dataframe between independent and dependent variables
X = df.drop('Churn',axis= 1)
y = df[['Churn']]

X.head()
y.head()
```

Out[20]:

	Children	Age	Income	Outage_sec_perweek	Email	Contacts	Yearly equip_f
0	-0.972338	0.720925	28561.99	-0.679978	-0.666282	-1.005852	0.9
1	-0.506592	-1.259957	21704.77	0.570331	-0.005288	-1.005852	0.9
2	0.890646	-0.148730	9609.57	0.252347	-0.996779	-1.005852	0.9
3	-0.506592	-0.245359	18925.23	1.650506	0.986203	1.017588	-0.6
4	-0.972338	1.445638	40074.19	-0.623156	1.316700	1.017588	0.9

Out[20]:

	Churn
0	0
1	1
2	0
3	0
4	1

```
In [21]: # split train and test
X_train, X_test, y_train, y_test = train_test_split(X, y, train_size = 0.8, test_si
```

```
In [22]: sm = SMOTE(random_state=493)
X_train, y_train = sm.fit_resample(X_train, y_train)
```

```
In [23]: X_train.to_csv('X_train2.csv')
X_test.to_csv('X_test2.csv')
y_train.to_csv('y_train2.csv')
y_test.to_csv('y_test2.csv')
```

## D2. Describe the analysis technique you used to appropriately analyze the data. Include screenshots of the intermediate calculations you performed.

Initially, I used a very simple Random Forest classifier with default parameters. The accuracy was okay (85%) and the AUC score of 92%. This is certainly good enough but it could be better! With the help of GridSearchCV() I was able to determine the optimal number of max\_depth to 14. My optimized model increased to an accuracy of 89% and an AUC score of 94%.

- Best number of max\_depth is 14
- n\_jobs: to use all cpu
- K-folds: 5 fold

The best number of max\_depth is 14 as determined when using GridSearchCV(). The number of k-folds we used is 5, and we're using all cpu's to run the jobs. We're also using the default parameters for everything else.

In the end, the parameter that made the most difference is the number of max\_depth.

## D3. Provide the code used to perform the classification analysis from part D2.

```
In [24]: # create model
clf0 = RandomForestClassifier(max_depth=2, random_state=0)

# fit the model
clf0.fit(X_train, y_train['Churn'])

# make predictions
y_pred = clf0.predict(X_test)
```

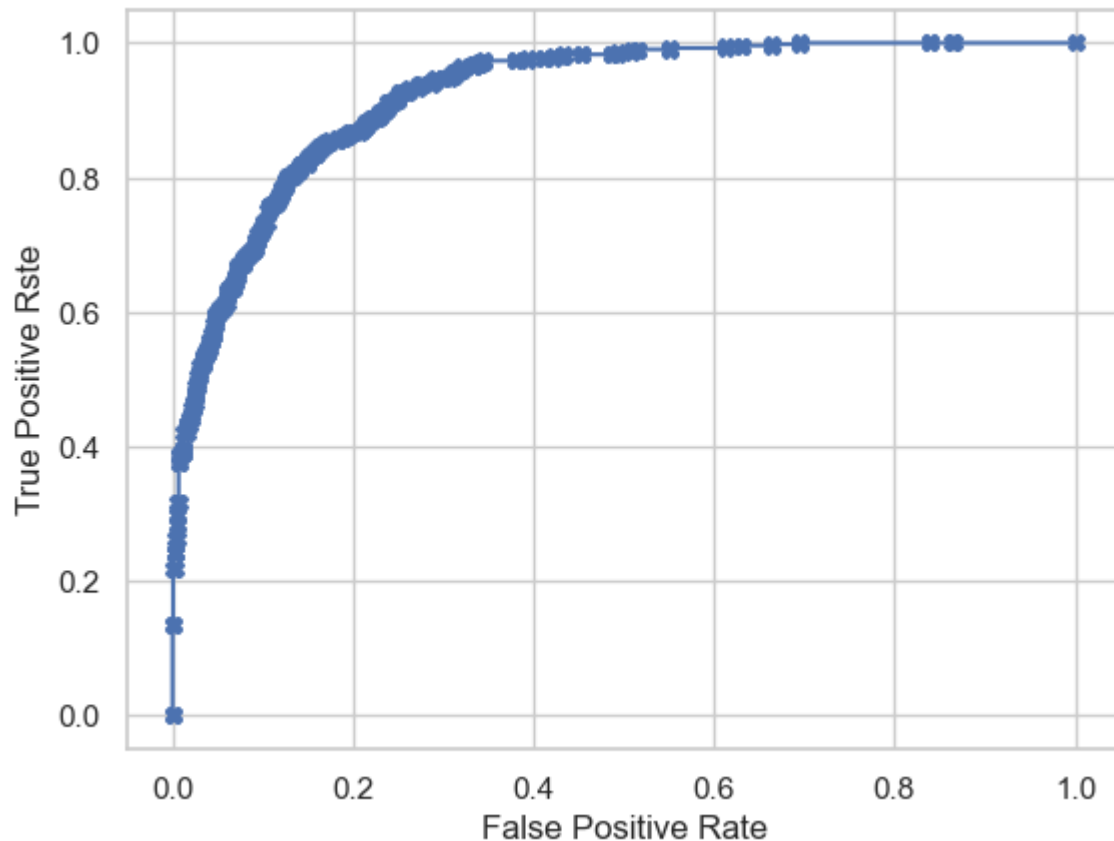
```
Out[24]: ▼      RandomForestClassifier
RandomForestClassifier(max_depth=2, random_state=0)
```

```
In [25]: # print the accuracy score
print("=====")
print("Accuracy score: " + str(clf0.score(X_test, y_test)))
print("=====")
print("Confusion matrix: \n" + str(confusion_matrix(y_test, y_pred)))
print("-----")
y_predicted_proba = clf0.predict_proba(X_test)[:,-1]
print("AUC score: " + str(roc_auc_score(y_test, y_predicted_proba)))
print("MSE: " + str(mean_squared_error(y_test, y_pred)))
```

```
=====
Accuracy score: 0.853
=====
Confusion matrix:
[[1297  173]
 [ 121  409]]
-----
AUC score: 0.9230490309331278
MSE: 0.147
```

```
In [26]: def viz_roc(model, X_test, y_test):
    probs = model.predict_proba(X_test)
    fpr, tpr, _ = roc_curve(y_test, probs[:,1])
    plt.plot(fpr, tpr, marker="X")
    plt.xlabel("False Positive Rate")
    plt.ylabel("True Positive Rste")
    plt.show()

viz_roc(clf0, X_test, y_test)
```



```
In [27]: clf0.get_params()
```

```
Out[27]: {'bootstrap': True,
          'ccp_alpha': 0.0,
          'class_weight': None,
          'criterion': 'gini',
          'max_depth': 2,
          'max_features': 'sqrt',
          'max_leaf_nodes': None,
          'max_samples': None,
          'min_impurity_decrease': 0.0,
          'min_samples_leaf': 1,
          'min_samples_split': 2,
          'min_weight_fraction_leaf': 0.0,
          'n_estimators': 100,
          'n_jobs': None,
          'oob_score': False,
          'random_state': 0,
          'verbose': 0,
          'warm_start': False}
```

```
In [28]: # Create the parameter grid based on the results of random search
param_grid = {
    'max_depth': np.arange(2,20),
}
```

```
In [29]: clf1 = RandomForestClassifier(random_state=493)
```

```
In [30]: # Instantiate the grid search model
grid_search = GridSearchCV(estimator = clf1, param_grid = param_grid,
                           cv = 5, n_jobs = -1, verbose = 2)
```

```
In [31]: # Fit the grid search to the data
grid_search.fit(X_train, y_train['Churn'])
grid_search.best_params_
```

Fitting 5 folds for each of 18 candidates, totalling 90 fits

```
Out[31]:
└─ GridSearchCV
  └─ estimator: RandomForestClassifier
    └─ RandomForestClassifier
```

```
Out[31]: {'max_depth': 14}
```

```
In [32]: print("Best params: " + str(grid_search.best_params_))
```

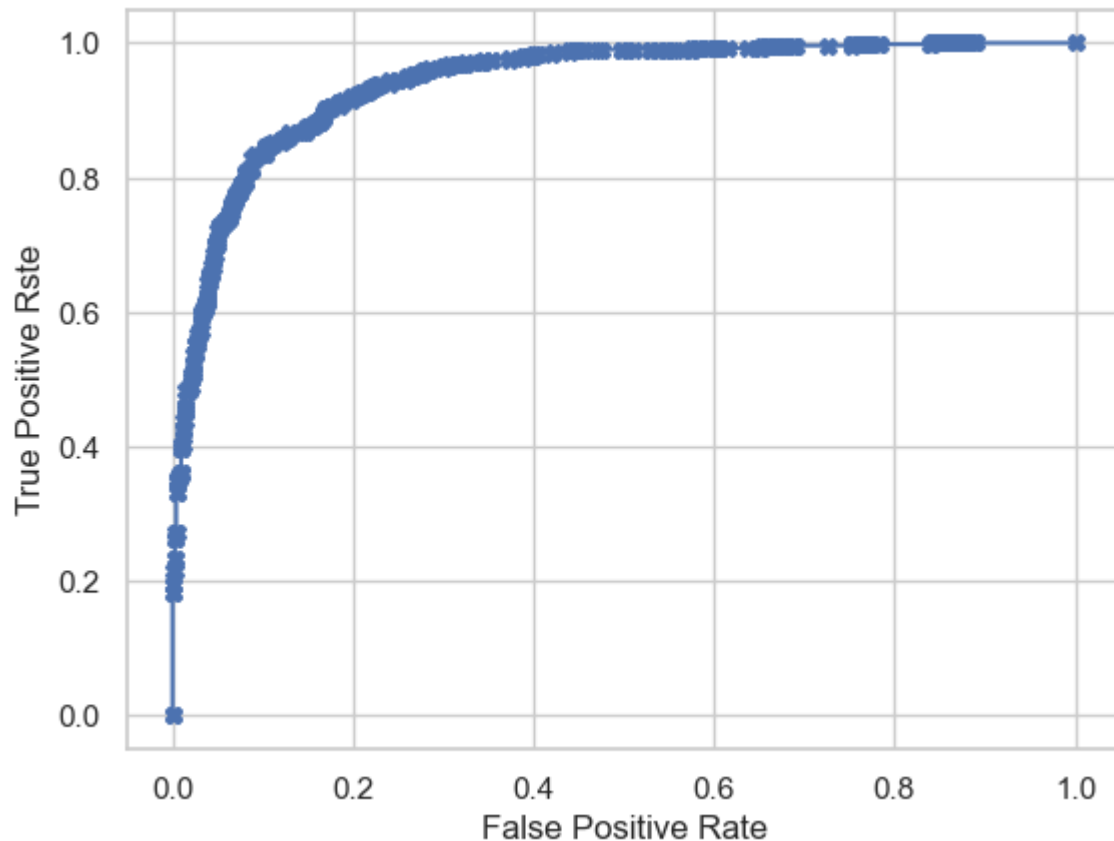
Best params: {'max\_depth': 14}

```
In [33]: # make predictions
y_pred = grid_search.predict(X_test)
```

```
In [34]: # print the accuracy score
print("=====")
print("Accuracy score: " + str(grid_search.score(X_test, y_test)))
print("=====")
print("Confusion matrix: \n" + str(confusion_matrix(y_test, y_pred)))
print("-----")
y_predicted_proba = grid_search.predict_proba(X_test)[:,1]
print("AUC score: " + str(roc_auc_score(y_test, y_predicted_proba)))
print("MSE: " + str(mean_squared_error(y_test, y_pred)))
```

```
=====
Accuracy score: 0.887
=====
Confusion matrix:
[[1383   87]
 [ 139 391]]
-----
AUC score: 0.9416602490052625
MSE: 0.113
```

```
In [35]: viz_roc(grid_search, X_test, y_test)
```



## E1. Explain the accuracy and the area-under-the-curve (AUC) of your classification model.

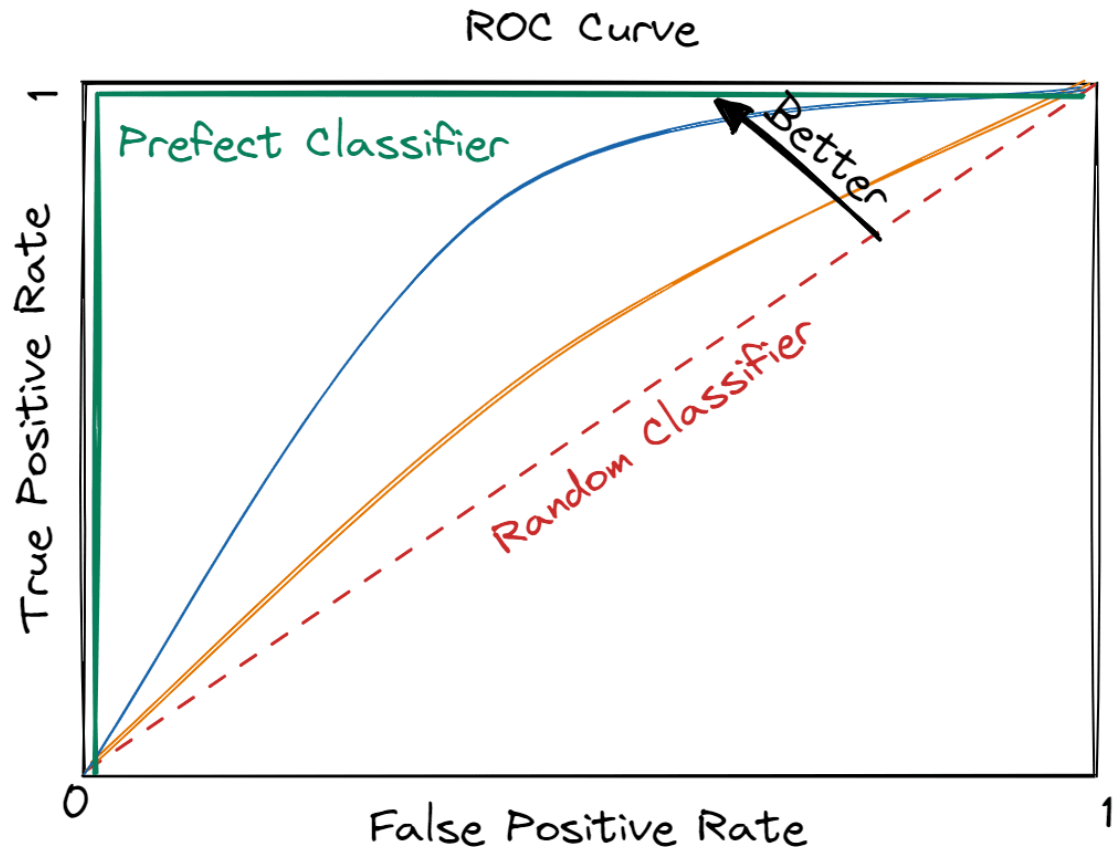
As mentioned, the accuracy, AUC, and MSE scores of the initial model are 0.85, 0.92, and 0.14, respectively, while the optimized model has an accuracy of 0.89, AUC score of 0.94, and MSE of 0.11. This means that the initial was able to predict correctly 85% of the time, while the optimized model was able to predict correctly 94% of the time. Conversely, we're better off looking at AUC because "it calibrates the trade-off between sensitivity and specificity at the best-chosen threshold" (Chugh, 2022).

## E2. Discuss the results and implications of your classification analysis.

An untrained, no-skill predictor has an AUC of 0.5. As the ROC plot shows, the curve nearly hugs the upper left corner of the graph which depicts the AUC score of 94%, which basically means 6 points less than perfect! This has great implications because this means that the organization can predict which customers will churn and be correct approximately 94% of the time. Practically, our model can power an advanced warning system for churn candidates. The marketing department can use this warning system to inform who to target for mitigation purposes, increasing the retention rate for the organization.

In [36]: `Image(url='https://www.kdnuggets.com/wp-content/uploads/chugh_metric_accuracy_auc_2`

Out[36]:



### E3. Discuss one limitation of your data analysis.

One limitation of our analysis lies in the data set used. Random forest is highly sensitive to imbalanced data sets and hence will need to be resampled. In this case, we used SMOTE to resample the data set.

### E4. Recommend a course of action for the real-world organizational situation from part A1 based on your results and implications discussed in part E2.

Based on the optimized RF model's favorable result, I recommend that the organization begin the effort to productionize this model and deploy it at scale.

### F. Provide a Panopto video recording that includes a demonstration of the functionality of the code used for the analysis and a summary of the programming environment.

URL: <https://wgu.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=355e3231-33b6-47fb-a34e-b05b0167d4a7>

## G. Record the web sources used to acquire data or segments of third-party code to support the analysis. Ensure the web sources are reliable.

- <https://towardsdatascience.com/applying-smote-for-class-imbalance-with-just-a-few-lines-of-code-python-cdf603e58688>
- <https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html>
- <https://towardsdatascience.com/hyperparameter-tuning-the-random-forest-in-python-using-scikit-learn-28d2aa77dd74>
- [https://scikit-learn.org/stable/modules/generated/sklearn.model\\_selection.GridSearchCV.html](https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html)
- [https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc\\_curve.html](https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html)
- [https://scikit-learn.org/stable/modules/generated/sklearn.metrics.mean\\_squared\\_error.html](https://scikit-learn.org/stable/modules/generated/sklearn.metrics.mean_squared_error.html)
- De Dios, EC. 2023. D209 Task 1 Performance Assessment.

## H. Acknowledge sources, using in-text citations and references, for content that is quoted, paraphrased, or summarized.

- <https://www.analyticsvidhya.com/blog/2021/06/understanding-random-forest/>
- ■ De Dios, EC. 2023. D209 Task 1 Performance Assessment.

```
In [37]: print("Successful run!")
```

Successful run!