In [2]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

In [3]:
```
# Import churn.csv
telco = pd.read_csv('../data/telco_data.csv')
telco
```

Out[3]:

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins	Intl_Mins
0	128	25	265.1	197.4	244.7	10.0
1	107	26	161.6	195.5	254.4	13.7
2	137	0	243.4	121.2	162.6	12.2
3	84	0	299.4	61.9	196.9	6.6
4	75	0	166.7	148.3	186.9	10.1
...	...	...	...	...	...	...
3328	192	36	156.2	215.5	279.1	9.9
3329	68	0	231.1	153.4	191.3	9.6
3330	28	0	180.8	288.8	191.9	14.1
3331	184	0	213.8	159.6	139.2	5.0
3332	74	25	234.4	265.9	241.4	13.7

3333 rows × 21 columns

EDA

In [465…
```
telco.head()
```

Out [465…

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins	Intl_Mins	Cus
0	128	25	265.1	197.4	244.7	10.0	
1	107	26	161.6	195.5	254.4	13.7	
2	137	0	243.4	121.2	162.6	12.2	
3	84	0	299.4	61.9	196.9	6.6	
4	75	0	166.7	148.3	186.9	10.1	

5 rows × 21 columns

In [471…

```
telco.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3333 entries, 0 to 3332
Data columns (total 21 columns):
 #   Column          Non-Null Count  Dtype  
---  ------          --------------  -----  
 0   Account_Length  3333 non-null   int64  
 1   Vmail_Message   3333 non-null   int64  
 2   Day_Mins        3333 non-null   float64
 3   Eve_Mins        3333 non-null   float64
 4   Night_Mins      3333 non-null   float64
 5   Intl_Mins       3333 non-null   float64
 6   CustServ_Calls  3333 non-null   int64  
 7   Churn           3333 non-null   int64  
 8   Intl_Plan       3333 non-null   int64  
 9   Vmail_Plan      3333 non-null   int64  
 10  Day_Calls       3333 non-null   int64  
 11  Day_Charge      3333 non-null   float64
 12  Eve_Calls       3333 non-null   int64  
 13  Eve_Charge      3333 non-null   float64
 14  Night_Calls     3333 non-null   int64  
 15  Night_Charge    3333 non-null   float64
 16  Intl_Calls      3333 non-null   int64  
 17  Intl_Charge     3333 non-null   float64
 18  State           3333 non-null   object 
 19  Area_Code       3333 non-null   int64  
 20  Phone           3333 non-null   object 
dtypes: float64(8), int64(11), object(2)
memory usage: 546.9+ KB
```

In [467…

```
telco.describe()
```

Out[467…

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins	
count	3333.000000	3333.000000	3333.000000	3333.000000	3333.000000	33
mean	101.064806	8.099010	179.775098	200.980348	200.872037	
std	39.822106	13.688365	54.467389	50.713844	50.573847	
min	1.000000	0.000000	0.000000	0.000000	23.200000	
25%	74.000000	0.000000	143.700000	166.600000	167.000000	
50%	101.000000	0.000000	179.400000	201.400000	201.200000	
75%	127.000000	20.000000	216.400000	235.300000	235.300000	
max	243.000000	51.000000	350.800000	363.700000	395.000000	

In [427…

```
telco['Churn'].value_counts()
```

Out[427…

```
Churn
no     2850
yes     483
Name: count, dtype: int64
```

In [428…

```
# Group telco by 'Churn' and compute the mean
telco.groupby(['Churn']).mean(numeric_only=True)

# Adapt your code to compute the standard deviation
telco.groupby(['Churn']).std(numeric_only=True)
```

Out[428…

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins	Intl_Mins
Churn						
no	39.88235	13.913125	50.181655	50.292175	51.105032	2.784489
yes	39.46782	11.860138	68.997792	51.728910	47.132825	2.793190

In [429…

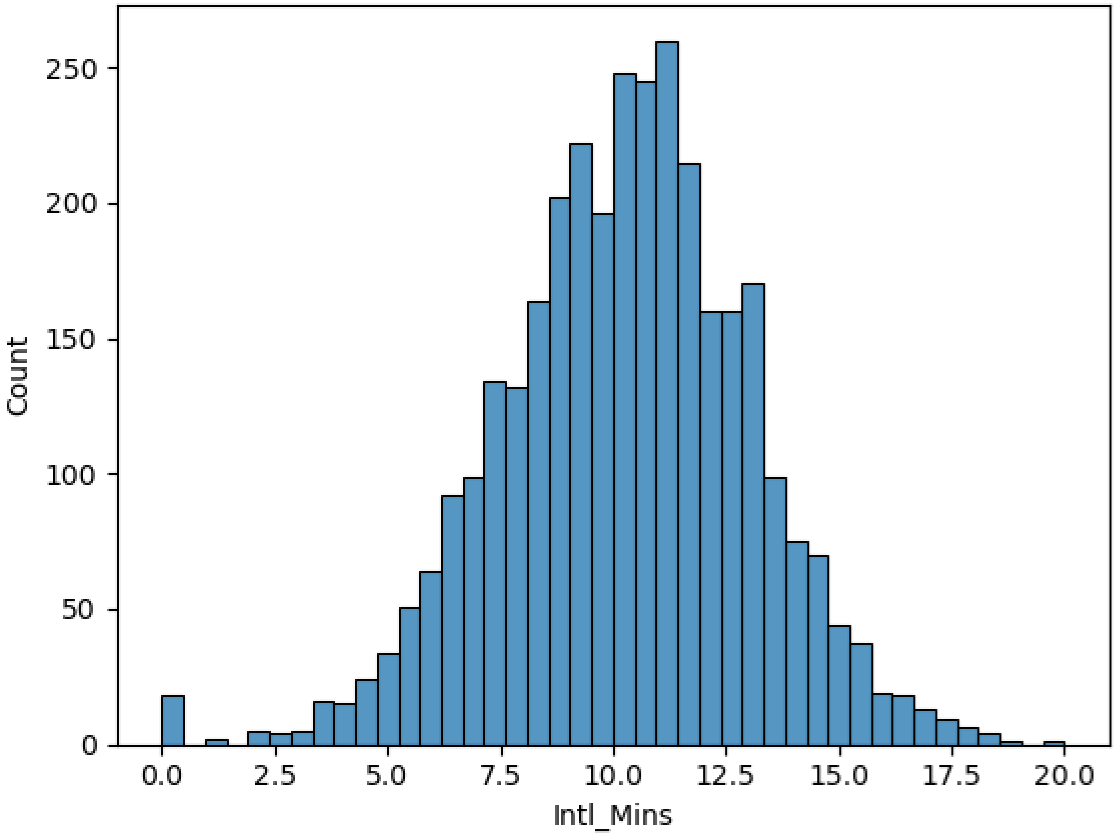
```
# Count the number of churners and non-churners by State
telco.groupby('State')['Churn'].value_counts()

# Filter the data to show only California
telco[telco['State'] == 'CA'].groupby('State')['Churn'].value_counts()
```

Out[429…

```
State  Churn
CA     no       25
       yes       9
Name: count, dtype: int64
```

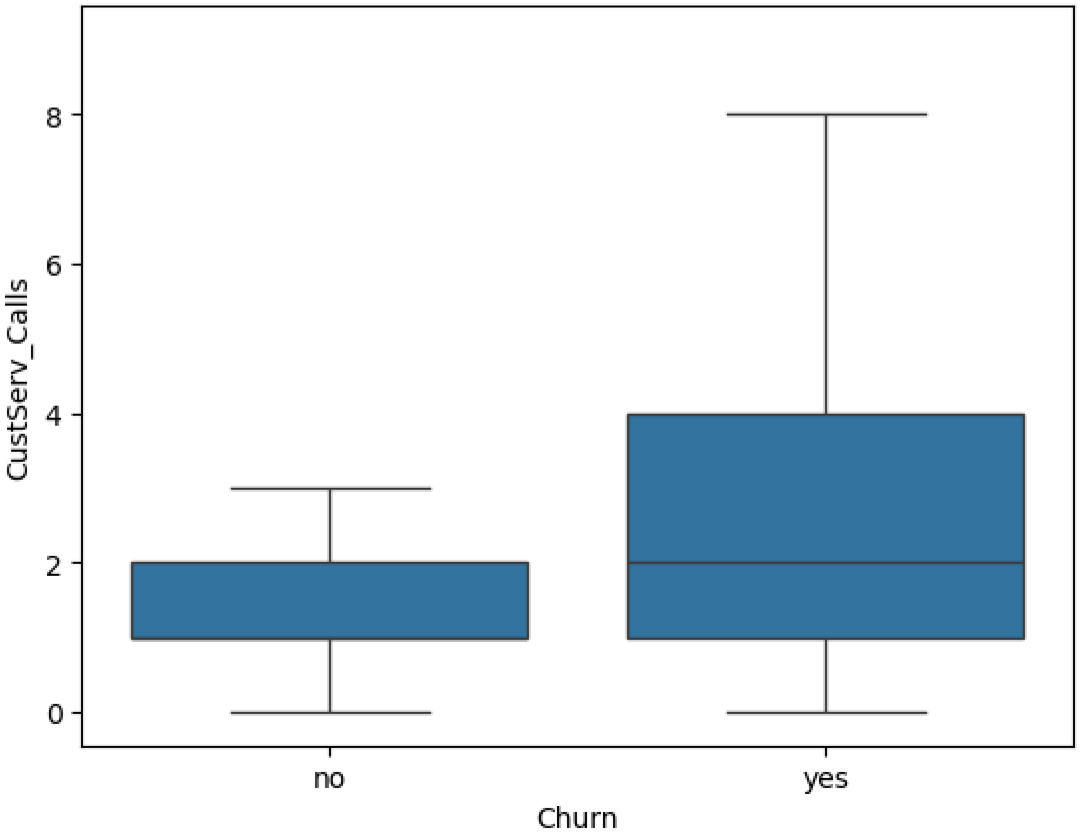
In [430…

```
# Visualize the distribution of 'Intl_Mins'
sns.histplot(telco['Intl_Mins'])

# Display the plot
plt.show()
```



In [431…

```
# Add "Intl_Plan" as a third variable
sns.boxplot(x = 'Churn',
            y = 'CustServ_Calls',
            data = telco,
            fliersize = 0, # Remove outliers
            # hue = "Intl_Plan" # Add third variable
            )

# Display the plot
plt.show()
```



Data Preprocessing

Encoding Binary Features

In [468…

```
pd.set_option('future.no_silent_downcasting', True)

# Replace 'no' with 0 and 'yes' with 1 in 'Vmail_Plan'
# telco['Vmail_Plan'] = telco['Vmail_Plan'].replace({'no': 0 , 'yes': 1})
telco['Vmail_Plan'] = telco['Vmail_Plan'].replace({'no': 0 , 'yes': 1}).infe

# Replace 'no' with 0 and 'yes' with 1 in 'Churn'
# telco['Churn'] = telco['Churn'].replace({'no': 0 , 'yes': 1})
telco['Churn'] = telco['Churn'].replace({'no': 0 , 'yes': 1}).infer_objects(

# Print the results to verify
print(telco['Vmail_Plan'].head())
print(telco['Churn'].head())
```

```
0    1
1    1
2    0
3    0
4    0
Name: Vmail_Plan, dtype: int64
0    0
1    0
2    0
3    0
4    0
Name: Churn, dtype: int64
```

Encoding Categorical Features using One-Hot Encoding

In [469…

```
telco_state = pd.get_dummies(telco, columns=['State'], drop_first=True)
telco_state
```

Out[469…

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins	Intl_Mins
0	128	25	265.1	197.4	244.7	10.0
1	107	26	161.6	195.5	254.4	13.7
2	137	0	243.4	121.2	162.6	12.2
3	84	0	299.4	61.9	196.9	6.6
4	75	0	166.7	148.3	186.9	10.1
...	...	...	...	...	...	...
3328	192	36	156.2	215.5	279.1	9.9
3329	68	0	231.1	153.4	191.3	9.6
3330	28	0	180.8	288.8	191.9	14.1
3331	184	0	213.8	159.6	139.2	5.0
3332	74	25	234.4	265.9	241.4	13.7

3333 rows × 70 columns

In [470…

```
# Encode categorical columns
telco['Intl_Plan'] = LabelEncoder().fit_transform(telco['Intl_Plan'])
```

Feature Scaling using Standardization

In [472…

```
# Import StandardScaler
from sklearn.preprocessing import StandardScaler

# Select only the numeric columns for scaling
numeric_cols = telco.select_dtypes(include=['float64', 'int64']).columns

# Scale telco
telco_scaled = StandardScaler().fit_transform(telco[numeric_cols])
```

```python
# Add column names back for readability
telco_scaled_df = pd.DataFrame(telco_scaled, columns=numeric_cols)

# Print summary statistics
print(telco_scaled_df.describe())
```

```
       Account_Length  Vmail_Message      Day_Mins      Eve_Mins  \
count    3.333000e+03   3.333000e+03  3.333000e+03  3.333000e+03
mean     1.470971e-16   7.035077e-17  7.312216e-16 -6.821892e-17
std      1.000150e+00   1.000150e+00  1.000150e+00  1.000150e+00
min     -2.513172e+00  -5.917599e-01 -3.301096e+00 -3.963622e+00
25%     -6.797448e-01  -5.917599e-01 -6.624241e-01 -6.780300e-01
50%     -1.627644e-03  -5.917599e-01 -6.887677e-03  8.276141e-03
75%      6.513740e-01   8.695542e-01  6.725198e-01  6.768330e-01
max      3.564766e+00   3.134591e+00  3.140422e+00  3.209066e+00

         Night_Mins     Intl_Mins  CustServ_Calls         Churn     Intl_Pla
n  \
count  3.333000e+03  3.333000e+03    3.333000e+03  3.333000e+03  3.333000e+0
3
mean   7.887813e-17 -3.336332e-16    8.527366e-18  5.542788e-17 -4.796643e-1
7
std    1.000150e+00  1.000150e+00    1.000150e+00  1.000150e+00  1.000150e+0
0
min   -3.513648e+00 -3.667413e+00   -1.188218e+00 -4.116718e-01 -3.275805e-0
1
25%   -6.698545e-01 -6.223690e-01   -4.279320e-01 -4.116718e-01 -3.275805e-0
1
50%    6.485803e-03  2.246393e-02   -4.279320e-01 -4.116718e-01 -3.275805e-0
1
75%    6.808485e-01  6.672969e-01    3.323545e-01 -4.116718e-01 -3.275805e-0
1
max    3.839081e+00  3.497397e+00    5.654360e+00  2.429119e+00  3.052685e+0
0

         Vmail_Plan     Day_Calls    Day_Charge     Eve_Calls    Eve_Charge
\
count  3.333000e+03  3.333000e+03  3.333000e+03  3.333000e+03  3.333000e+03
mean  -6.608708e-17 -1.934646e-16 -2.835349e-16  3.288365e-16  1.385697e-16
std    1.000150e+00  1.000150e+00  1.000150e+00  1.000150e+00  1.000150e+00
min   -6.183963e-01 -5.005247e+00 -3.301162e+00 -5.025911e+00 -3.963679e+00
25%   -6.183963e-01 -6.695701e-01 -6.623760e-01 -6.583610e-01 -6.783123e-01
50%   -6.183963e-01  2.812491e-02 -6.730063e-03 -5.738630e-03  8.459274e-03
75%    1.617086e+00  6.759846e-01  6.726790e-01  6.970854e-01  6.766695e-01
max    1.617086e+00  3.217588e+00  3.140803e+00  3.508382e+00  3.207980e+00

        Night_Calls  Night_Charge    Intl_Calls   Intl_Charge     Area_Code
count  3.333000e+03  3.333000e+03  3.333000e+03  3.333000e+03  3.333000e+03
mean  -4.903235e-17 -4.370275e-17 -8.527366e-18  2.728757e-16  4.221046e-16
std    1.000150e+00  1.000150e+00  1.000150e+00  1.000150e+00  1.000150e+00
min   -3.429870e+00 -3.515366e+00 -1.820289e+00 -3.668210e+00 -6.888343e-01
25%   -6.699340e-01 -6.676792e-01 -6.011951e-01 -6.164341e-01 -6.888343e-01
50%   -5.505089e-03  4.691242e-03 -1.948306e-01  2.045823e-02 -5.236033e-01
75%    6.589239e-01  6.814562e-01  6.178983e-01  6.706192e-01  1.718817e+00
max    3.827739e+00  3.836763e+00  6.307001e+00  3.496829e+00  1.718817e+00
```

In [473…

```
# Select only the "Intl_Calls" and "Night_Mins" columns
selected_cols = ['Intl_Calls', 'Night_Mins']
telco_selected_scaled_df = telco_scaled_df[selected_cols]
telco_selected_scaled_df.describe()
```

Out[473…

	Intl_Calls	Night_Mins
count	3.333000e+03	3.333000e+03
mean	-8.527366e-18	7.887813e-17
std	1.000150e+00	1.000150e+00
min	-1.820289e+00	-3.513648e+00
25%	-6.011951e-01	-6.698545e-01
50%	-1.948306e-01	6.485803e-03
75%	6.178983e-01	6.808485e-01
max	6.307001e+00	3.839081e+00

Feature Selection

In [474…

```
# Drop the unnecessary features
telco = telco.drop(telco[['Area_Code','Phone']], axis=1)

# Verify dropped features
print(telco.columns)
```

```
Index(['Account_Length', 'Vmail_Message', 'Day_Mins', 'Eve_Mins', 'Night_Min
s',
       'Intl_Mins', 'CustServ_Calls', 'Churn', 'Intl_Plan', 'Vmail_Plan',
       'Day_Calls', 'Day_Charge', 'Eve_Calls', 'Eve_Charge', 'Night_Calls',
       'Night_Charge', 'Intl_Calls', 'Intl_Charge', 'State'],
      dtype='object')
```

In [479…

```
telco = telco.drop(telco[['State']], axis=1)
```

In [475…

```
# Select only numeric columns for correlation computation
numeric_telco = telco.select_dtypes(include=['float64', 'int64'])
numeric_telco.corr()  # Identify correlated features
```

Out [475…

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins
Account_Length	1.000000	-0.004628	0.006216	-0.006757	-0.008955
Vmail_Message	-0.004628	1.000000	0.000778	0.017562	0.007681
Day_Mins	0.006216	0.000778	1.000000	0.007043	0.004323
Eve_Mins	-0.006757	0.017562	0.007043	1.000000	-0.012584
Night_Mins	-0.008955	0.007681	0.004323	-0.012584	1.000000
Intl_Mins	0.009514	0.002856	-0.010155	-0.011035	-0.015207
CustServ_Calls	-0.003796	-0.013263	-0.013423	-0.012985	-0.009288
Churn	0.016541	-0.089728	0.205151	0.092796	0.035493
Intl_Plan	0.024735	0.008745	0.049396	0.019100	-0.028905
Vmail_Plan	0.002918	0.956927	-0.001684	0.021545	0.006079
Day_Calls	0.038470	-0.009548	0.006750	-0.021451	0.022938
Day_Charge	0.006214	0.000776	1.000000	0.007050	0.004324
Eve_Calls	0.019260	-0.005864	0.015769	-0.011430	-0.002093
Eve_Charge	-0.006745	0.017578	0.007029	1.000000	-0.012592
Night_Calls	-0.013176	0.007123	0.022972	0.007586	0.011204
Night_Charge	-0.008960	0.007663	0.004300	-0.012593	0.999999
Intl_Calls	0.020661	0.013957	0.008033	0.002541	-0.012353
Intl_Charge	0.009546	0.002884	-0.010092	-0.011067	-0.015180

In [476…

```
# Compute the correlation matrix
corr_matrix = numeric_telco.corr().abs()

# Select the upper triangle of the correlation matrix
upper = corr_matrix.where(np.triu(np.ones(corr_matrix.shape), k=1).astype(bo
upper
```

Out[476…

	Account_Length	Vmail_Message	Day_Mins	Eve_Mins	Night_Mins
Account_Length	NaN	0.004628	0.006216	0.006757	0.008955
Vmail_Message	NaN	NaN	0.000778	0.017562	0.007681
Day_Mins	NaN	NaN	NaN	0.007043	0.004323
Eve_Mins	NaN	NaN	NaN	NaN	0.012584
Night_Mins	NaN	NaN	NaN	NaN	NaN
Intl_Mins	NaN	NaN	NaN	NaN	NaN
CustServ_Calls	NaN	NaN	NaN	NaN	NaN
Churn	NaN	NaN	NaN	NaN	NaN
Intl_Plan	NaN	NaN	NaN	NaN	NaN
Vmail_Plan	NaN	NaN	NaN	NaN	NaN
Day_Calls	NaN	NaN	NaN	NaN	NaN
Day_Charge	NaN	NaN	NaN	NaN	NaN
Eve_Calls	NaN	NaN	NaN	NaN	NaN
Eve_Charge	NaN	NaN	NaN	NaN	NaN
Night_Calls	NaN	NaN	NaN	NaN	NaN
Night_Charge	NaN	NaN	NaN	NaN	NaN
Intl_Calls	NaN	NaN	NaN	NaN	NaN
Intl_Charge	NaN	NaN	NaN	NaN	NaN

In [477…

```
# Find features with correlation greater than a specified threshold (e.g., 0
threshold = 0.8
to_drop = [column for column in upper.columns if any(upper[column] > thresho
to_drop
```

Out[477…

```
['Vmail_Plan', 'Day_Charge', 'Eve_Charge', 'Night_Charge', 'Intl_Charge']
```

In [441…

```
# # Drop the highly correlated features
# numeric_telco_filtered = numeric_telco.drop(columns=to_drop)

# # Display the filtered dataframe
# numeric_telco_filtered.head()
```

In [478…

```
# Create the new feature
telco['Avg_Night_Calls'] = telco['Night_Mins'] / telco['Night_Calls']

# Print the first five rows of 'Avg_Night_Calls'
print(telco['Avg_Night_Calls'].head())
```

```
0    2.689011
1    2.469903
2    1.563462
3    2.212360
4    1.544628
Name: Avg_Night_Calls, dtype: float64
```

Churn Prediction

Model Selection

- Logistic Regression: Good baseline, interpretable.
- Random Forests: Captures complex relationships.
- Support Vector Machines (SVMs): Effective with high-dimensional data.

In [480…

```
# Define the features
features = ['Account_Length', 'Vmail_Message', 'Day_Mins', 'Eve_Mins', 'Nigh

# Define a new customer for prediction
new_customer = pd.DataFrame({
        'Account_Length': [100],
        'Vmail_Message': [20],
        'Day_Mins': [200],
        'Eve_Mins': [150],
        'Night_Mins': [180],
        'Intl_Mins': [10],
        'CustServ_Calls': [2],
        'Day_Calls': [100],
        'Eve_Calls': [100],
        'Night_Calls': [100],
        'Intl_Calls': [5],
        # 'Area_Code': [415]
})
```

In [481…

```
# Import LogisticRegression
from sklearn.linear_model import LogisticRegression

# Instantiate the classifier
clf = LogisticRegression()

# Fit the classifier
clf.fit(telco[features], telco['Churn'])

# Predict the label of new_customer
print(clf.predict(new_customer))
```

```
[0]
```

```
/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/linear_mode
l/_logistic.py:469: ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regre
ssion
  n_iter_i = _check_optimize_result(
```

In [482…

```python
# Import DecisionTreeClassifier
from sklearn.tree import DecisionTreeClassifier

# Instantiate the classifier
clf = DecisionTreeClassifier()

# Fit the classifier
clf.fit(telco[features], telco['Churn'])

# Predict the label of new_customer
print(clf.predict(new_customer))
```

```
[0]
```

Model Evaluation

In [483…

```python
# Import train_test_split
from sklearn.model_selection import train_test_split

# Create feature variable
X = telco.drop('Churn', axis=1)

# Create target variable
y = telco['Churn']

# Create training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
```

In [484…

```python
print(X_train.shape)
print(X_test.shape)
print(len(X_test))
```

```
(2333, 18)
(1000, 18)
1000
```

In [485…

```python
from sklearn.preprocessing import LabelEncoder

# # Encode 'Intl_Plan' column
# le = LabelEncoder()
# X_train['Intl_Plan'] = le.fit_transform(X_train['Intl_Plan'])
# X_test['Intl_Plan'] = le.transform(X_test['Intl_Plan'])

# Import RandomForestClassifier
from sklearn.ensemble import RandomForestClassifier
```

```
# Instantiate the classifier
clf = RandomForestClassifier()

# Fit to the training data
clf.fit(X_train, y_train)

# Compute accuracy
print(clf.score(X_test, y_test))
```

```
0.955
```

In [486…

```
# Import confusion_matrix
from sklearn.metrics import confusion_matrix

# Make predictions on the test set
y_pred = clf.predict(X_test)

# Print the confusion matrix
print(confusion_matrix(y_test, y_pred))
```

```
[[862   3]
 [ 42  93]]
```

In [487…

```
# Create feature variable
X = telco.drop('Churn', axis=1)

# Create target variable
y = telco['Churn']
```

In [488…

```
# Import train_test_split
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder

# Create training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)

# Import RandomForestClassifier
from sklearn.ensemble import RandomForestClassifier

# Instantiate the classifier
clf = RandomForestClassifier()

# Fit to the training data
clf.fit(X_train, y_train)

# Predict the labels of the test set
y_pred = clf.predict(X_test)

# Import confusion_matrix
from sklearn.metrics import confusion_matrix

# Print confusion matrix
print(confusion_matrix(y_test, y_pred))
```

```
[[564   6]
 [ 25  72]]
```

In [489…

```python
# Import train_test_split
from sklearn.model_selection import train_test_split

# Create training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.1)

# Import RandomForestClassifier
from sklearn.ensemble import RandomForestClassifier

# Instantiate the classifier
clf = RandomForestClassifier()

# Fit to the training data
clf.fit(X_train, y_train)

# Predict the labels of the test set
y_pred = clf.predict(X_test)
```

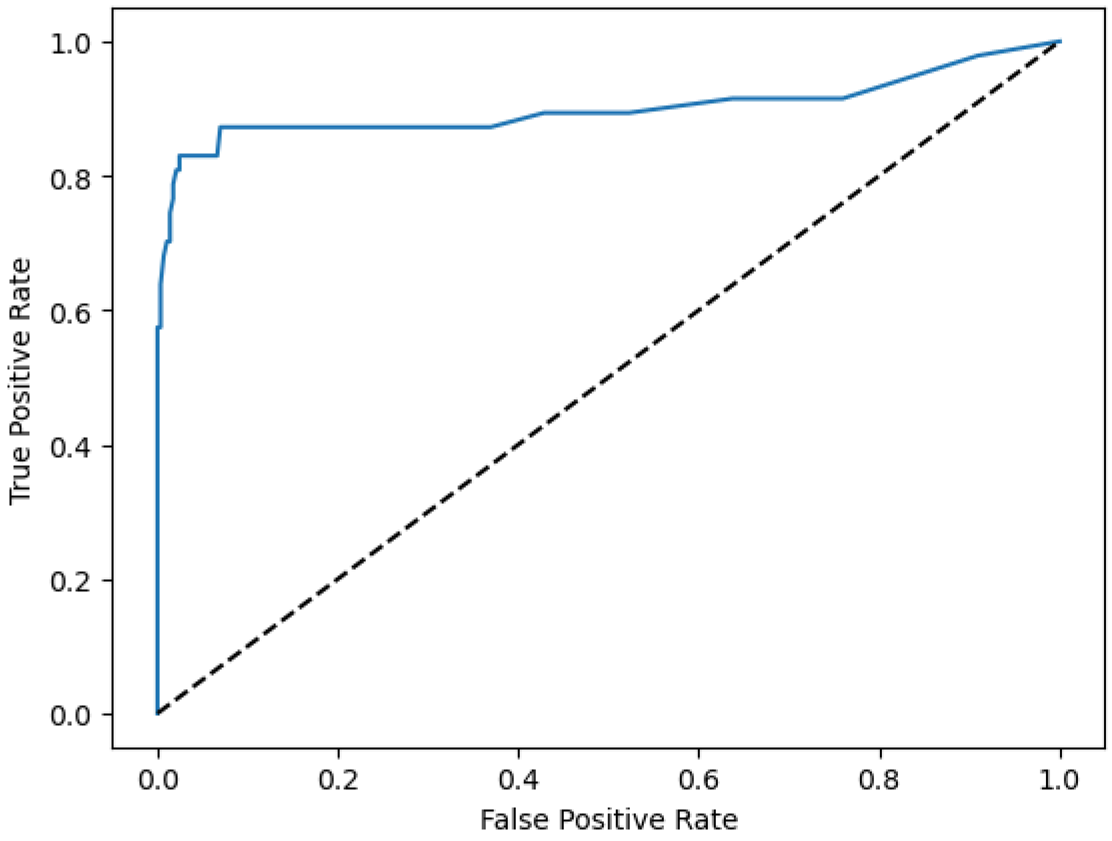
In [490…

```python
from sklearn.metrics import precision_score
from sklearn.metrics import recall_score

# Print the precision
print(precision_score(y_test, y_pred))

# Print the recall
print(recall_score(y_test, y_pred))
```

```
0.9666666666666667
0.6170212765957447
```

In [491…

```python
# Generate the probabilities
y_pred_prob = clf.predict_proba(X_test)[:, 1]

# Import roc_curve
from sklearn.metrics import roc_curve

# Calculate the roc metrics
fpr, tpr, thresholds = roc_curve(y_test, y_pred_prob)

# Plot the ROC curve
plt.plot(fpr, tpr)

# Add labels and diagonal line
plt.xlabel("False Positive Rate")
plt.ylabel("True Positive Rate")
plt.plot([0, 1], [0, 1], "k--")
plt.show()
```



In [456…

```
# Import roc_auc_score
from sklearn.metrics import roc_auc_score

# Print the AUC
print(roc_auc_score(y_test, y_pred_prob))
```

```
0.9515398550724639
```

In [492…

```
# Instantiate the classifier
clf = RandomForestClassifier()

# Fit to the training data
clf.fit(X_train, y_train)

# Predict the labels of the test set
y_pred = clf.predict(X_test)

# Import f1_score
from sklearn.metrics import f1_score

# Print the F1 score
print(f1_score(y_test, y_pred))
```

```
0.72
```

Model Tuning

In [493…

```
# Import GridSearchCV
from sklearn.model_selection import GridSearchCV
```

```
# Create the hyperparameter grid
param_grid = {'max_features': ['auto', 'sqrt', 'log2']}

# Call GridSearchCV
grid_search = GridSearchCV(clf, param_grid, cv=3)

# Fit the model
grid_search.fit(X, y)

# Print the optimal parameters
print(grid_search.best_params_)
```

```
/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/model_selec
tion/_validation.py:540: FitFailedWarning:
3 fits failed out of a total of 9.
The score on these train-test partitions for these parameters will be set to
nan.
If these failures are not expected, you can try to debug them by setting err
or_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
----
3 fits failed with the following error:
Traceback (most recent call last):
  File "/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/mod
el_selection/_validation.py", line 888, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/bas
e.py", line 1466, in wrapper
    estimator._validate_params()
  File "/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/bas
e.py", line 666, in _validate_params
    validate_parameter_constraints(
  File "/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/uti
ls/_param_validation.py", line 95, in validate_parameter_constraints
    raise InvalidParameterError(
sklearn.utils._param_validation.InvalidParameterError: The 'max_features' pa
rameter of RandomForestClassifier must be an int in the range [1, inf), a fl
oat in the range (0.0, 1.0], a str among {'sqrt', 'log2'} or None. Got 'aut
o' instead.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/opt/anaconda3/envs/example/lib/python3.12/site-packages/sklearn/model_selec
tion/_search.py:1103: UserWarning: One or more of the test scores are non-fi
nite: [       nan 0.95139514 0.95349535]
  warnings.warn(
{'max_features': 'log2'}
```

In [494…

```
# Import GridSearchCV
from sklearn.model_selection import GridSearchCV

# Create the hyperparameter grid
param_grid = {"max_depth": [3, None],
              "max_features": [1, 3, 10],
              "bootstrap": [True, False],
              "criterion": ["gini", "entropy"]}

# Call GridSearchCV
grid_search = GridSearchCV(clf, param_grid, cv=3)

# Fit the model
grid_search.fit(X, y)

# Print the best hyperparameters
print(grid_search.best_params_)
```

```
{'bootstrap': True, 'criterion': 'entropy', 'max_depth': None, 'max_feature
s': 10}
```

In [495…

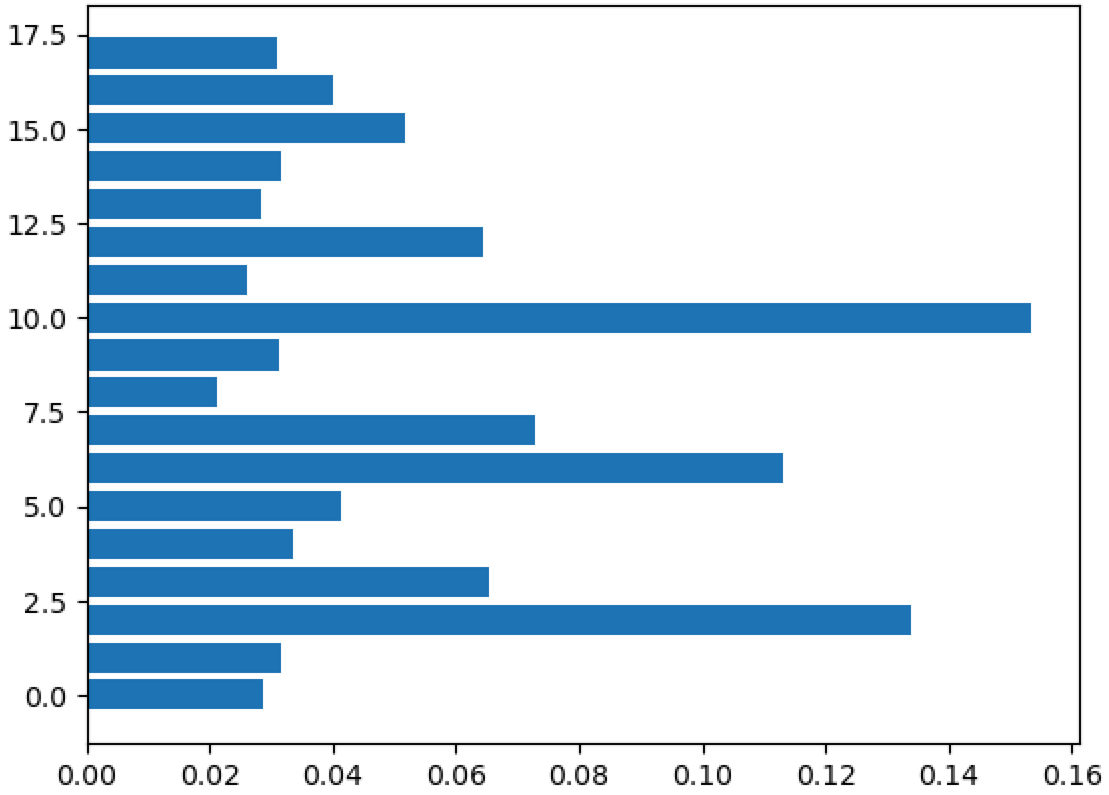
```
# Import RandomizedSearchCV
from sklearn.model_selection import RandomizedSearchCV
from scipy.stats import randint

# Create the hyperparameter grid
param_dist = {"max_depth": [3, None],
              "max_features": randint(1, 11),
              "bootstrap": [True, False],
              "criterion": ["gini", "entropy"]}

# Call RandomizedSearchCV
random_search = RandomizedSearchCV(clf, param_dist, cv=3)

# Fit the model
random_search.fit(X, y)

# Print best parameters
print(random_search.best_params_)
```

```
{'bootstrap': True, 'criterion': 'gini', 'max_depth': None, 'max_features':
10}
```

Feature Importance

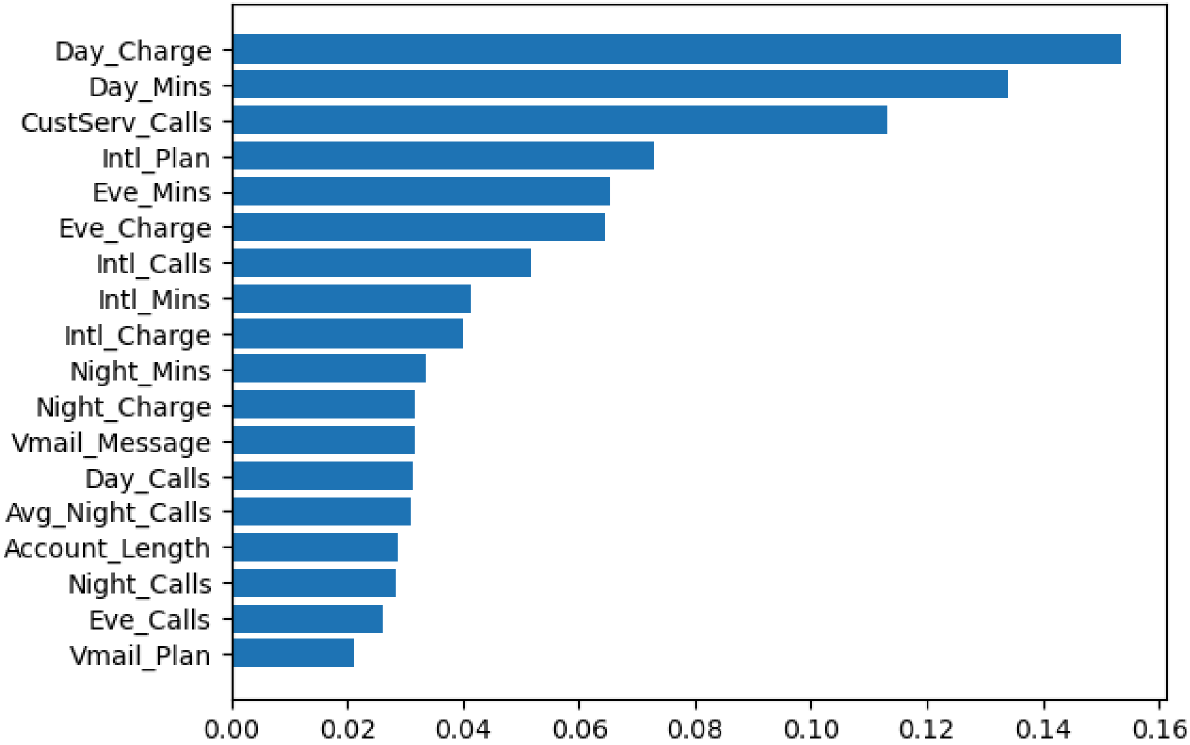
In [496…

```
# Calculate feature importances
importances = clf.feature_importances_

# Create plot
plt.barh(range(X.shape[1]), importances)
plt.show()
```



In [497…

```
# Sort importances
sorted_index = np.argsort(importances)

# Create labels
labels = X.columns[sorted_index]

# Clear current plot
plt.clf()

# Create plot
plt.barh(range(X.shape[1]), importances[sorted_index], tick_label=labels)
plt.show()
```



In [498…

```
# Import necessary modules
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestClassifier

# Create training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)

# Instantiate the classifier
clf = RandomForestClassifier()

# Fit to the data
clf.fit(X_train, y_train)

# Print the accuracy
print(clf.score(X_test, y_test))
```

```
0.95
```

In [499…

```
# Import f1_score
from sklearn.metrics import f1_score

# Instantiate the classifier
clf = RandomForestClassifier()

# Fit to the data
clf.fit(X_train, y_train)

# Predict the labels of the test set
y_pred = clf.predict(X_test)

# Print the F1 score
print(f1_score(y_test, y_pred))
```

```
0.7967479674796748
```