

MachineLearningandOptimization_CT7205_4107143_ChanySubasingha

July 26, 2022

1 Machine Learning Assignment Report

This report presents analysis of two datasets. Exploratory analysis has been carried out to understand data. Regression models, Classification models and Artificial Neural Networks have been used to train models to predict the target variable values.

Student Name: Chanya Subasingha Arachchige

Student Code: S4107143

Module Title: CT7205 - Machine Learning and Optimization

Module Tutor: Dr. Bhupesh Mishra

School of Computing and Technology

University of Gloucestershire

```
[993]: # Import libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error, r2_score, confusion_matrix, \
    classification_report, accuracy_score
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import GaussianNB
from sklearn import svm
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import AdaBoostClassifier
from sklearn.model_selection import GridSearchCV
import tensorflow as tf
from sklearn.preprocessing import LabelEncoder
from sklearn.preprocessing import StandardScaler
from sklearn.preprocessing import MinMaxScaler
import warnings
warnings.filterwarnings('ignore')
```

1.1 Question 1: Medical Insurance

1.1.1 Introduction

The dataset contains data on medical costs and related variables. People around the world use medical insurance to cover their medical costs such as hospital visits, doctor appointments, and surgeries. Insurance companies calculate premiums depending on the analysis of the insured person's health and lifestyle factors related to health. Some conditions are related to certain diseases, such as smoking related to lung cancer. Other factors such as the age of the person number of dependents under the insurance coverage are also important factors to consider to predict medical costs.

Identifying the relationship and approximate medical cost per individual helps insurance companies to manage insurance premiums more productively. The correct prediction helps insurance companies to offer better plans, and people get more value from their insurance plans. This analysis uses the below independent variables to predict the medical cost of an individual.

- age: age of the primary beneficiary
- sex: insurance contractor Sex: female or male
- bmi: body mass index calculated by weight in kilograms divided by the square of the height in centimetres
- children: number of children covered by health insurance
- smoker: yes or no
- region: the payees' residential area in the US, northeast, southeast, southwest, northwest
- medicalCost: individual medical costs billed by medical insurance.

1.1.2 Data Understanding

Examining the dataset more closely is a part of the data understanding step. This phase is essential for preventing unforeseen issues during data preparation and model training.

Accessing and exploring the dataset using tables and visualising using graphs are necessary for data interpretation. This permits the assessment of the data quality and selection of the most suitable data transformation and prediction models.

```
[994]: # Read data from csv to pandas dataframe
df1 = pd.read_csv('insurance.csv')
df1.head()
```

```
[994]:
```

	age	sex	bmi	children	smoker	region	medicalCost
0	19	female	27.900	0	yes	southwest	16884.92400
1	18	male	33.770	1	no	southeast	1725.55230
2	28	male	33.000	3	no	southeast	4449.46200
3	33	male	22.705	0	no	northwest	21984.47061
4	32	male	28.880	0	no	northwest	3866.85520

```
[995]: print('Number of rows and columns in the dataset: ', df1.shape)
print('The dataset has 1338 observations and seven variables, including six_
↳dependent variables and the target variable.')
```

Number of rows and columns in the dataset: (1338, 7)

The dataset has 1338 observations and seven variables, including six dependent variables and the target variable.

The distribution of the target variable is analysed to select a method to predict data. A histogram is used here because the target variable has continuous values.

```
[996]: # Distribution of the target class
medicalCost = df1[['medicalCost']].to_numpy()

plt.hist(medicalCost)
plt.xlabel('Medical Cost')
plt.ylabel('Frequency')
plt.title('Distribution of Medical Cost')
plt.show()
print('Figure 1: Distribution of the Medical Cost')
```

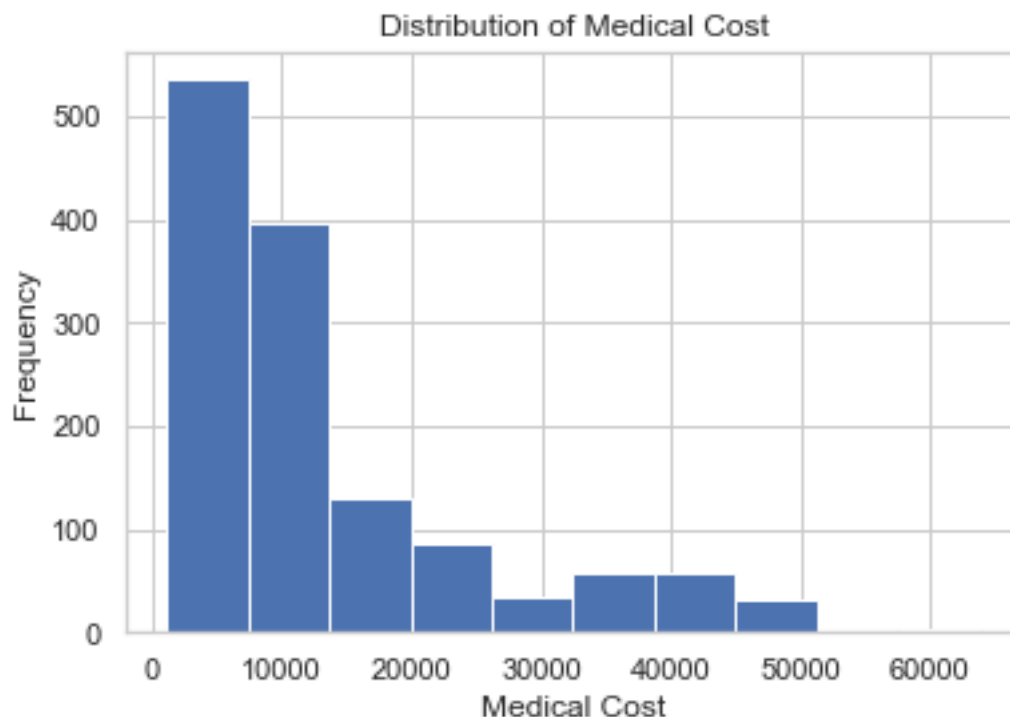


Figure 1: Distribution of the Medical Cost

The target variable, medical cost values are known and present in the dataset. Therefore, a supervised method is more suitable for predicting medical costs.

Since the target variable has continuous values, as shown in figure 1, regression analysis is better for predicting medical costs than classification or clustering. Additionally, for classification, labelled classes have to introduce to the medical cost variable and clustering is mainly done when the target class is unknown.

```
[997]: # Distribution of the log transformation of the target class
sns.histplot(np.log(df1['medicalCost']), bins=40,
              color='green', stat='count', kde=True)
plt.xlabel('Medical Cost in log scale')
plt.ylabel('Frequency')
plt.title('Distribution of Medical Cost in log scale')
plt.show()

print('Figure 2: Distribution of Medical Cost in log scale')
```

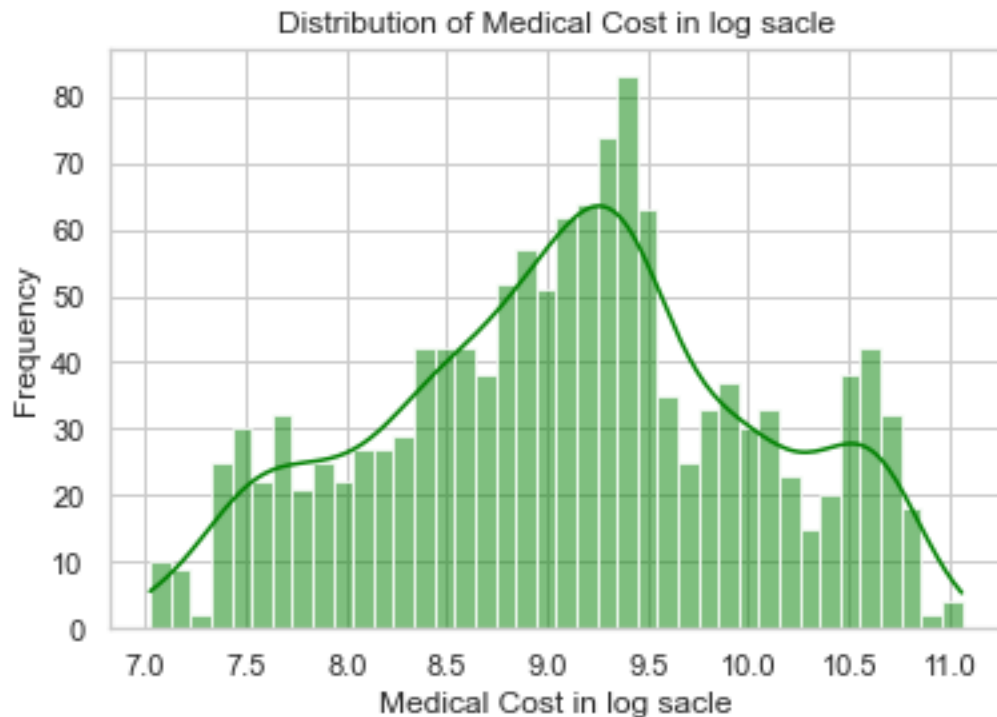


Figure 2: Distribution of Medical Cost in log scale

Medical cost is highly skewed. According to the figure 1, majority of the values lies below 2000, while maximum value exceeds 60000. Therefore, a log scale is used to visualise data in order to extract features of the dense area of the distribution. Log scale values of the medical cost show a distribution closer to a normal distribution. There are three modes and one of them is prominent.

```
[998]: # Percentage of values missing in each column
for column in df1.columns:
    percentage = df1[column].isnull().mean()
    print(f'{column}: {round(percentage*100,4)}%')
```

```
age: 0.0%
sex: 0.0%
bmi: 0.0%
```

```
children: 0.0%
smoker: 0.0%
region: 0.0%
medicalCost: 0.0%
```

Analysis of missing values found that there are no missing values in the dataset.

```
[999]: print('Table 1: Basic statistics of the continuous variables')
df1.describe()
```

Table 1: Basic statistics of the continuous variables

```
[999]:
```

	age	bmi	children	medicalCost
count	1338.000000	1338.000000	1338.000000	1338.000000
mean	39.207025	30.663397	1.094918	13270.422265
std	14.049960	6.098187	1.205493	12110.011237
min	18.000000	15.960000	0.000000	1121.873900
25%	27.000000	26.296250	0.000000	4740.287150
50%	39.000000	30.400000	1.000000	9382.033000
75%	51.000000	34.693750	2.000000	16639.912515
max	64.000000	53.130000	5.000000	63770.428010

The age variable has values from 18 to 64. A mean of 39.2 for the age variable shows that distribution is approximately balanced, with slightly more observations having lower values. The standard deviation of 14 shows a high spread of values over the range.

BMI shows that half of the values range from 26.2 to 34.6. A small standard deviation shows a low spread.

The children variable has close to 25% of values with zero, and half of the values are less than or equal to one. This shows a highly skewed distribution. The standard deviation of 1.2 shows low spread of the values around mean 1.09

```
[1000]: # Distribution of continuous variables
fig, ax = plt.subplots(1, 3, figsize=(15, 4))

plt.subplot(1, 3, 1)
plt.hist(df1.iloc[:, 0], rwidth=0.9)
plt.xlabel(df1.columns[0], fontsize=15)

plt.subplot(1, 3, 2)
plt.hist(df1.iloc[:, 2], rwidth=0.9)
plt.xlabel(df1.columns[2], fontsize=15)

plt.subplot(1, 3, 3)
plt.hist(df1.iloc[:, 3], rwidth=0.9)
plt.xlabel(df1.columns[3], fontsize=15)
plt.tight_layout()
plt.show()
```

```
print('Figure 3: Distribution of the continuous variables')
```

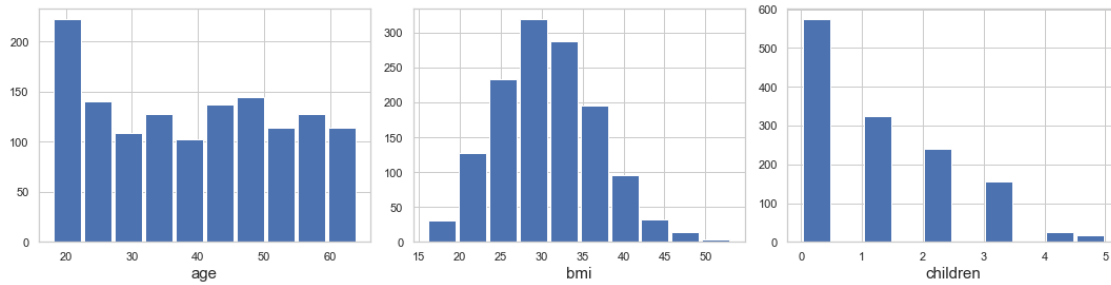


Figure 3: Distribution of the continuous variables

Figure 3 shows the distribution of the continuous variables. The age distribution shows a closely uniform distribution with a higher bar at age 20. This shows that there is more observation recorded for ages around 20. Age values have a minimum of 18 and a maximum of 64 when compared to Table 1.

Bmi shows a unimodal normal distribution with a mean of 30.6. Values lie from 15.96 to 53.13 and have a standard deviation of 6.0. This shows most people are in the unhealthy range of Bmi as per the NHS guidelines (2022).

The number of children per individual is declining sharply with the number of children. There are close to 600 individuals with no children and little over 300 individuals with one child, and only 18 individuals with five children. The mean of the distribution is 1.09, with a minimum of 0 and a maximum of 5, suggesting a highly skewed distribution

```
[1001]: # Boxplot of continuous variables
fig, ax = plt.subplots(1, 4, figsize=(15, 5))

plt.subplot(1, 4, 1)
plt.boxplot(df1[['age']])
plt.xlabel(df1.columns[0], fontsize=15)

plt.subplot(1, 4, 2)
plt.boxplot(df1[['bmi']])
plt.xlabel(df1.columns[2], fontsize=15)

plt.subplot(1, 4, 3)
plt.boxplot(df1[['children']])
plt.xlabel(df1.columns[3], fontsize=15)

plt.subplot(1, 4, 4)
plt.boxplot(df1[['medicalCost']])
plt.xlabel(df1.columns[6], fontsize=15)

plt.tight_layout()
```

```
plt.show()
print('Figure 4: Boxplot of the continuous variables')
```

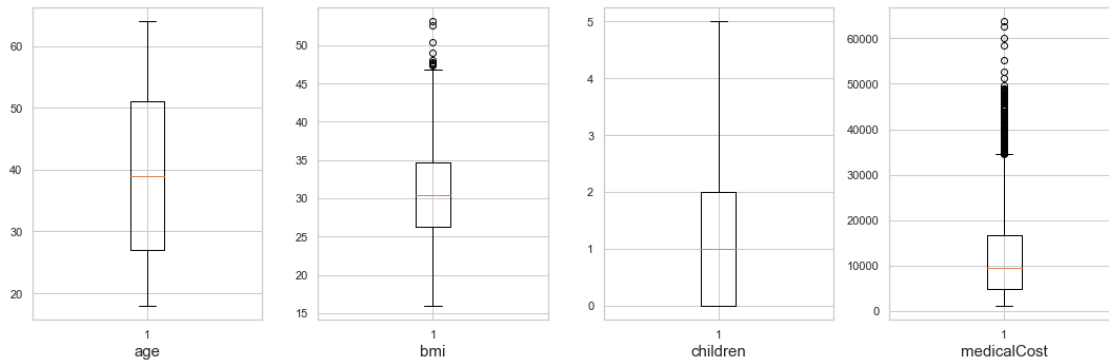


Figure 4: Boxplot of the continuous variables

Figure 4 shows that the age variable has a more balanced distribution and no outliers. Bmi is also a balanced distribution. However, it has outliers at the higher end of the distribution, The analysis is not removing outliers as they can be important to certain health conditions such as obesity. The number of children variable has no outliers, but there are more individuals with a low number of children than a high number of children, as seen in histograms in Figure 3.

The target variable medical cost has more low-cost values than high-cost values. There are a lot of outliers at the higher end, and few outliers exist over 50000. The outliers with highest values are analysed further.

```
[1002]: # Extreme outliers are analysed more closely.
df1[df1['medicalCost'] > 50000]
```

```
[1002]:
```

	age	sex	bmi	children	smoker	region	medicalCost
34	28	male	36.400	1	yes	southwest	51194.55914
543	54	female	47.410	0	yes	southeast	63770.42801
577	31	female	38.095	1	yes	northeast	58571.07448
819	33	female	35.530	0	yes	northwest	55135.40209
1146	60	male	32.800	0	yes	southwest	52590.82939
1230	52	male	34.485	3	yes	northwest	60021.39897
1300	45	male	30.360	0	yes	southeast	62592.87309

There are no clear patterns or no prominent features identified except every one is smokers from this outlier of the medical cost variable. It does not seems like errornous data. Therefore, they are not dropped from the analysis. These values can result from an accident or emergency surgeries, so they might add value to the analysis.

```
[1003]: # Bar chart of Medical Cost vs Sex
sns.set_theme(style="whitegrid")
sns.barplot(x='sex', y='medicalCost', data=df1, ci=None)
plt.ylabel('Medical Cost')
```

```
plt.ylabel('Sex')
plt.title('Medical Cost vs Sex')
plt.show()
print('Figure 5: Medical cost vs Sex')
```

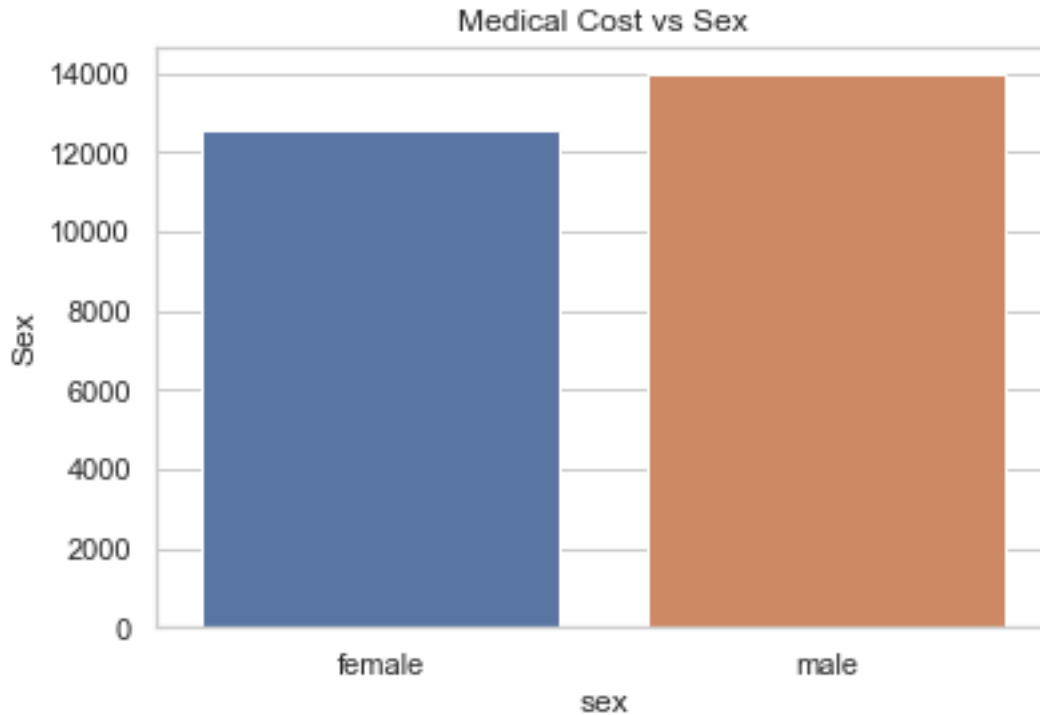


Figure 5: Medical cost vs Sex

According to figure 5, Even though males has higher medical cost recorded at around 14000, there is only slight difference in the medical costs as females have medical expense recorded just below 13000.

```
[1004]: # Violin plot of Medical Cost vs Sex
f = plt.figure(figsize=(14, 6))

sns.violinplot(x='sex', y='medicalCost', data=df1, palette='Wistia')
plt.title('Violin plot of Medical Cost vs sex')
plt.show()
print('Figure 6: Violin plot of Medical Cost vs Sex')
```




Figure 6: Violin plot of Medical Cost vs Sex

Figure 6 shows that there are more males in the higher range of medical costs than females. For the lower range around zero to 20000, the distribution shows approximately the same number of individuals for males and females. The mean is also same in the two distributions and closer to the population mean of 13270 when reference to the table 1.

```
[1005]: # Count plot of Smoker variable
f = plt.figure(figsize=(15, 5))
ax = f.add_subplot(121)
sns.countplot(x='smoker', palette='PRGn', data=df1, ax=ax)
print('Figure 2.1: Number of observations representing each value of the smoker_
↪label')
plt.ylabel('Count')
plt.xlabel('Smoker')
plt.title('Counplot for Smoker')

# Bar chart of Medical Cost vs Smoker
sns.set_theme(style="whitegrid")
ax = f.add_subplot(122)
sns.barplot(x='smoker', y='medicalCost',
            palette='PRGn', data=df1, ci=None, ax=ax)
plt.ylabel('Medical Cost')
plt.xlabel('Smoker')
plt.title('Medical Cost vs Smoker')
plt.show()
print('Figure 7: Medical Cost vs Smoker')

plt.show()
```

Figure 2.1: Number of observations representing each value of the smoker label

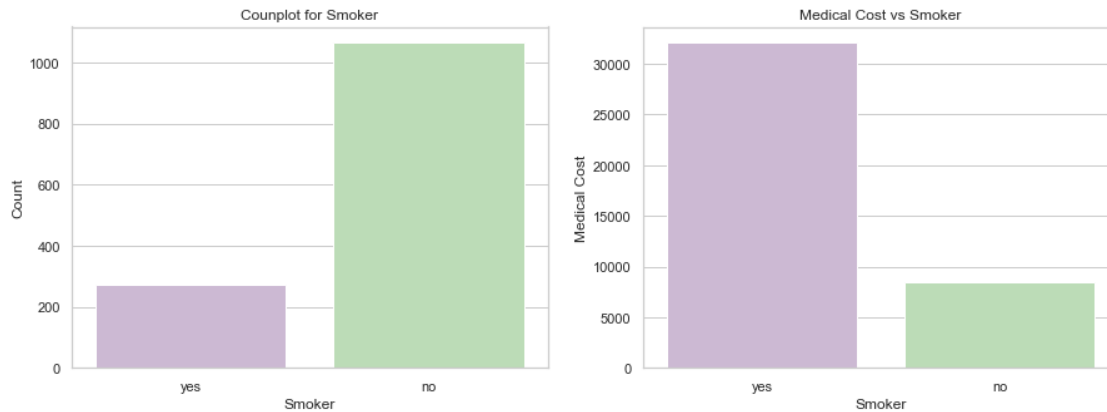


Figure 7: Medical Cost vs Smoker

According to figure 7, it is clear that smoking individuals have spent more on medical costs. This graph shows a drastic difference in medical costs for smoking and non-smoking individuals. The dataset only has around 250 smokers; in contrast, there are over 1000 non-smokers.

```
[1006]: # Violin plot of Medical Cost vs Smoker
f = plt.figure(figsize=(14, 6))

sns.violinplot(x='smoker', y='medicalCost', data=df1, palette='magma')
plt.title('Violin plot of Medical Cost vs Smoker')
plt.axhline(y=35000, color='g', linestyle='dotted')
plt.axhline(y=7000, color='b', linestyle='dotted')

plt.show()
print('Figure 8: Violin plot of Medical Cost vs Smoker')
```

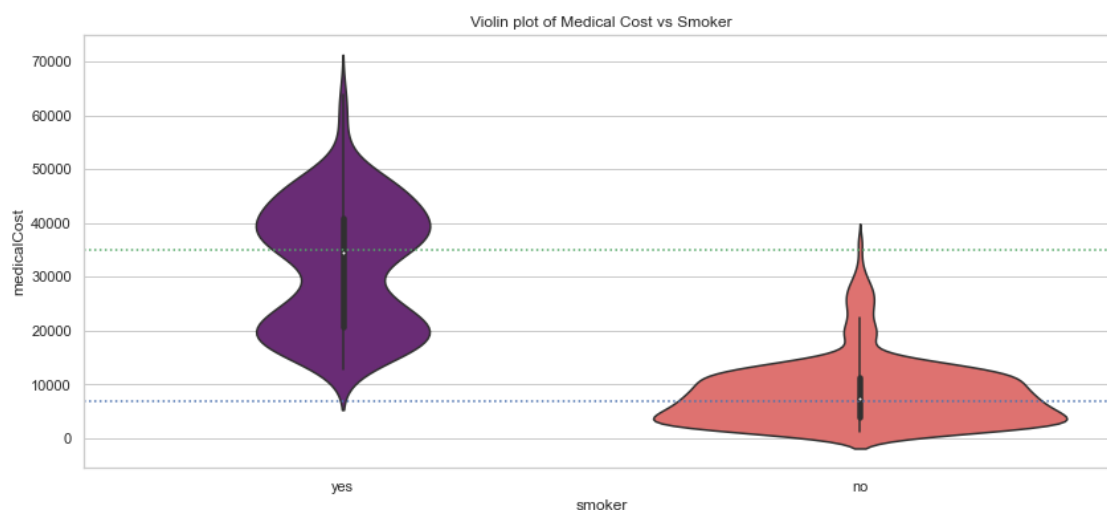


Figure 8: Violin plot of Medical Cost vs Smoker

Figure 8 shows that the medical cost for smokers is a much wide range compared to non-smokers. It is clear also that the highest value of medical cost for a non-smoking person is around 40000, and most values distributed below 20000; while for a smoking person, the medical cost goes over 60000, majority of the records lie between 15000 to 50000. The average Medical cost for a non-smoker is approximately 7000; for a smoker, the minimum medical cost is around 7000. The highest value of medical expenditure for non-smoking individuals and mean value for smoking individuals lie very closely. These observations show that there is a significant difference in medical costs for smoking and non-smoking person.

```
[1007]: # Bar chart of Medical Cost vs Region
sns.set_theme(style="whitegrid")
sns.barplot(x='region', y='medicalCost', data=df1, palette='PuBuGn', ci=None)
plt.ylabel('Medical Cost')
plt.xlabel('Region')
plt.title('Medical Cost vs Region')
plt.show()
print('Figure 9: Medical Cost vs Region')
```

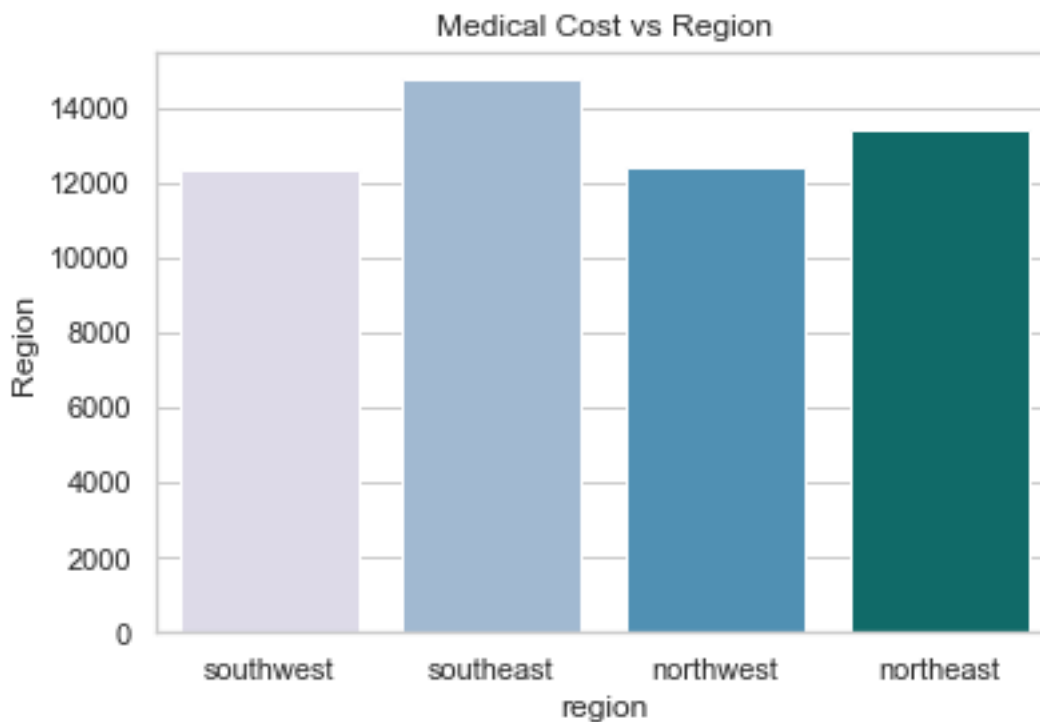


Figure 9: Medical Cost vs Region

Medical cost does not show much difference in the region. Southeast shows a slightly higher value for the medical cost, and the northeast shows the lowest value.

```
[1008]: # Bar chart of Medical Cost vs Children
sns.set_theme(style="whitegrid")
sns.barplot(x='children', y='medicalCost',
            data=df1, palette='terrain', ci=None)
plt.ylabel('Medical Cost')
plt.xlabel('Number of Children')
plt.title('Medical Cost vs Number of Children')
plt.show()
print('Figure 10: Medical Cost vs Number of Children')
```

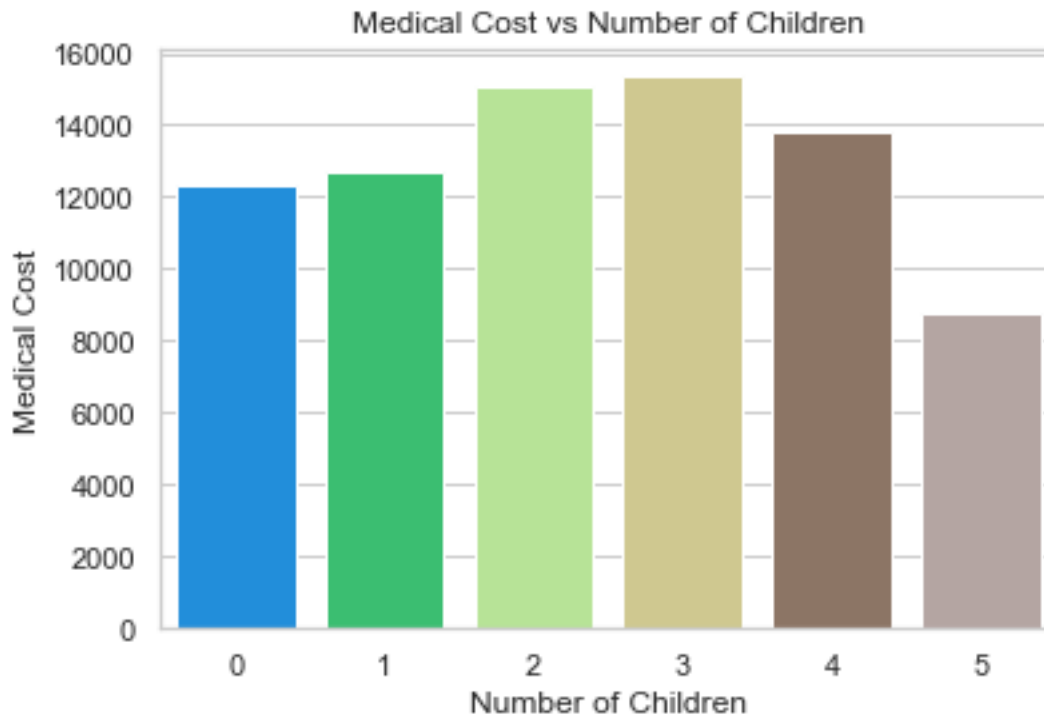


Figure 10: Medical Cost vs Number of Children

Medical cost vs a number of children shows that individuals with two and three children spend more on medical costs than other groups. The lowest value for medical cost resulted from individuals with five children.

```
[1009]: # Bar chart of Medical Cost vs Region by Sex
f = plt.figure(figsize=(12, 5))
sns.set_theme(style="whitegrid")
sns.barplot(x='sex', y='medicalCost', hue='region',
            data=df1, palette='PuBuGn', ci=None)
plt.ylabel('Medical Cost')
plt.legend(loc='upper left')
plt.xlabel('Sex')
```

```
plt.title('Medical Cost vs Sex grouped by Region')
plt.show()
print('Figure 11: Medical Cost vs Sex grouped by Region')
```

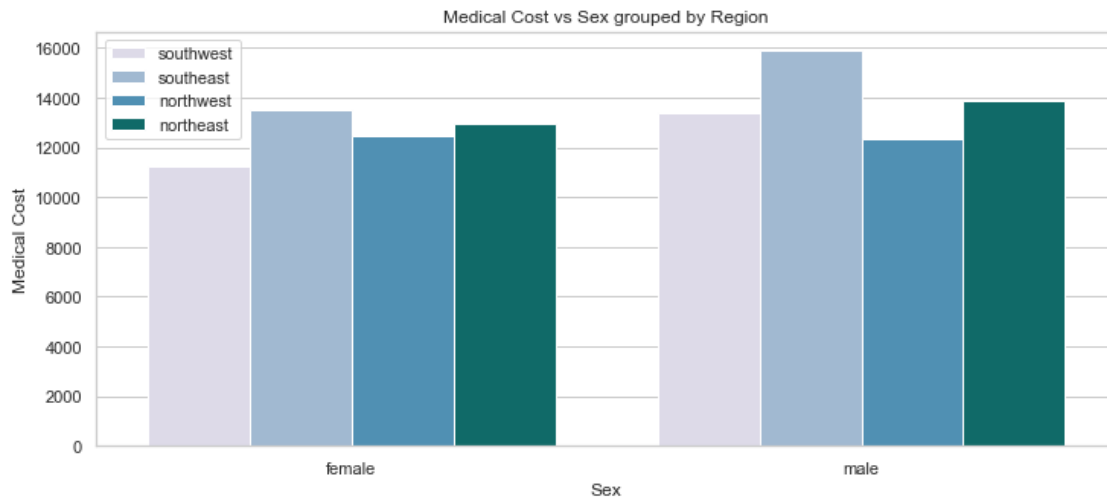


Figure 11: Medical Cost vs Sex grouped by Region

Medical cost for Sex, when grouped by region, shows the highest for the southeast, same as the graph for the whole population in figure 9. However, in contrast to figure 9, the lowest for females was recorded from the southwest, while the lowest for males was recorded from the northwest, as same as figure 9.

```
[1010]: # Scatter plots of Medical Cost vs continuous variables and Region
f = plt.figure(figsize=(15, 5))
ax = f.add_subplot(131)
sns.scatterplot(x='age', y='medicalCost', data=df1,
                palette='magma', hue='region', ax=ax)
ax.set_title('Scatter plot of Medical Cost vs Age')

ax = f.add_subplot(132)
sns.scatterplot(x='bmi', y='medicalCost', data=df1,
                palette='viridis', hue='region')
ax.set_title('Scatter plot of Medical Cost vs BMI')

ax = f.add_subplot(133)
sns.scatterplot(x='children', y='medicalCost', data=df1,
                palette='YlOrBr', hue='region')
ax.set_title('Scatter plot of Medical Cost vs Children')
plt.show()

print('Figure 12: Medical Cost vs continuous variables and Region')
```

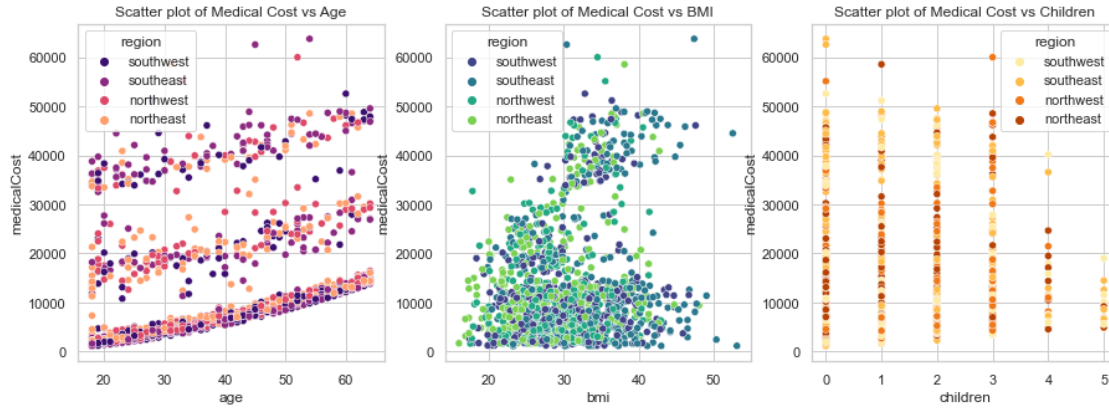


Figure 12: Medical Cost vs continuous variables and Region

Medical costs are getting higher with age. According to figure 12, there are three separate regions for medical spending when plotted with age. Further analysis can be done to identify any factors affecting this separation. Bmi values for the highest medical costs lie towards the highest end. There are not many high medical cost records in the lower BMIs. However, no clear patterns are visible with the BMI and medical costs. As discussed when analysing figure 10, individuals with five children show lower values for medical costs. The highest numbers are recorded among individuals with no children.

Scatter plots do not show any identifiable pattern with the region in any of the plots.

```
[1011]: # Scatter plots of Medical Cost vs continuous variables and Smoker
f = plt.figure(figsize=(15, 5))
ax = f.add_subplot(131)
sns.scatterplot(x='age', y='medicalCost', data=df1,
                palette='ocean', hue='smoker', ax=ax)
ax.set_title('Scatter plot of Medical Cost vs Age')

ax = f.add_subplot(132)
sns.scatterplot(x='bmi', y='medicalCost', data=df1,
                palette='twilight_shifted', hue='smoker')
ax.set_title('Scatter plot of Medical Cost vs BMI')

ax = f.add_subplot(133)
sns.scatterplot(x='children', y='medicalCost', data=df1,
                palette='gist_earth', hue='smoker')
ax.set_title('Scatter plot of Medical Cost vs Children')
plt.show()

print('Figure 13: Medical Cost vs continuous variables and Smoker')
```

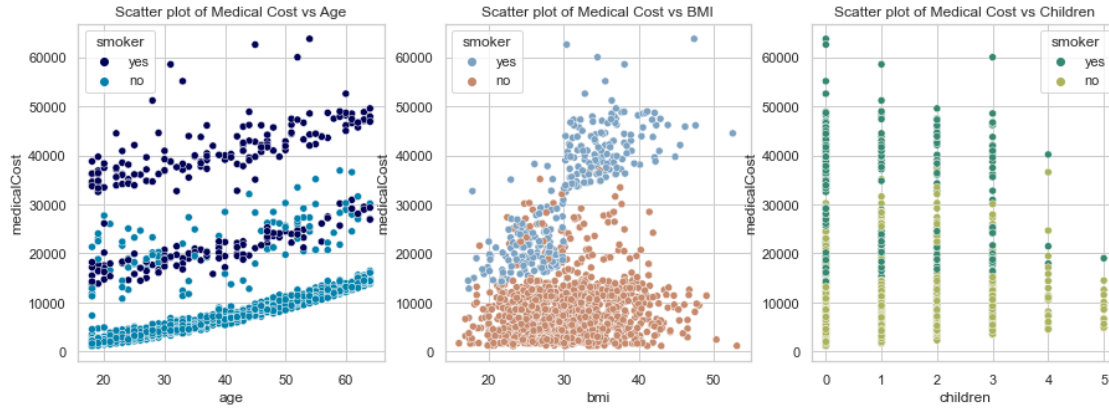


Figure 13: Medical Cost vs continuous variables and Smoker

Figure 13 shows the band that appears in medical cost vs age relates to smoking. The lowest band only has non-smoking individuals. The middle band has both smoking and non-smoking individuals, while the upper band only has smoking individuals. The other two graphs also show more smoking individuals at the higher end of the graph.

1.1.3 Transform categorical variables to numerical

Label encoding is used where ever possible to avoid increasing dimensionality. When there are more than two unique values in the column and no specific ordering, Dummy values are used.

[1012]: *# The label encoding is used to transform Smoker and Sex variables*

```
le = LabelEncoder()

# Sex variable
le.fit(df1.sex.drop_duplicates())
df1.sex = le.transform(df1.sex)

# Smoker variable
le.fit(df1.smoker.drop_duplicates())
df1.smoker = le.transform(df1.smoker)
```

[1013]: *# Dummy variable introduced for region variable*

```
df1_encode = pd.get_dummies(data=df1, prefix='RE', prefix_sep='_',
                             columns=['region'],
                             drop_first=False,
                             dtype='int8')

df1_encode.head(2)
```

```
[1013]:   age  sex   bmi  children  smoker  medicalCost  RE_northeast  RE_northwest  \
0   19   0  27.90         0        1    16884.9240             0             0
1   18   1  33.77         1        0    1725.5523             0             0
```

	RE_southeast	RE_southwest
0	0	1
1	1	0

1.1.4 Correlation

Correlation is used to identify the relationship between variables and to choose the three best predictors for medical cost. Since there are outliers, Spearman correlation was used here as it calculates correlation using the ranking method. Moreover, the Pearson correlation compares numerical relationships and is sensitive to outliers.

```
[1014]: plt.figure(figsize=(15, 5))

# Plot the heatmap, since there are outliers Spearman correlation was used here.
sns.heatmap(df1_encode.corr(method='pearson'),
            cmap='BuPu',
            annot=True,)

plt.show()
print('Figure 14: Correlation plot for all the variables in the dataset')
```

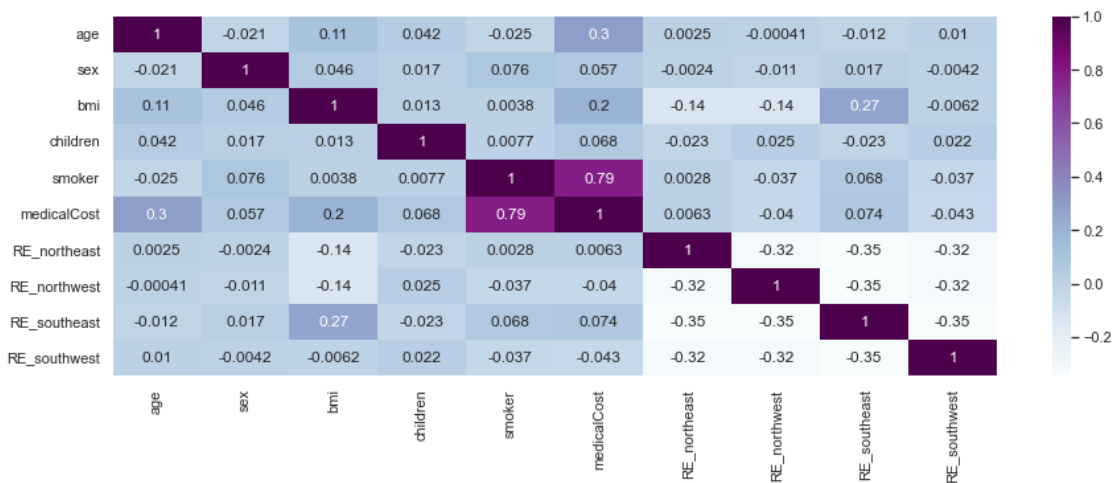


Figure 14: Correlation plot for all the variables in the dataset

Correlation analysis shows the highest correlation with the smoker column and second higher for the age column, and the third for BMI. The smoker variable shows a strong positive correlation with 0.79. Age and BMI show a weak positive correlation with 0.3 and 0.2. All the other variables show almost no correlation, with a correlation coefficient of less than 0.1. Therefore age, smoker and BMI are identified as the best three predictors for medical cost.

1.1.5 Simple linear models to predict Medical Cost

Simple linear model to predict Medical Cost with Age


```
[1015]: # Select dependent and independent variable
x1 = df1_encode[['age']]
y = df1_encode[['medicalCost']]

# Split data in to train and test set
x1_train, x1_test, y_train, y_test = train_test_split(
    x1, y, test_size=0.2, random_state=3)

# Initialise the Linear Regression model
model = LinearRegression()

# Fit data to the model
model.fit(x1_train, y_train)

print(f'intercept: {model.intercept_}')
print(f'slope: {model.coef_}')
y_pred = model.predict(x1_test)

mse = mean_squared_error(y_test, y_pred)
print(f'Mean squared error: {mse}')

r2 = r2_score(y_test, y_pred)
print(f'R-squared: {r2}')
```

```
intercept: [3089.27775168]
slope: [[258.24833494]]
Mean squared error: 137276316.90775076
R-squared: 0.08984531343011881
```

The model has an R-squared of 0.08, which suggest the dependent variable does not explain the variation of the independent variable properly, as the R-squared is closer to 0 than 1. The slope of 258 shows that for each year increase in age, there is a 258 increase in medical cost. The mean squared error is equal to 137,276,316, a fairly large value. As figure 15 shows, the three bands of medical costs had to predict when using simple regression. Figure 15 also shows the increase of the medical cost when the age increases.

```
[1016]: sns.regplot(x=x1_train, y=y_train, color='#66AA88')
plt.show()
print('Figure 15: Regression line for Medical Cost and Age')
```

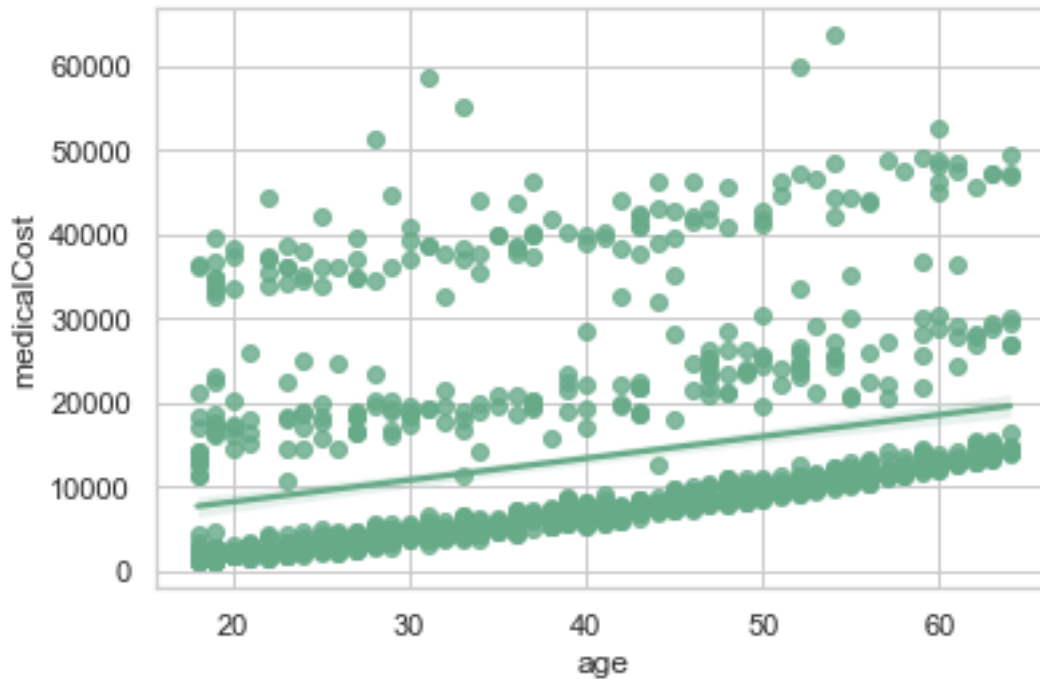


Figure 15: Regression line for Medical Cost and Age

The higher value of residual error can be resulted from the significant variation of medical cost for a certain age value as seen in figure 15.

Simple linear model to predict Medical Cost with Smoker

```
[1017]: # Select dependent and independent variable
x1 = df1[['smoker']]
y = df1[['medicalCost']]

# Split data in to train and test set
x1_train, x1_test, y_train, y_test = train_test_split(
    x1, y, test_size=0.2, random_state=3)

# Initialise the Linear Regression model
model = LinearRegression()

# Fit data to the model
model.fit(x1_train, y_train)

print(f'intercept: {model.intercept_}')
print(f'slope: {model.coef_}')
y_pred = model.predict(x1_test)

mse = mean_squared_error(y_test, y_pred)
```

```
print(f'Mean squared error: {mse}')

r2 = r2_score(y_test, y_pred)
print(f'R-squared: {r2}')
```

```
intercept: [8433.799658]
slope: [[23506.57981273]]
Mean squared error: 55347801.452357695
R-squared: 0.6330389537107518
```

The model has R-squared 0.6, which is slightly a better prediction as the value is closer to the middle value between 0 and 1. Dependent variable somewhat explains the difference in independent variable. Here slope does not hold much information as the dependent variable is a binary variable. The mean squared error is equal to 55,347,801, a fairly large value. Figure 16 shows a regression line fitted to the data. Figure 16 also shows the increase of the medical cost in the two category of smoking and non-smoking.

```
[1018]: sns.regplot(x=x1_train, y=y_train, color='#1177FF')
plt.show()
print('Figure 16: Regression line for Medical Cost and Smoker')
```

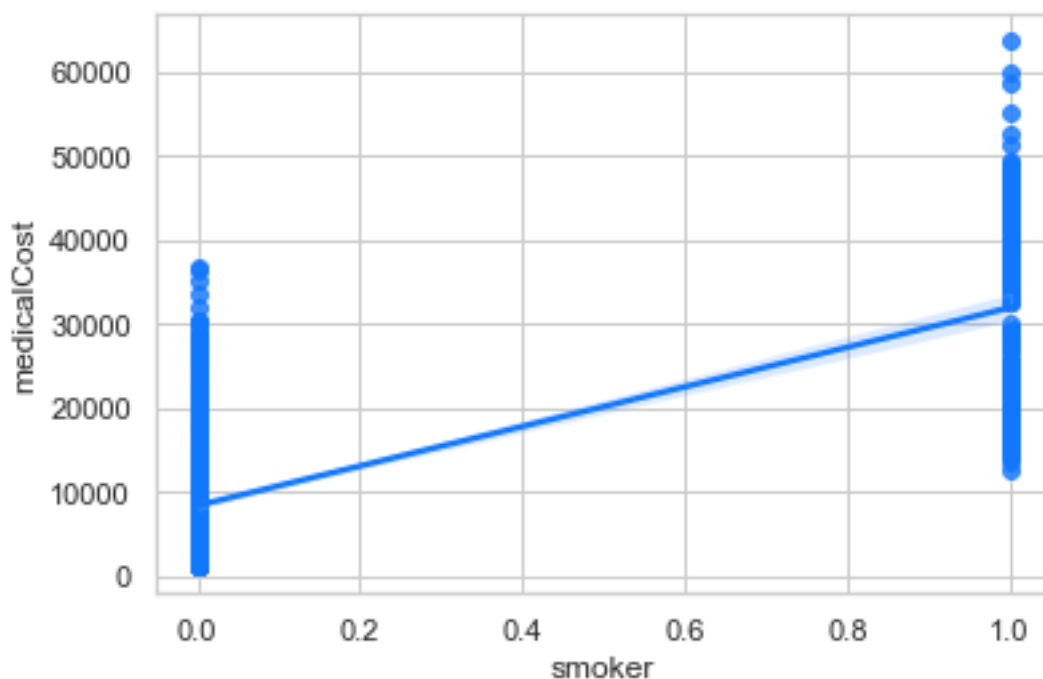


Figure 16: Regression line for Medical Cost and Smoker

There is a clear pattern for medical costs for smokers and non-smokers. The regression plot in figure 16 shows the increase in medical costs for smoking individuals. Clearly, there are a significant amount of residuals.

Simple linear model to predict Medical Cost with BMI

```
[1019]: # Select dependent and independent variable
x1 = df1_encode[['bmi']]
y = df1_encode[['medicalCost']]

# Split data in to train and test set
x1_train, x1_test, y_train, y_test = train_test_split(
    x1, y, test_size=0.2, random_state=3)

# Initialise the Linear Regression model
model = LinearRegression()

# Fit data to the model
model.fit(x1_train, y_train)

print(f'intercept: {model.intercept_}')
print(f'slope: {model.coef_}')
y_pred = model.predict(x1_test)

mse = mean_squared_error(y_test, y_pred)
print(f'Mean squared error: {mse}')

r2 = r2_score(y_test, y_pred)
print(f'R-squared: {r2}')
```

```
intercept: [1310.83699573]
slope: [[387.33454902]]
Mean squared error: 144140190.02346116
R-squared: 0.04433719939408365
```

The model has R-squared 0.04, which suggests the BMI does not explain the change in medical cost well as R-squared is closer to 0 than 1. The slope shows a 387 increase in medical cost for a unit increase in BMI. The mean squared error is equal to 144,140,190, a reasonably large value. Figure 17 shows that there is a lot of observation lying fairly far away from the regression line toward the higher values of BMI.

```
[1020]: sns.regplot(x=x1_train, y=y_train, color='purple')
plt.show()
print('Figure 17: Regression line for Medical Cost and BMI')
```

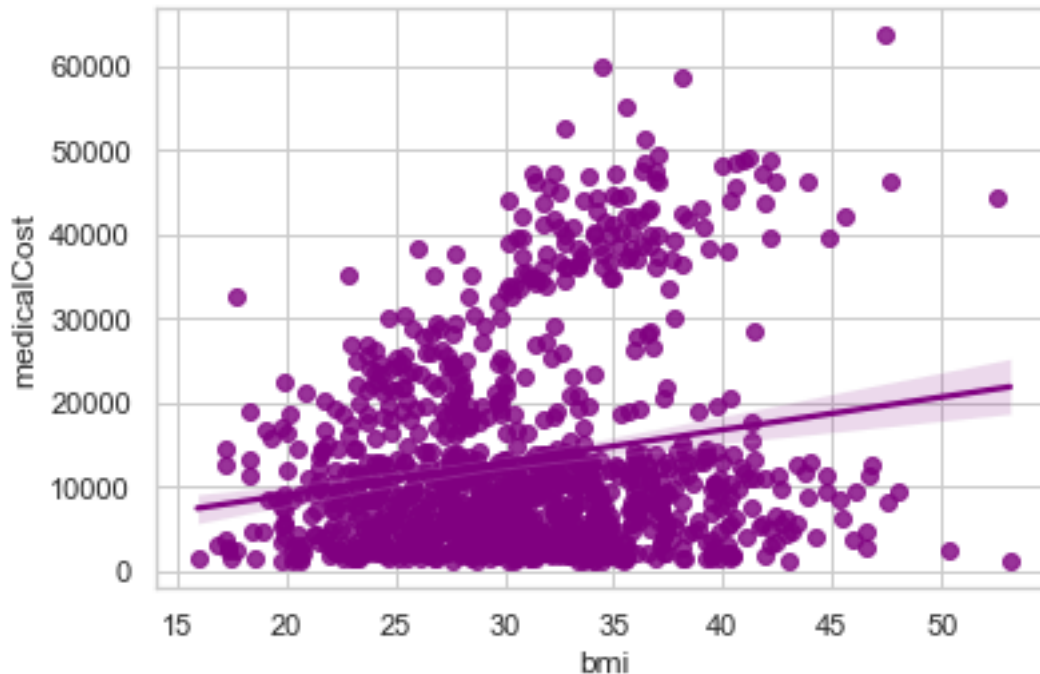


Figure 17: Regression line for Medical Cost and BMI

Figure 17 shows that when BMI increases, the residuals get larger as the medical cost spreads in a larger range.

Models with BMI and Age have a much smaller R-squared value than the one with Smoker. The Smoker variable has been able to explain the difference in medical cost more than Age and BMI. The line in figure 16 has a higher angle with a slope value of 23506 than the linear model for BMI with a slope value of 387 and age with a slope value of 258. **Overall, the model with the smoker variable performs better** when compared R-squared value and mean squared error.

1.1.6 Multivariate regression models to predict Medical Cost

There are two multivariate models created with three best predictors and with all the variables.

Multivariate regression model to predict Medical Cost with Age, Smoker and BMI.

```
[1021]: # Dropping all the variables except three highest correlated variables from
        ↳ dependent variables.
x1 = df1_encode.drop(columns=['sex', 'medicalCost', 'RE_northeast',
                              'RE_northwest', 'RE_southeast', 'RE_southwest',
                              ↳ 'children'])
# Select dependent variable
y = df1_encode[['medicalCost']]

# Split data in to train and test set
```

```

x1_train, x1_test, y_train, y_test = train_test_split(
    x1, y, test_size=0.2, random_state=3)

# Initialise the Linear Regression model
model = LinearRegression()

# Fit data to the model
model.fit(x1_train, y_train)

print(f'intercept: {model.intercept_}')
print(f'slope: {model.coef_}')
y_pred = model.predict(x1_test)

mse = mean_squared_error(y_test, y_pred)
print(f'Mean squared error: {mse}')

r2 = r2_score(y_test, y_pred)
print(f'R-squared: {r2}')

```

```

intercept: [-12297.07065608]
slope: [[ 265.48317257  333.28328133 23817.80914975]]
Mean squared error: 38904433.375912696
R-squared: 0.7420600059569823

```

The multivariate model with all three variables has a lower mean squared error than simple linear models with each of them. Where a model with age has 137,276,316, a model with a smoker has 55,347,801, the model with BMI has 144,140,190, and the model with all three variables has 38,904,433, which is a better value than the best simple leaner model.

R-squared value also shows a similar result, with value of 0.74 for the multivariate model with three variables which is much closer to 1 than 0. Slopes for each variable stay closer to the linear models. Three dependent variables together has been able to explain the difference in Medical Cost than separately.

```

[1022]: fig, ax = plt.subplots()

# Scatter plot of Actual value vs predicted value
ax.scatter(y_test, y_pred, color='brown')
fig.suptitle('Actual values vs predicted values')
plt.ylabel('Predicted medical cost')
plt.xlabel('Actual medical cost')
plt.show()
print('Figure 18: Actual value vs predicted value plot for multivariate model_
    ↳with Age, BMI and Smoker variables as independent variables')

```

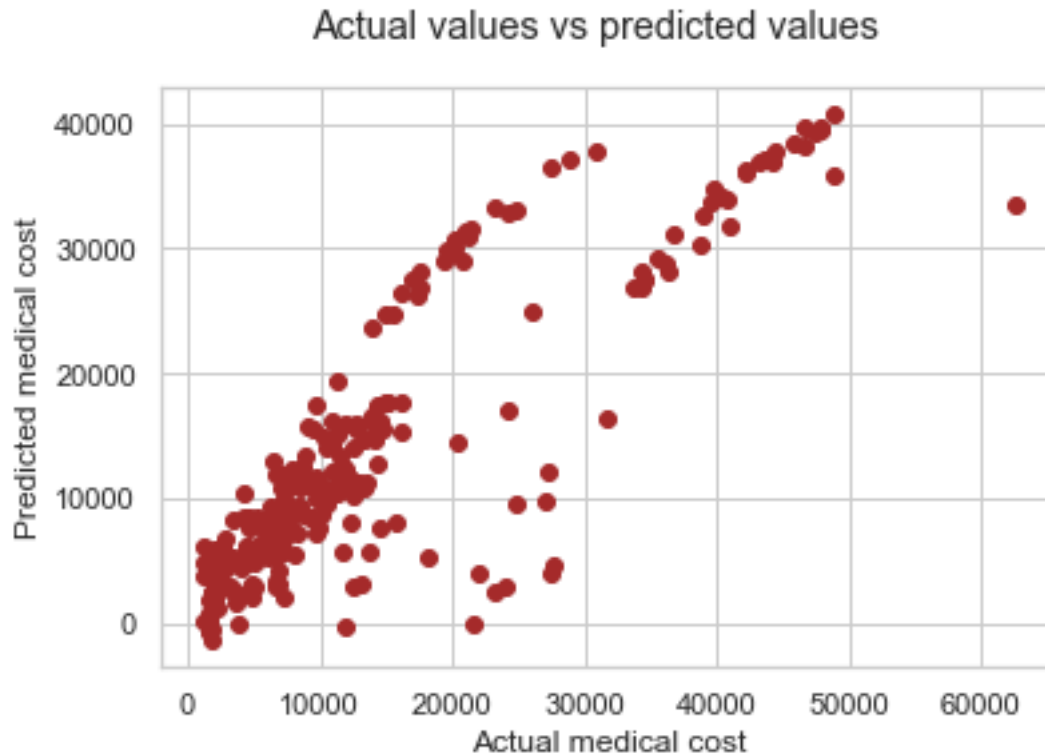


Figure 18: Actual value vs predicted value plot for multivariate model with Age, BMI and Smoker variables as independent variables

Figure 18 shows that higher values are predicted for higher actual values. However, in the range of 10000 to 30000 medical costs, there seems to have a wider range of expected values distributed from around zero to closer to 40000. These are the values that introduced more errors into the model. Lower values of medical costs also have a good prediction.

```
[1023]: # Residual plot
plt.scatter(y_test, (y_test - y_pred), color='orange')
plt.axhline(y=0.0, color='g', linestyle='-')
fig.suptitle('Actual values vs residuals')
plt.ylabel('Predicted medical cost')
plt.xlabel('Actual medical cost')
plt.show()
print('Figure 19: Residual plot for multivariate model with Age, BMI and Smoker_
↪variables as independent variables')
```

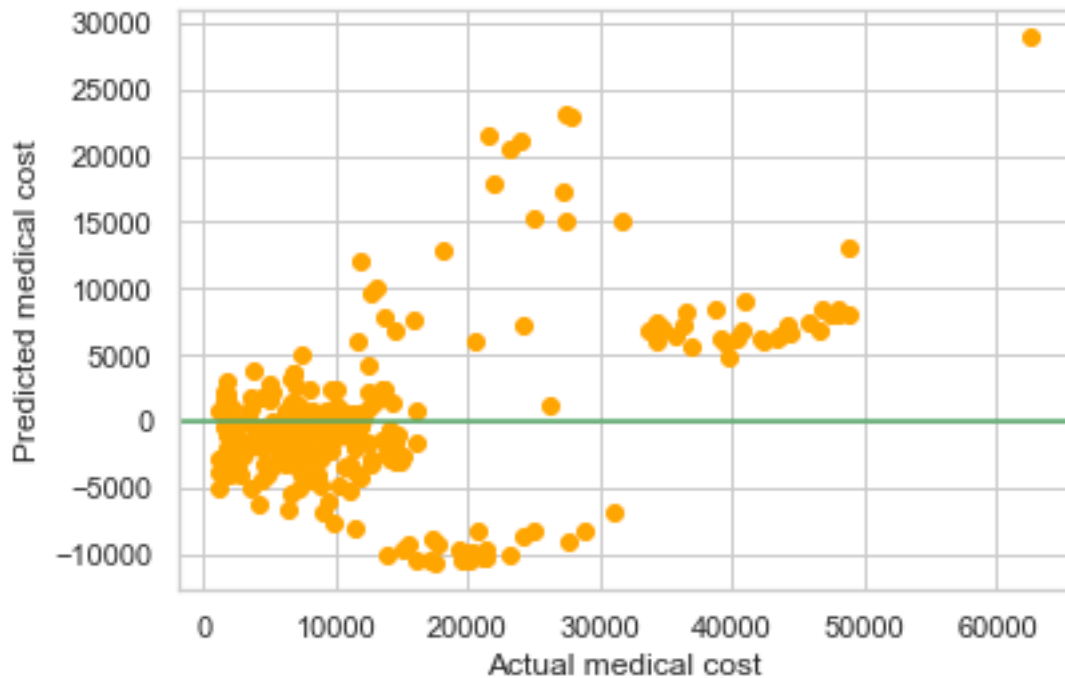


Figure 19: Residual plot for multivariate model with Age, BMI and Smoker variables as independent variables

The residual plot in figure 19 also confirms the results of figure 18. In the mid-range, there is a higher variation of residual values. It is also clear from figure 19 that the values over 60000 have resulted in the most significant residual of the model.

```
[1024]: # Distribution of the residuals
residuals = (y_test - y_pred)

plt.hist(residuals, color='purple')
plt.show()
print('Figure 20: Histogram of residuals for multivariate model with Age, BMI,
      ↪and Smoker variables as independent variables')
```

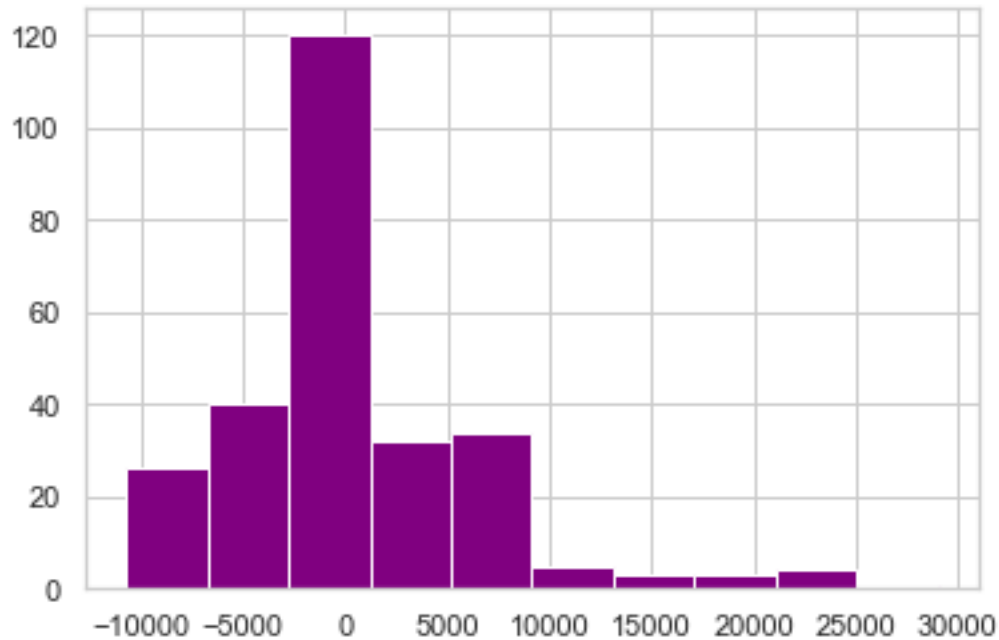



Figure 20: Histogram of residuals for multivariate model with Age, BMI and Smoker variables as independent variables

The histogram in figure 20 shows that the distribution of residuals is skewed. There are more zero or negative values than positive values. It is also clear there is a long tail towards the positive end, having larger positive residuals than negative residuals.

Multivariate regression model to predict Medical Cost all the variables.

```
[1025]: x1 = df1_encode.drop(columns=['medicalCost'])
y = df1_encode[['medicalCost']]

# Split data in to train and test set
x1_train, x1_test, y_train, y_test = train_test_split(
    x1, y, test_size=0.2, random_state=3)

# Initialise the Linear Regression model
model = LinearRegression()

# Fit data to the model
model.fit(x1_train, y_train)

print(f'intercept: {model.intercept_}')
print(f'slope: {model.coef_}')
y_pred = model.predict(x1_test)

mse = mean_squared_error(y_test, y_pred)
```

```
print(f'Mean squared error: {mse}')
```

```
r2 = r2_score(y_test, y_pred)
```

```
print(f'R-squared: {r2}')
```

```
intercept: [-13172.39719688]
```

```
slope: [[ 262.31558491 -222.45944647  349.53918186  574.50846193  
 23827.48548329  625.80325666  204.49787511 -537.19360189  
 -293.10752988]]
```

```
Mean squared error: 39202908.26059814
```

```
R-squared: 0.7400810898464749
```

The model has a 0.74 R-squared error which shows a good prediction for the medical cost. The multivariate regression model with all the variables is performing closer to the multivariate model with the three best variables. The performance here is slightly reduced than the model with three variables when comparing the R-squared value and mean squared error.

```
[1026]: fig, ax = plt.subplots()
```

```
# Scatter plot of Actual value vs predicted value
```

```
ax.scatter(y_test, y_pred, color='brown')
```

```
plt.ylabel('Predicted medical cost')
```

```
plt.xlabel('Actual medical cost')
```

```
fig.suptitle('Actual values vs predicted values')
```

```
plt.show()
```

```
print('Figure 21: Actual value vs predicted value plot for multivariate model,  
→with all the independent variables')
```

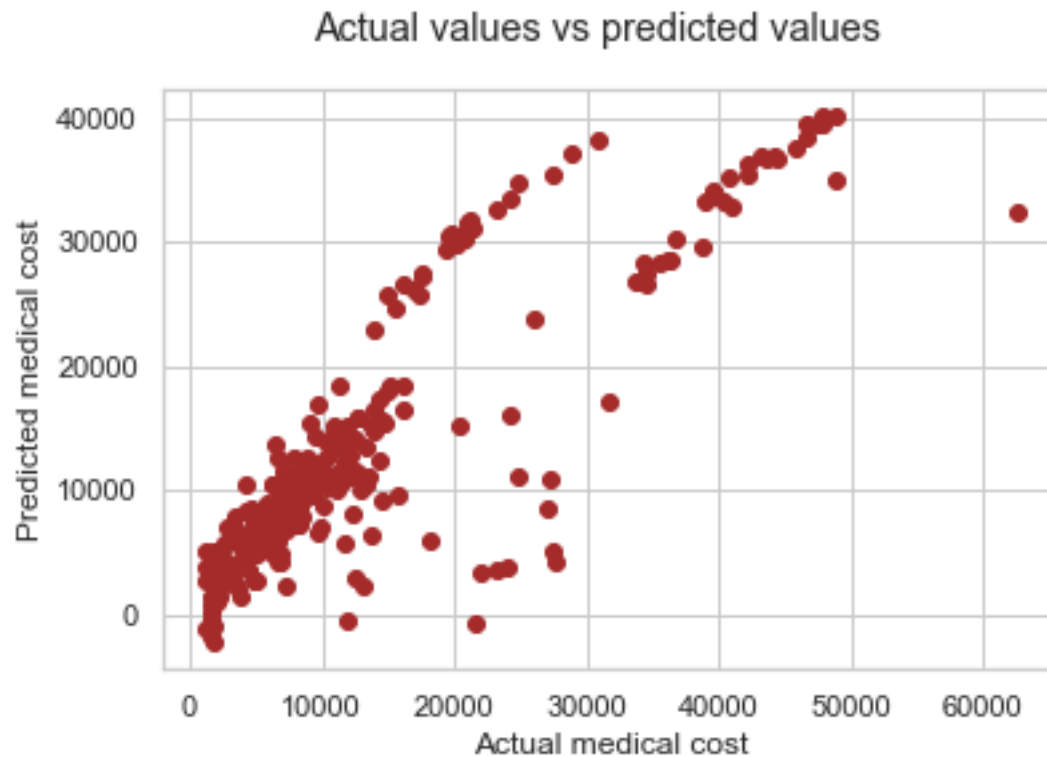


Figure 21: Actual value vs predicted value plot for multivariate model with all the independent variables

```
[1027]: # Residual plot
plt.scatter(y_test, (y_test - y_pred), color='orange')
plt.axhline(y=0.0, color='g', linestyle='--')
plt.title('Actual values vs residuals')
plt.show()
print('Figure 22: Residual plot for multivariate model with all the independent_
      ↪variables')
```



Figure 22: Residual plot for multivariate model with all the independent variables

```
[1028]: # Distribution of the residuals
residuals = (y_test - y_pred)

plt.hist(residuals, color='purple')
plt.show()
print('Figure 23: Histogram of residuals for multivariate model with all the_
      ↪ independent variables')
```

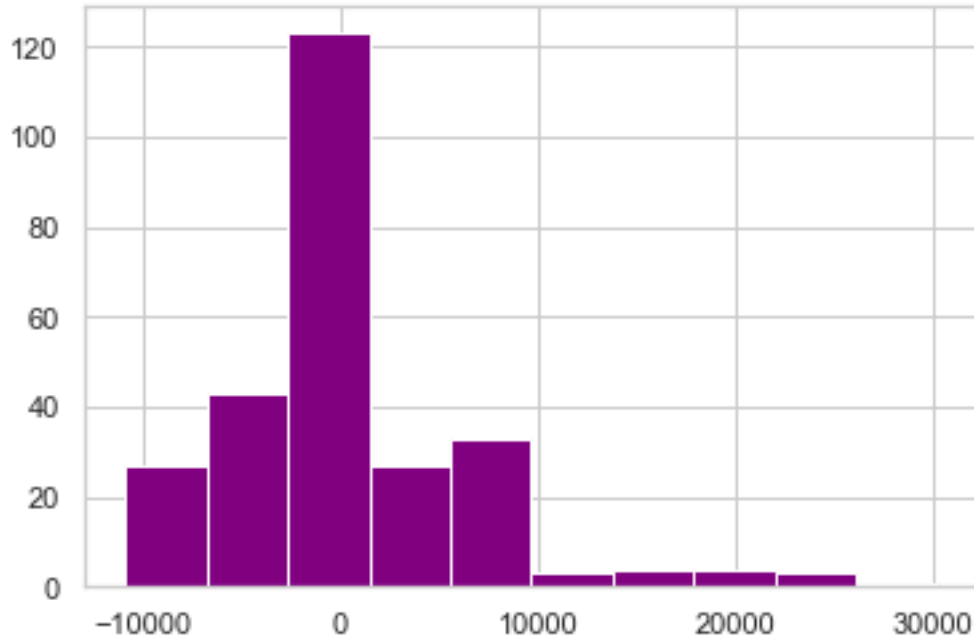


Figure 23: Histogram of residuals for multivariate model with all the independent variables

The actual value vs predicted value plot in the figure 21, actual values vs residuals in figure 22 and the distribution of the residuals in figure 23 show almost similar results for the respective plot for the multivariate model with the best three predictors. The highest positive error value seems slightly higher in the model with all the variables in it than in the model with only the three best predictors.

Overall, it is clear from the above results that the multivariate regression model with the three best predictors predicts medical cost better than all the other four models trained in this task. Given the time taken to train the model using all of the variables and best-correlated variables, and that compared with the accuracy of the prediction, the model with the best predictors chosen based on correlation seems the best choice.

1.2 Question 2: Census Income

1.2.1 Introduction

The dataset contains US census data, and the task is to predict whether a given individual earns more than \$50000. The data set is labelled and includes two classes. Five machine learning models with different classifiers and two artificial neural network models with a different number of layers are used to predict the income of an individual. The list of variables in the dataset is:

- age: the age of an individual
- workclass: employment status of an individual
- fnlwgt: final weight. The number of people the census believes the entry represents

- education: the highest level of education achieved by an individual
- education-num: the highest level of education achieved in numerical form
- marital-status: marital status of an individual.
- occupation: the general type of occupation of an individual
- relationship: represents what this individual is relative to others
- sex: the biological sex of the individual
- capital-gain: capital gains for an individual
- capital-loss: capital loss for an individual
- hours-per-week: the hours an individual has reported to work per week
- native-country: country of origin for an individual
- label: whether or not an individual makes more than \$50,000 annually.

1.2.2 Data Understanding and Preperation

The distribution of the data, type of the data, missing values, and a number of unique values in the data are analysed. Missing values are imputed based on the distribution of the data. Correlation is used to understand the relationship of the variables.

Label encoding, One hot encoding is used to transform categorical data and scaling is done before using data in the machine learning models.

```
[1031]: # Read data from csv to pandas dataframe
df2 = pd.read_csv('CensusDB.csv', na_values=['?'])
df2.head()
```

```
[1031]:
```

	age	workclass	fnlwgt	education	education-num	marital-status	\
0	90	NaN	77053	HS-grad	9	Widowed	
1	82	Private	132870	HS-grad	9	Widowed	
2	66	NaN	186061	Some-college	10	Widowed	
3	54	Private	140359	7th-8th	4	Divorced	
4	41	Private	264663	Some-college	10	Separated	
5	34	Private	216864	HS-grad	9	Divorced	
6	38	Private	150601	10th	6	Separated	
7	74	State-gov	88638	Doctorate	16	Never-married	
8	68	Federal-gov	422013	HS-grad	9	Divorced	
9	41	Private	70037	Some-college	10	Never-married	

	occupation	relationship	sex	capital-gain	capital-loss	\
0	NaN	Not-in-family	Female	0	4356	
1	Exec-managerial	Not-in-family	Female	0	4356	
2	NaN	Unmarried	Female	0	4356	
3	Machine-op-inspct	Unmarried	Female	0	3900	
4	Prof-specialty	Own-child	Female	0	3900	
5	Other-service	Unmarried	Female	0	3770	
6	Adm-clerical	Unmarried	Male	0	3770	
7	Prof-specialty	Other-relative	Female	0	3683	
8	Prof-specialty	Not-in-family	Female	0	3683	
9	Craft-repair	Unmarried	Male	0	3004	

	hours-per-week	native-country	income
0	40	United-States	<=50K
1	18	United-States	<=50K
2	40	United-States	<=50K
3	40	United-States	<=50K
4	40	United-States	<=50K
5	45	United-States	<=50K
6	40	United-States	<=50K
7	20	United-States	>50K
8	40	United-States	<=50K
9	60	NaN	>50K

```
[893]: print('Number of rows and columns in the dataset: ', df2.shape)
print('There are six continuous variables and eight categorical variables.')
```

Number of rows and columns in the dataset: (32561, 14)
There are six continuous variables and eight categorical variables.

```
[894]: df2.isnull().sum()
```

```
[894]: age                0
workclass             1836
fnlwgt                0
education              0
education-num         0
marital-status        0
occupation            1843
relationship          0
sex                   0
capital-gain           0
capital-loss           0
hours-per-week        0
native-country        583
income                0
dtype: int64
```

```
[895]: # Percentage of values missing in each column
for column in df2.columns:
    percentage = df2[column].isnull().mean()
    print(f'{column}: {round(percentage*100,4)}%')
```

```
age: 0.0%
workclass: 5.6386%
fnlwgt: 0.0%
education: 0.0%
education-num: 0.0%
marital-status: 0.0%
```

```
occupation: 5.6601%
relationship: 0.0%
sex: 0.0%
capital-gain: 0.0%
capital-loss: 0.0%
hours-per-week: 0.0%
native-country: 1.7905%
income: 0.0%
```

There are missing values present in the dataset. According to the distribution of the variables, missing values should be imputed as there are only three missing values per row at maximum. Dropping the row is a disadvantage to the analysis because it deletes the information of the other variables.

```
[896]: max_missing = 0
# Count of missing values across rows
for i in range(len(df2.index)):
    missing_current_row = df2.iloc[i].isnull().sum()
    if(max_missing < missing_current_row):
        max_missing = missing_current_row

print('maximum null values in a row : ', max_missing,
      '\nTherefore, dropping rows containing missing values is disadvantageous.▯
↳Dropping the entire rows not considered as it deletes data of the other 11▯
↳rows')
print()
```

```
maximum null values in a row : 3
```

Therefore, dropping rows containing missing values is disadvantageous. Dropping the entire rows not considered as it deletes data of the other 11 rows

```
[1030]: # Countplot for Income
sns.countplot(x='income', palette='viridis', data=df2)
plt.title('Counplot for income')
plt.show()
print('Figure 2.1: Number of observations representing each value of the income▯
↳label')
```

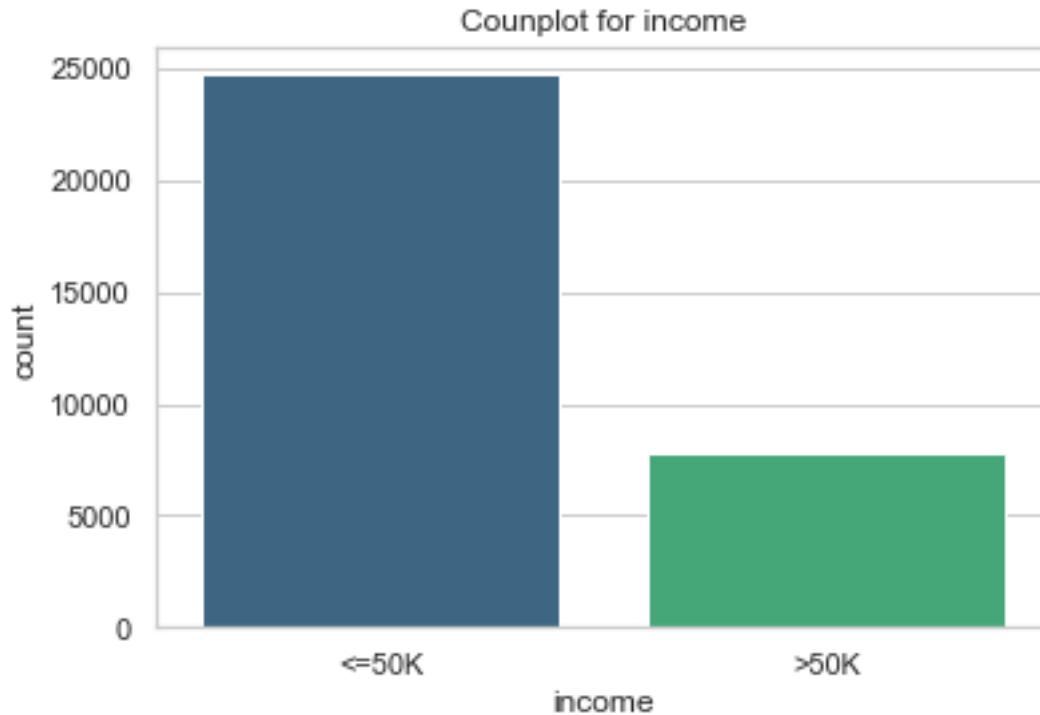



Figure 2.1: Number of observations representing each value of the income label

Figure 2.1 shows the target class does not have a balanced number of observations for each label of the target class. The models should be evaluated depending on this to get better performance from the unbalanced dataset.

```
[898]: df2.describe()
```

```
[898]:
```

	age	fnlwgt	education-num	capital-gain	capital-loss \
count	32561.000000	3.256100e+04	32561.000000	32561.000000	32561.000000
mean	38.581647	1.897784e+05	10.080679	1077.648844	87.303830
std	13.640433	1.055500e+05	2.572720	7385.292085	402.960219
min	17.000000	1.228500e+04	1.000000	0.000000	0.000000
25%	28.000000	1.178270e+05	9.000000	0.000000	0.000000
50%	37.000000	1.783560e+05	10.000000	0.000000	0.000000
75%	48.000000	2.370510e+05	12.000000	0.000000	0.000000
max	90.000000	1.484705e+06	16.000000	99999.000000	4356.000000

	hours-per-week
count	32561.000000
mean	40.437456
std	12.347429
min	1.000000
25%	40.000000

50%	40.000000
75%	45.000000
max	99.000000

```
[899]: fig, ax = plt.subplots(2, 3, figsize=(15, 8))

plt.subplot(2, 3, 1)
plt.hist(df2.iloc[:, 0], rwidth=0.9)
plt.xlabel(df2.columns[0], fontsize=15)

plt.subplot(2, 3, 2)
plt.hist(df2.iloc[:, 2], rwidth=0.9)
plt.xlabel(df2.columns[2], fontsize=15)

plt.subplot(2, 3, 3)
plt.hist(df2.iloc[:, 4], rwidth=0.9)
plt.xlabel(df2.columns[4], fontsize=15)

plt.subplot(2, 3, 4)
plt.hist(df2.iloc[:, 9], rwidth=0.9)
plt.xlabel(df2.columns[9], fontsize=15)

plt.subplot(2, 3, 5)
plt.hist(df2.iloc[:, 10], rwidth=0.9)
plt.xlabel(df2.columns[10], fontsize=15)

plt.subplot(2, 3, 6)
plt.hist(df2.iloc[:, 11], rwidth=0.9)
plt.xlabel(df2.columns[11], fontsize=15)

plt.tight_layout()
plt.show()
print('Figure 2.2: Distribution of the continuous variables')
```

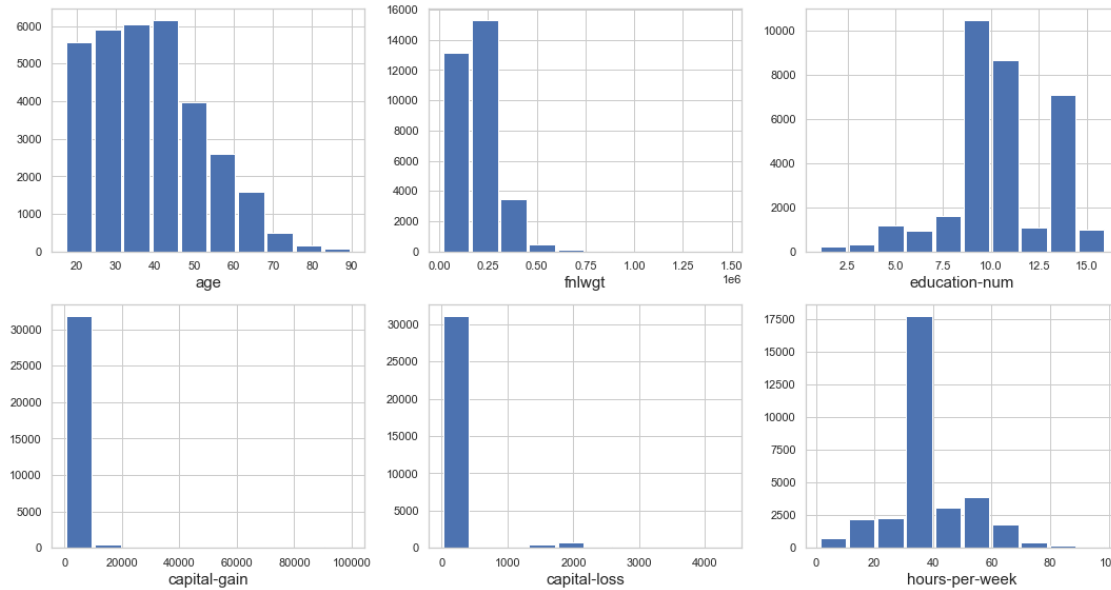


Figure 2.2: Distribution of the continuous variables

All the distributions are uneven distributions. Especially, Capital gain and Capital loss are highly skewed as can be seen in the boxplot in Figure 2.2. Hours per week shows a extremely high bar around 40 this can be interpreted as the normal hours for 8 or 7.5 hours per day working patern for a fultime employee. So it is understandable to have higher number of observations for this value.

```
[900]: # Boxplot of the continuous variables
fig, ax = plt.subplots(1, 6, figsize=(15, 5))

plt.subplot(1, 6, 1)
plt.boxplot(df2[['age']])
plt.xlabel('Age', fontsize=15)

plt.subplot(1, 6, 2)
plt.boxplot(df2[['fnlwgt']])
plt.xlabel('Final Weight.', fontsize=15)

plt.subplot(1, 6, 3)
plt.boxplot(df2[['education-num']])
plt.xlabel('Education', fontsize=15)

plt.subplot(1, 6, 4)
plt.boxplot(df2[['capital-gain']])
plt.xlabel('Capital Gain', fontsize=15)

plt.subplot(1, 6, 5)
plt.boxplot(df2[['capital-loss']])
```

```
plt.xlabel('Capital Loss', fontsize=15)

plt.subplot(1, 6, 6)
plt.boxplot(df2[['hours-per-week']])
plt.xlabel('Hours per Week', fontsize=15)

plt.tight_layout()
plt.show()
print('Figure 2.3: Boxplot of the continuous variables')
```

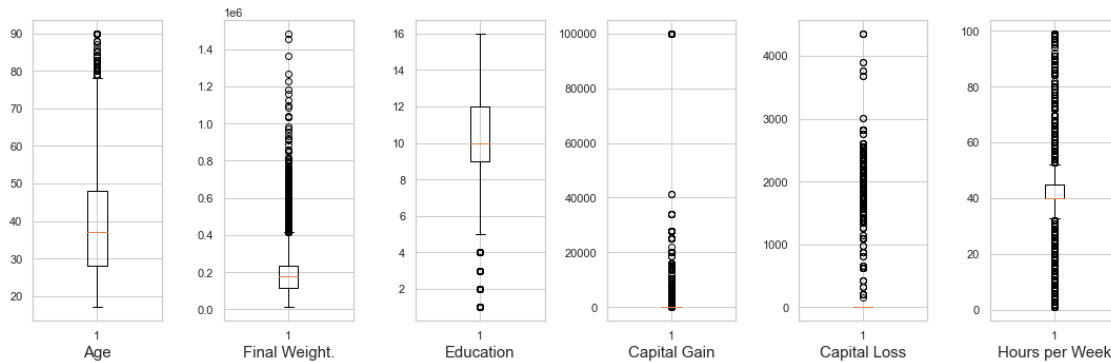


Figure 2.3: Boxplot of the continuous variables

A boxplot is used to identify outliers. From figure 2.3, it is clear that all the continuous variables have outliers. Age and Final Weight have outliers at the higher end of the distribution. Education has outliers at the lower end. The other three variables have outliers on both sides.

This analysis suggests that the capital-gain variable has extreme values at 99999. Observations with these values are dropped as it seems to be erroneous data, and not clear how to validate the data with the given information.

```
[901]: df2.drop(df2[df2['capital-gain'] >= 60000].index, inplace=True)
```

```
[902]: freq_table = pd.crosstab(df2['workclass'], df2['income'])
freq_table
```

```
[902]: income      <=50K  >50K
workclass
Federal-gov      589    370
Local-gov       1476    611
Never-worked        7     0
Private       17733   4881
Self-emp-inc     494    586
Self-emp-not-inc 1817   695
State-gov        945    352
Without-pay       14     0
```

```
[903]: sns.set_theme(style="whitegrid")
sns.countplot(y='workclass', hue='income', palette='rocket', data=df2)
plt.title('Countplot for workclass')
plt.show()
print('Figure 2.4: Countplot for Workclass')
```

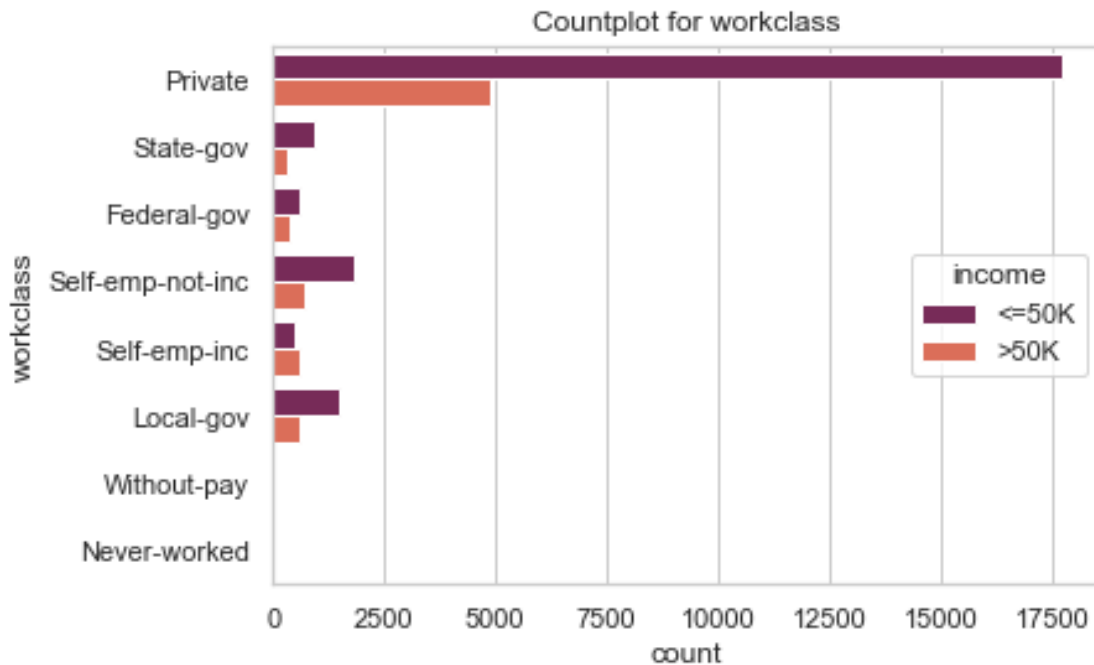


Figure 2.4: Countplot for Workclass

There are more low-income individuals, and fewer high-income individuals are visible in all the classes. In the private work-class category, the difference is significantly large.

```
[904]: df2['workclass'] = df2['workclass'].fillna(df2['workclass'].mode()[0])
```

```
[905]: freq_table = pd.crosstab(df2['occupation'], df2['income'])
freq_table
```

```
[905]: income
occupation
Adm-clerical      3263    501
Armed-Forces         8     1
Craft-repair      3170    921
Exec-managerial   2098   1926
Farming-fishing    879    115
Handlers-cleaners  1284     85
Machine-op-inspct  1752    249
Other-service     3158    135
```

Priv-house-serv	148	1
Prof-specialty	2281	1792
Protective-serv	438	210
Sales	2667	958
Tech-support	645	282
Transport-moving	1277	319

```
[906]: sns.countplot(y='occupation', hue='income', palette='viridis', data=df2)
plt.title('Countplot for Occupation')
plt.show()
print('Figure 2.5: Countplot for Occupation')
```

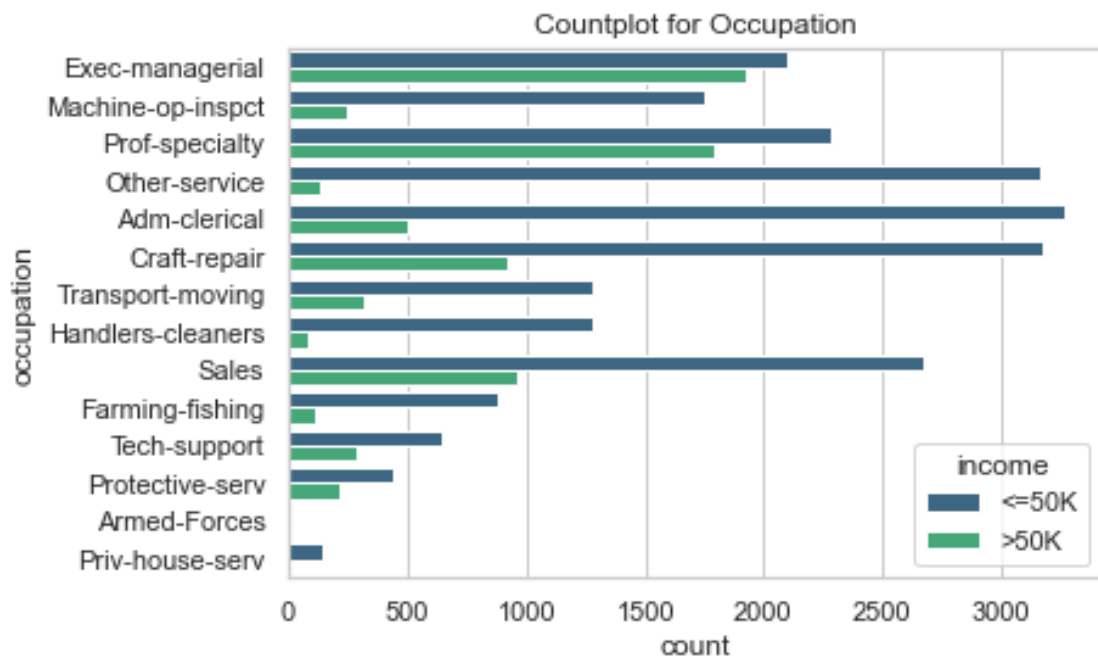


Figure 2.5: Countplot for Occupation

The same pattern of more low-income individuals and fewer high-income individuals is visible in all the classes. However, for Executive Managerial category and Professional Speciality categories have little difference in the two groups.

```
[907]: df2['occupation'] = df2['occupation'].fillna(df2['occupation'].mode()[0])
```

```
[908]: len(df2['native-country'].unique())
```

```
[908]: 42
```

There are too many unique values in the native countries variable. In order to reduce dimensionality, their values are categorised based on geographical location.

```
[909]: freq_table = pd.crosstab(df2['native-country'], df2['income'])
freq_table
```

```
[909]: income          <=50K  >50K
native-country
Cambodia              12      7
Canada               82     38
China                55     20
Columbia             57      2
Cuba                 70     25
Dominican-Republic   68      1
Ecuador             24      4
El-Salvador          97      9
England             60     30
France              17     12
Germany             93     44
Greece              21      8
Guatemala           61      3
Haiti                40      4
Holand-Netherlands    1      0
Honduras            12      1
Hong                14      6
Hungary             10      3
India               60     37
Iran                25     18
Ireland             19      5
Italy               48     25
Jamaica             71     10
Japan               38     23
Laos                16      2
Mexico              610     32
Nicaragua           32      2
Outlying-US(Guam-USVI-etc) 14      0
Peru                29      2
Philippines         137     60
Poland              48     12
Portugal            33      4
Puerto-Rico        102     12
Scotland            9      3
South               64     15
Taiwan              31     19
Thailand            15      3
Trinidad&Tobago      17      2
United-States       2199    7029
Vietnam             62      5
Yugoslavia          10      6
```

```
[910]: df2['native-country'] = df2['native-country'].fillna('Other')
```

The missing values in the native countries have been imputed with the value **other**. All the other wrong country names are categorised as ‘other’ in the next step, and other native countries are separated into groups depending on the region.

```
[911]: # Age grouping using mean values
df2.loc[df2['native-country'] == 'Cambodia', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'China', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Vietnam', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Thailand', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Taiwan', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Philippines', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Japan', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Hong', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'India', 'native-country'] = 'Asia'
df2.loc[df2['native-country'] == 'Iran', 'native-country'] = 'Asia'

df2.loc[df2['native-country'] == 'Portugal', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Poland', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Italy', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Ireland', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] ==
    'Holand-Netherlands', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Greece', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Germany', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'France', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'England', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Scotland', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Yugoslavia', 'native-country'] = 'Europe'
df2.loc[df2['native-country'] == 'Hungary', 'native-country'] = 'Europe'

df2.loc[df2['native-country'] == 'Trinidad&Tobago',
    'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Puerto-Rico', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Peru', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Nicaragua', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Mexico', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Jamaica', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Honduras', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Haiti', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Guatemala', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'El-Salvador', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Ecuador', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Dominican-Republic',
```



```

        'native-country' = 'America'
df2.loc[df2['native-country'] == 'Cuba', 'native-country'] = 'America'
df2.loc[df2['native-country'] == 'Columbia', 'native-country'] = 'America'

df2.loc[df2['native-country'] == 'South', 'native-country'] = 'Other'
df2.loc[df2['native-country'] == 'Laos', 'native-country'] = 'Other'
df2.loc[df2['native-country'] ==
        'Outlying-US(Guam-USVI-etc)', 'native-country'] = 'Other'

```

```
[912]: pd.crosstab(df2['native-country'], df2['income'])
```

```
[912]: income          <=50K  >50K
native-country
America          1290    109
Asia              449    198
Canada             82     38
Europe            369    152
Other             531    156
United-States   21999   7029
```

```
[913]: sns.countplot(x='native-country', hue='income', palette='cubehelix', data=df2)
plt.title('Countplot for native country')
plt.show()
print('Figure 2.6: Countplot for grouped Native Country')
```

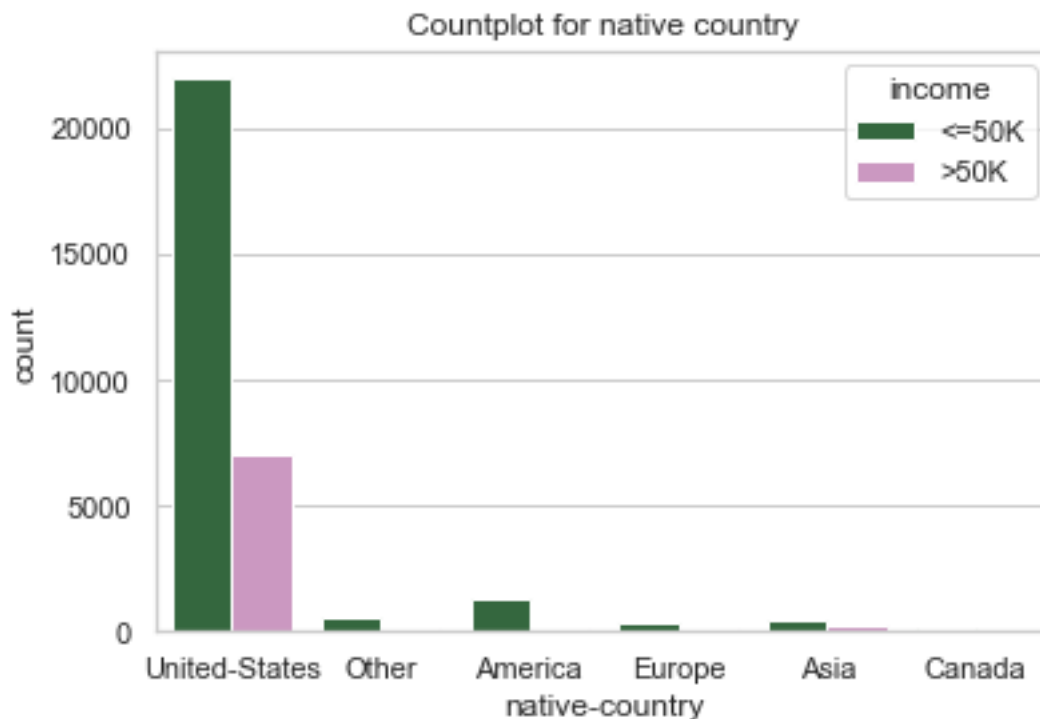


Figure 2.6: Countplot for grouped Native Country

The Native country has the most observations for the United States. There is only a small amount of observations are recorded for other countries. The bar for lower income than 50000 dollars is prominent across all the countries.

Transforming categorical variables with label encoding and OneHot encoding Label encoding is used where ever possible to avoid increasing dimensionality. When there are more than two unique values in the column and no specific ordering, Dummy values are used.

```
[914]: # Label encoding sex, income
# Because there are only two classes in the below two variables, label encoding
# is used
le = LabelEncoder()

# Sex variable
le.fit(df2.sex.drop_duplicates())
df2.sex = le.transform(df2.sex)

# Smoker variable
le.fit(df2.income.drop_duplicates())
df2.income = le.transform(df2.income)
```

```
[915]: # Dummy variable
# Because there are several values of native country, workclass,
# marital-status, occupation and relationship, and has no ordering, OneHot
# encoding is used
df2 = pd.get_dummies(data=df2, prefix='country', prefix_sep='_', columns=[
    'native-country'], drop_first=False, dtype='int8')
df2 = pd.get_dummies(data=df2, prefix='wc', prefix_sep='_', columns=[
    'workclass'], drop_first=False, dtype='int8')
df2 = pd.get_dummies(data=df2, prefix='ms', prefix_sep='_', columns=[
    'marital-status'], drop_first=False, dtype='int8')
df2 = pd.get_dummies(data=df2, prefix='oc', prefix_sep='_', columns=[
    'occupation'], drop_first=False, dtype='int8')
df2 = pd.get_dummies(data=df2, prefix='re', prefix_sep='_', columns=[
    'relationship'], drop_first=False, dtype='int8')
```

```
[916]: # Drop categorical values as they have transformed into other variables
df2 = df2.drop(['education'], axis=1)
```

Correlation analysis

```
[917]: plt.figure(figsize=(10, 5))
sns.heatmap(df2[['age', 'sex', 'fnlwgt', 'education-num', 'capital-gain',
    'capital-loss', 'hours-per-week', 'income']].corr(method='spearman'),
```

```

        annot=True, fmt='.2f', cmap='PRGn')
plt.title('Correlation plot for continuous variables')
plt.show()
print('Figure 2.7: Correlation plot for continuous variables')

```

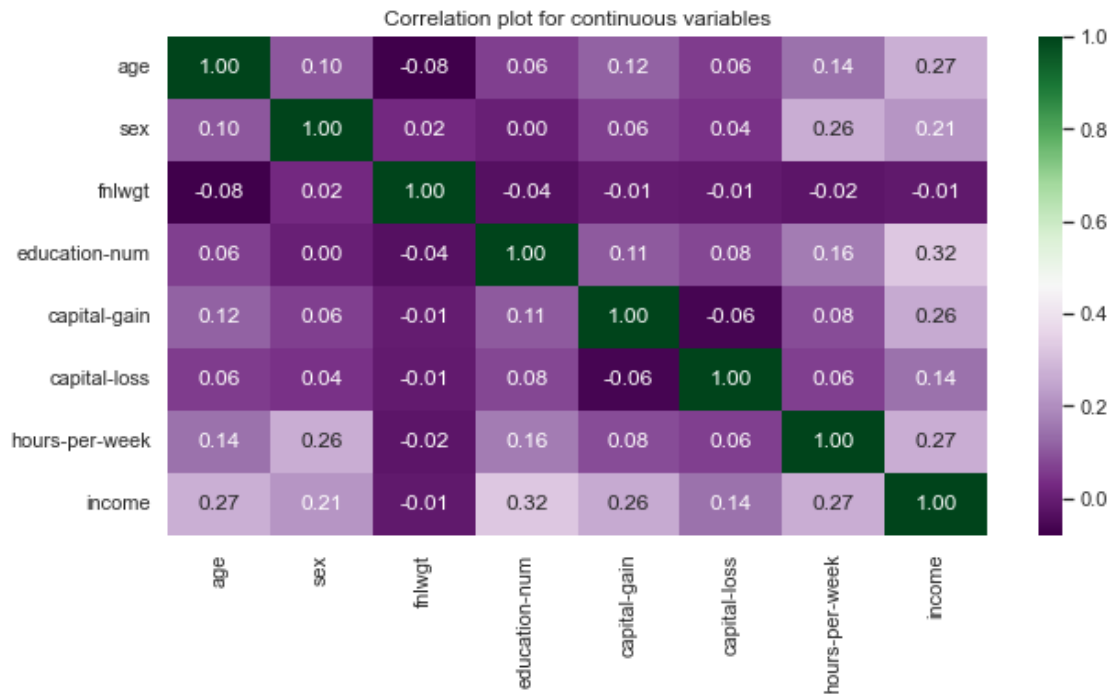


Figure 2.7: Correlation plot for continuous variables

```

[918]: plt.figure(figsize=(10, 5))
sns.heatmap(df2[['re_Husband', 're_Not-in-family', 're_Other-relative',
↪ 're_Own-child', 're_Unmarried', 're_Wife', 'income']]).
↪ corr(method='spearman'),
        annot=True, fmt='.2f', cmap='PRGn')
plt.title('Correlation plot for Relationship variable')
plt.show()
print('Figure 2.8: Correlation plot for Relationship variable')

```

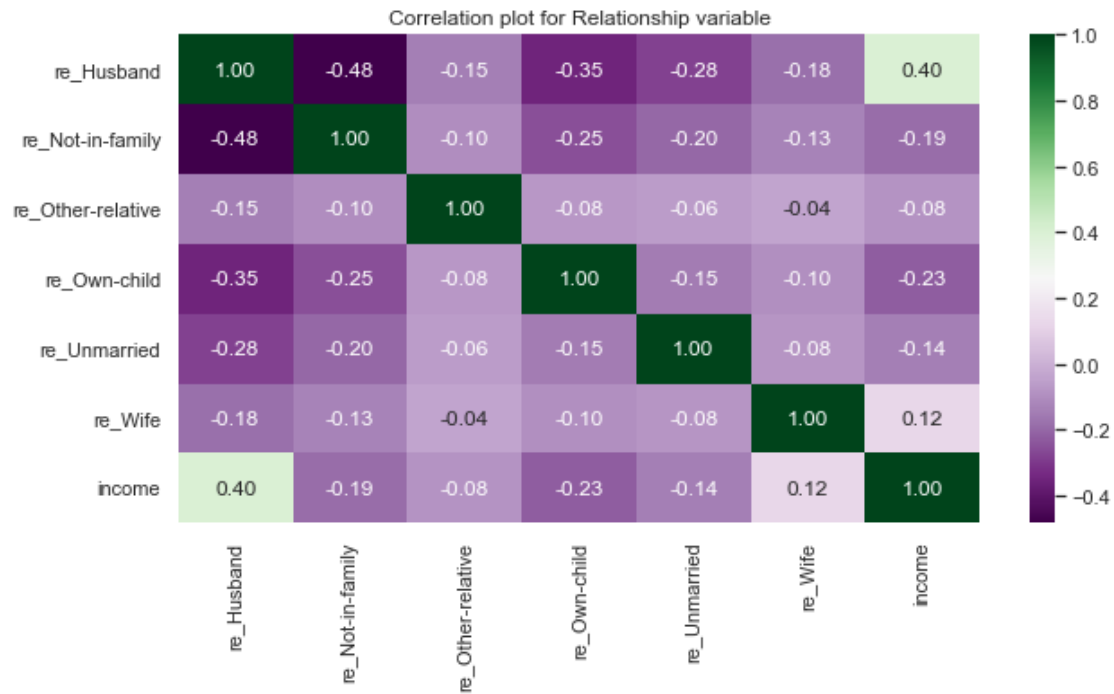


Figure 2.8: Correlation plot for Relationship variable

```
[919]: plt.figure(figsize=(10, 5))
sns.heatmap(df2[['country_America', 'country_Asia', 'country_Canada', 'country_Europe', 'country_Other', 'country_United-States', 'income']],
            corr(method='spearman'),
            annot=True, fmt='.2f', cmap='PRGn')
plt.title('Correlation plot for Native Country variable')
plt.show()
print('Figure 2.9: Correlation plot for Native Country variable')
```

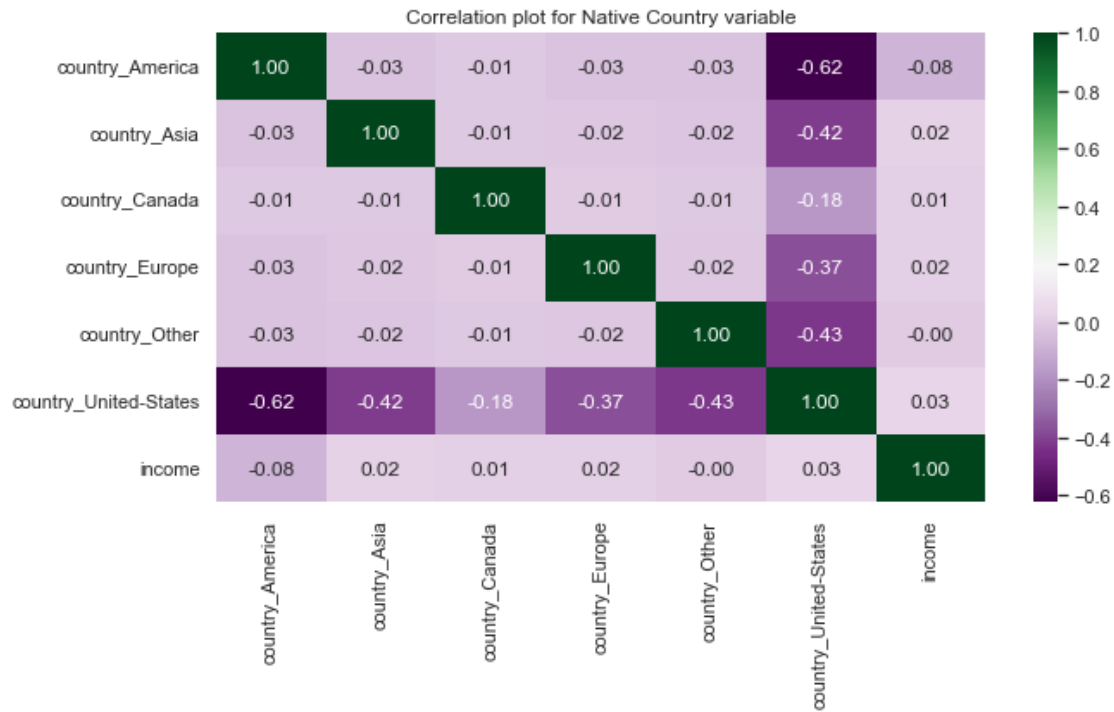


Figure 2.9: Correlation plot for Native Country variable

```
[920]: plt.figure(figsize=(10, 5))
sns.heatmap(df2[['wc_Federal-gov', 'wc_Local-gov', 'wc_Never-worked',
↪ 'wc_Private', 'wc_Self-emp-inc', 'wc_Self-emp-not-inc', 'wc_State-gov',
↪ 'wc_Without-pay', 'income']].corr(method='spearman'),
          annot=True, fmt='.2f', cmap='PRGn')
plt.title('Correlation plot for Workclass variable')
plt.show()
print('Figure 2.10: Correlation plot for Workclass variable')
```

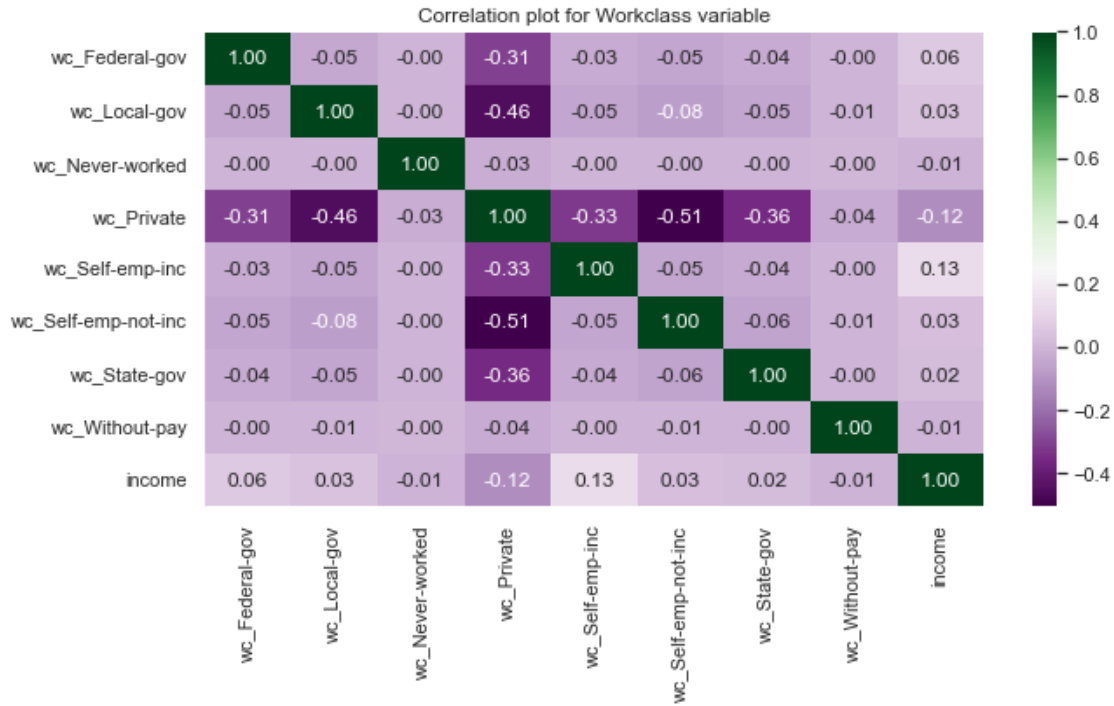


Figure 2.10: Correlation plot for Workclass variable

```
[921]: plt.figure(figsize=(10, 5))
sns.heatmap(df2[['ms_Divorced', 'ms_Married-AF-spouse', 'ms_Married-civ-spouse', 'ms_Married-spouse-absent', 'ms_Never-married', 'ms_Separated', 'ms_Widowed', 'income']].corr(method='spearman'),
            annot=True, fmt='.2f', cmap='PRGn')
plt.title('Correlation plot for Married-status variable')
plt.show()
print('Figure 2.11: Correlation plot for Married-status variable')
```

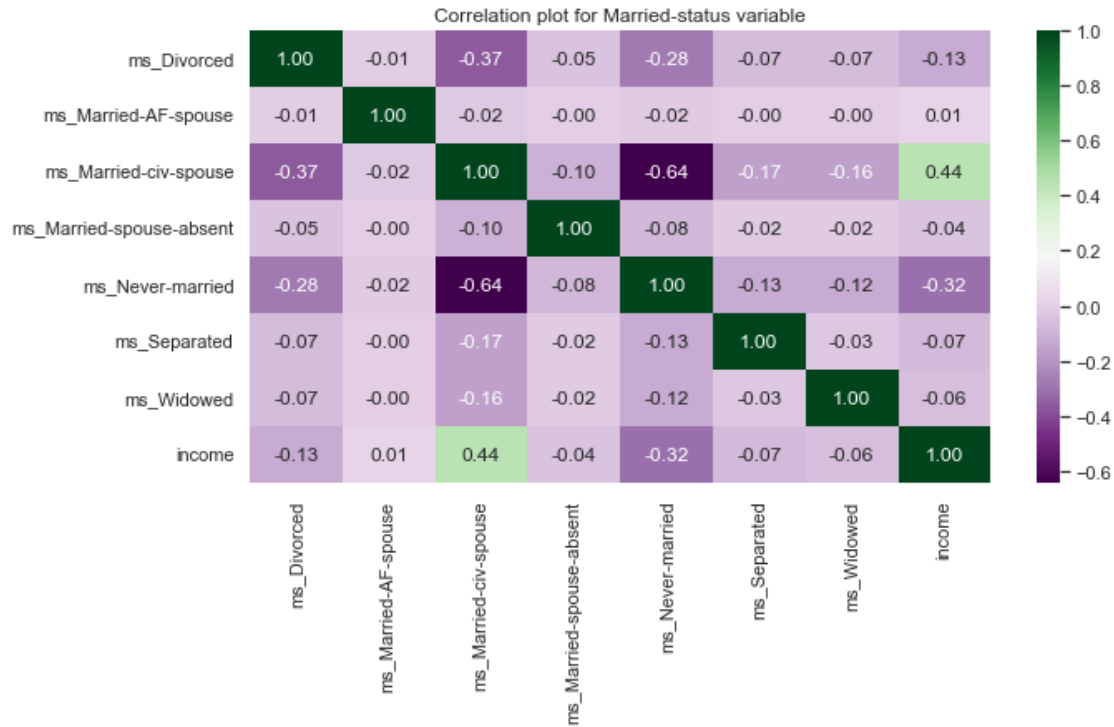


Figure 2.11: Correlation plot for Married-status variable

```
[922]: plt.figure(figsize=(15, 8))
sns.heatmap(df2[['oc_Adm-clerical', 'oc_Armed-Forces', 'oc_Craft-repair',
↳ 'oc_Exec-managerial', 'oc_Farming-fishing', 'oc_Handlers-cleaners',
      'oc_Machine-op-inspct', 'oc_Other-service',
↳ 'oc_Priv-house-serv', 'oc_Prof-specialty', 'oc_Protective-serv', 'oc_Sales',
↳ 'oc_Tech-support',
      'oc_Transport-moving', 'income']].corr(method='spearman'),
↳ annot=True, fmt='.2f', cmap='PRGn')
plt.title('Correlation plot for Occupation variable')
plt.show()
print('Figure 2.12: Correlation plot for Occupation variable')
```

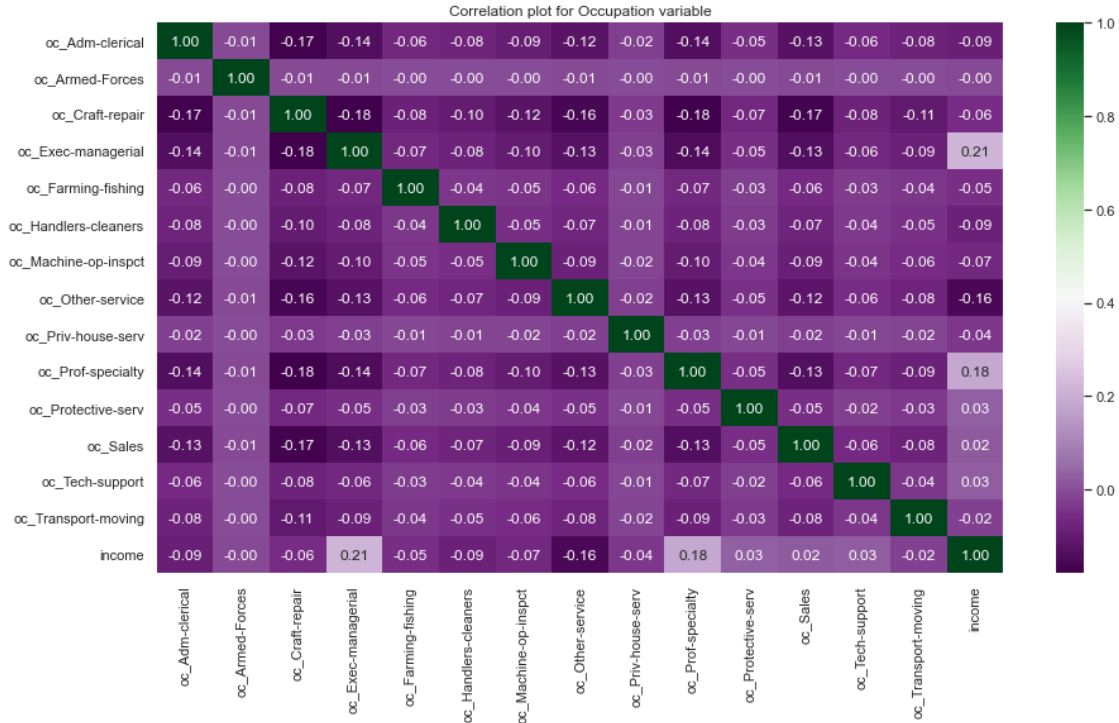


Figure 2.12: Correlation plot for Occupation variable

Correlation analysis shows that for the target variable, there is no strong correlation with any of the other variables. The maximum absolute values found in the correlation analysis are 0.44 for ms_Married-civ-spouse, 0.4 for re_Husband and 0.32 for education-num variables. All the variables are considered for the machine learning model because there are no prominent variables.

```
[923]: # Separating dependent and independent variables
x2 = df2.drop(columns=['income'])
y2 = df2.income

# Scaling dependent variables using standard scaler
ssc = StandardScaler()
x2 = ssc.fit_transform(x2)

# Separate dataset to train and test sets with 80% to train and 20% to test
x2_train, x2_test, y2_train, y2_test = train_test_split(
    x2, y2, test_size=0.2, random_state=3)
```

1.2.3 Machine Learning model to predict whether an individual is going to earn more than \$50,000 annually

There are four classification models, Logistic Regression, Support Vector Machine, Random Forest and Gaussian Naive Bayes and two Artificial Neural Network models.

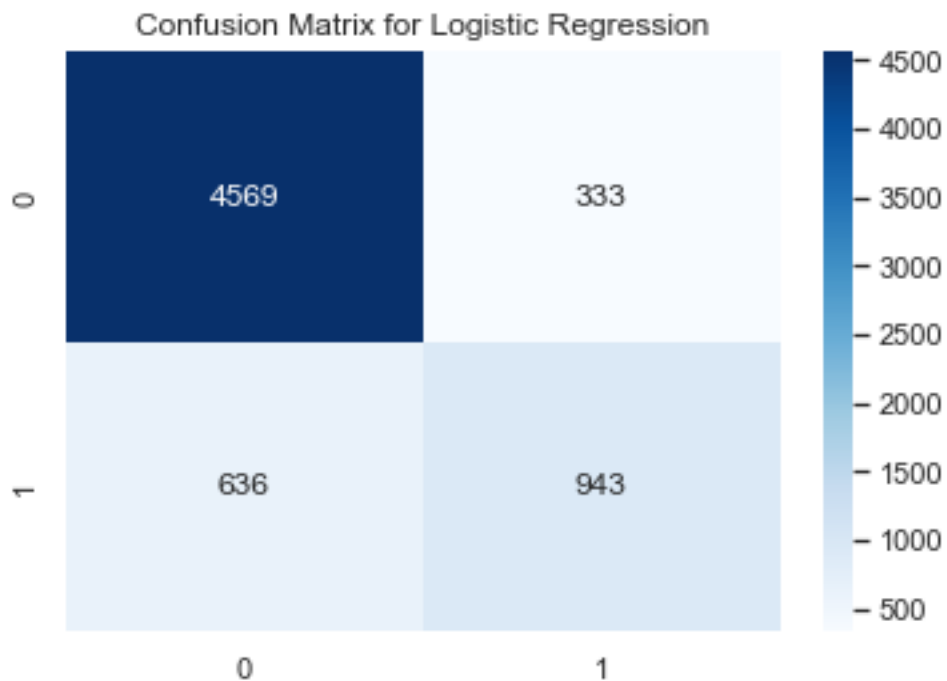
Classification models

Logistic Regression

```
[924]: model_lr = LogisticRegression(random_state=0)
model_lr.fit(x2_train, y2_train)
pred_lr = model_lr.predict(x2_test)
matrix = confusion_matrix(y2_test, pred_lr)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
print(classification_report(y2_test, pred_lr))
plt.title('Confusion Matrix for Logistic Regression')
print('Figure 2.13: Confusion Matrix for Logistic Regression')
```

	precision	recall	f1-score	support
0	0.88	0.93	0.90	4902
1	0.74	0.60	0.66	1579
accuracy				0.85
macro avg				0.81
weighted avg				0.84

Figure 2.13: Confusion Matrix for Logistic Regression



The Logistic Regression model has an accuracy of 0.85, which means that 85% of the sample has been correctly classified. The F1 score is 0.9 shows that for label one, classification is performing

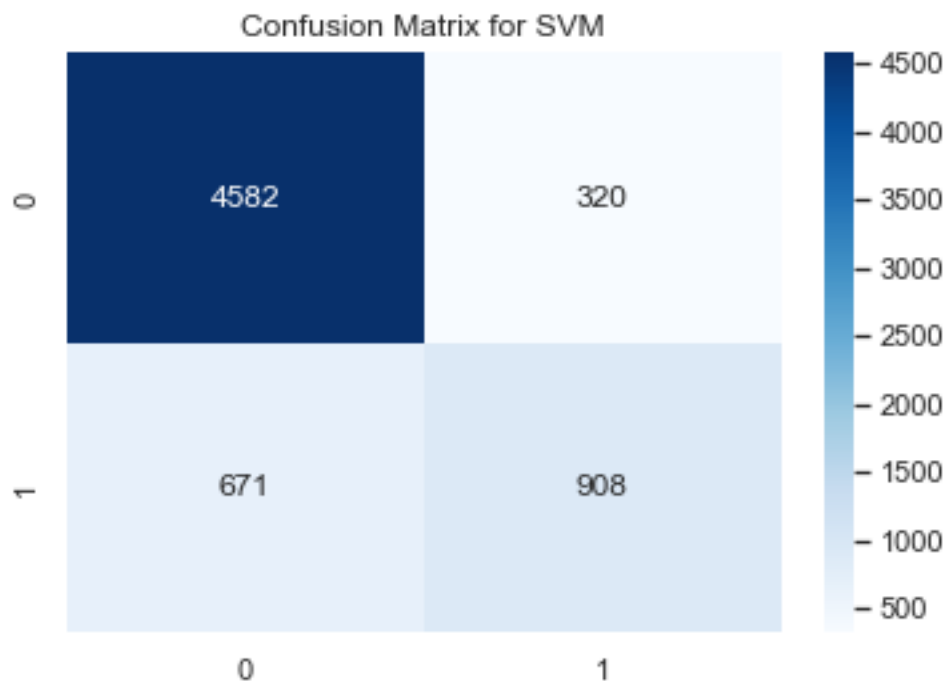
well. However, for label zero, just above average F1 score. High precision of 0.88 and recall of 0.9 shows that a high proportion of class one values of the output have been identified by the model correctly within the class and between classes. For the class, zero scores are a little lower.

Support Vector Machine

```
[925]: model_svm = svm.SVC(kernel='poly')
model_svm.fit(x2_train, y2_train)
pred_svm = model_svm.predict(x2_test)
matrix = confusion_matrix(y2_test, pred_svm)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
print(classification_report(y2_test, pred_svm))
plt.title('Confusion Matrix for SVM')
print('Figure 2.14: Confusion Matrix for Supported Vector Machine')
```

	precision	recall	f1-score	support
0	0.87	0.93	0.90	4902
1	0.74	0.58	0.65	1579
accuracy			0.85	6481
macro avg	0.81	0.75	0.77	6481
weighted avg	0.84	0.85	0.84	6481

Figure 2.14: Confusion Matrix for Supported Vector Machine



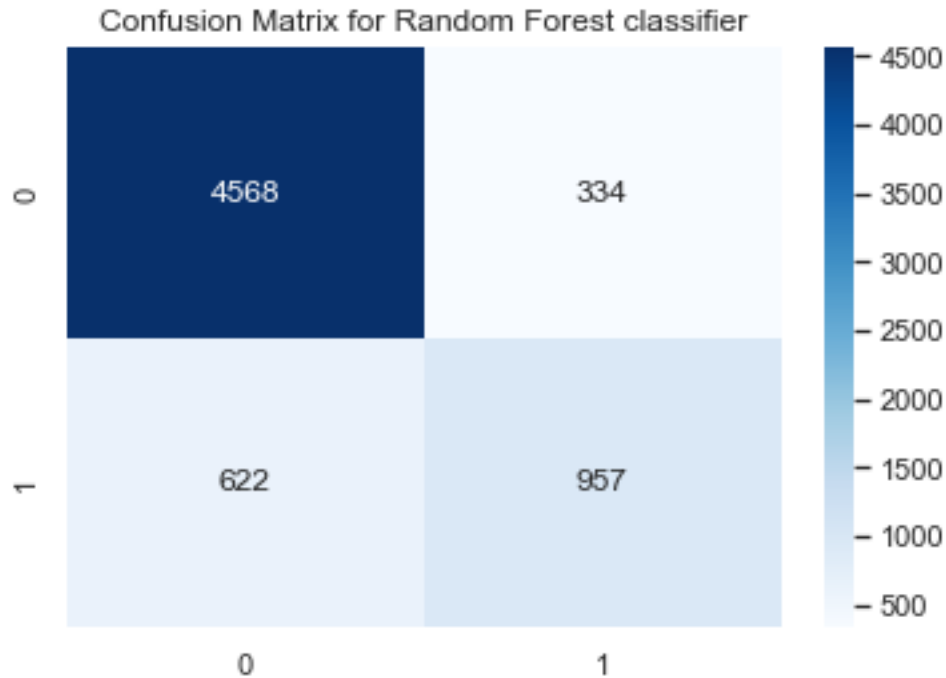
The Supported Vector machine Model has an accuracy of 0.85, which means that 85% of the sample has been correctly classified. The F1 score is 0.9 shows that for class one, classification is performing well. However, for label zero, just above average F1 score. High precision of 0.87 and recall of 0.93 shows that a high proportion of class one values of the output have been identified by the model correctly within the class and between classes. For the class, zero scores are a little lower. All the model evaluation parameter values are approximately equal to the respective values from Logistic Regression.

Random Forest Classifier

```
[926]: model_rf = RandomForestClassifier()
model_rf.fit(x2_train, y2_train)
pred_rf = model_rf.predict(x2_test)
matrix = confusion_matrix(y2_test, pred_rf)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
print(classification_report(y2_test, pred_rf))
plt.title('Confusion Matrix for Random Forest classifier')
print('Figure 2.15: Confusion Matrix for Random Forest Classifier')
```

	precision	recall	f1-score	support
0	0.88	0.93	0.91	4902
1	0.74	0.61	0.67	1579
accuracy			0.85	6481
macro avg	0.81	0.77	0.79	6481
weighted avg	0.85	0.85	0.85	6481

Figure 2.15: Confusion Matrix for Random Forest Classifier



The Random Forest classifier has an accuracy of 0.85, which means that 85% of the sample has been correctly classified. The F1 score is 0.9 shows that for class one, classification is performing well. However, for label zero, just above average F1 score. High precision of 0.88 and recall of 0.93 shows that a high proportion of class one values of the output have been identified by the model correctly within the class and between classes. For the class, zero scores are a little lower. All the model evaluation parameter values are approximately equal to the respective values from Logistic Regression and Supported Vector Machine.

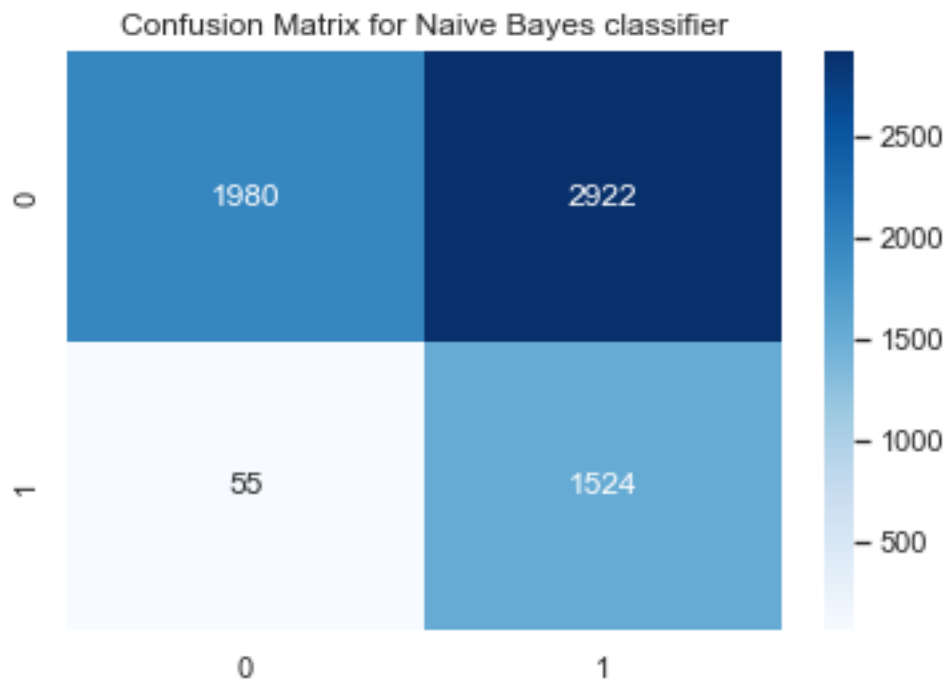
Naive Bayes Classifier

```
[927]: model_gnb = GaussianNB()
model_gnb.fit(x2_train, y2_train)
pred_gnb = model_gnb.predict(x2_test)
matrix = confusion_matrix(y2_test, pred_gnb)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
print(classification_report(y2_test, pred_gnb))
plt.title('Confusion Matrix for Naive Bayes classifier')
print('Figure 2.16: Confusion Matrix for Naive Bayes Classifier')
```

	precision	recall	f1-score	support
0	0.97	0.40	0.57	4902
1	0.34	0.97	0.51	1579
accuracy			0.54	6481
macro avg	0.66	0.68	0.54	6481

weighted avg	0.82	0.54	0.56	6481
--------------	------	------	------	------

Figure 2.16: Confusion Matrix for Naive Bayes Classifier



The Gaussian Naive Bayes Model has an accuracy of 0.54, which means that only 54% of the sample has been correctly classified. F1 score of 0.57 and 0.51 for class one and zero shows that when considering both output cases, classification only has an average performance. A high value of 0.97 precision shows that the model is performing better for one output label. However, the low value of precision of 0.34 suggests that for the other class, the model is not performing well. The confusion matrix shows there are 2922 wrong classifications for class label 1. The low recall value for class one and low precision for class zero explains the average accuracy of the model.

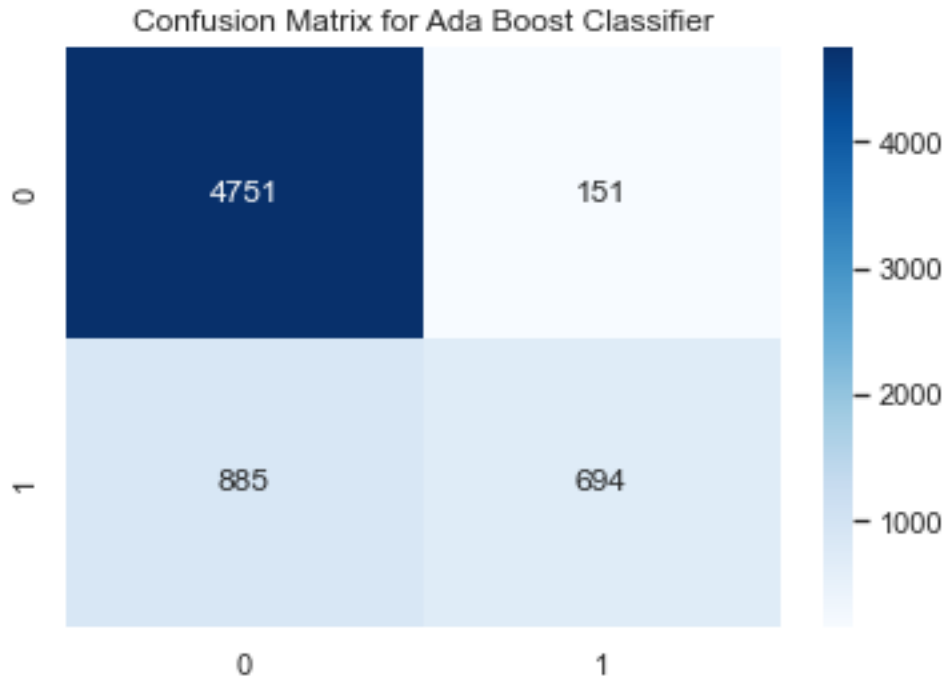
AdaBoost Classifier

```
[928]: model = AdaBoostClassifier(learning_rate=0.15, n_estimators=25)
model.fit(x2_train, y2_train)
y_pred = model.predict(x2_test)
print(classification_report(y2_test, y_pred))
matrix = confusion_matrix(y2_test, y_pred)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for Ada Boost Classifier')
print('Figure 2.17: Confusion Matrix for Ada Boost Classifier')
```

	precision	recall	f1-score	support
0	0.84	0.97	0.90	4902

1	0.82	0.44	0.57	1579
accuracy			0.84	6481
macro avg	0.83	0.70	0.74	6481
weighted avg	0.84	0.84	0.82	6481

Figure 2.17: Confusion Matrix for Ada Boost Classifier



The Ada Boost classifier Model has an accuracy of 0.84, which means that only 84% of the sample has been correctly classified. F1 score of 0.9 for class one and 0.57 for class zero shows that the performance difference in the two classes observed in Logistic regression, SVM and Random Forrest, is the same in this model. A high value of 0.84 and 0.82 for class one and class zero, respectively, shows that the model performs better when identifying the true positives model performs better. However, a low value of recall of 0.34 for class zero suggests that the proportion of actual positives is not high. The confusion matrix shows there are 2922 wrong classifications for class label 1.

When comparing classification models, four models are performing well, and one model, the Naive Bayes model, is not performing well for one output label of the target class, reducing the accuracy of that model. F1 score is almost the same for the first three models, Logistic Regression, Supported Vector Machine and Random Forest, fairly good for AdaBoost Classifier. However, the average for the Naive Bayes model. Accuracy is better in Logistic Regression, Random Forest and Supported Vector Machine. The naive Bayes classifier has the highest precision value of .97 for class one and the highest recall of .97 for class zero, even though all the other metrics have low values. Ada Boost classifier also has 0.97 recall for class one. The Random Forest classier has the highest performance, even though it is only a slight difference from the other two top classifiers.

Artificial Neural Network models Two Artificial Neural Network models have been trained. One with the input layer, two hidden layers, and the output layer. And another with the input layer, one hidden layer, and the output layer. Models are also different in the number of nodes in the hidden layers.

Artificial Neural Network model one

```
[929]: # Initialise ANN
model_ann1 = tf.keras.models.Sequential()
# Add two hidden layers
model_ann1.add(tf.keras.layers.Dense(units=20, activation='relu'))
model_ann1.add(tf.keras.layers.Dense(units=10, activation='relu'))
# Add output layer
model_ann1.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann1.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann1.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=50, epochs=15)
loss, acc = model_ann1.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))
```

Epoch 1/15

519/519 [=====] - 1s 2ms/step - loss: 0.4015 - accuracy: 0.8053 - val_loss: 0.3272 - val_accuracy: 0.8466

Epoch 2/15

519/519 [=====] - 1s 1ms/step - loss: 0.3177 - accuracy: 0.8532 - val_loss: 0.3232 - val_accuracy: 0.8496

Epoch 3/15

519/519 [=====] - 1s 1ms/step - loss: 0.3123 - accuracy: 0.8549 - val_loss: 0.3220 - val_accuracy: 0.8517

Epoch 4/15

519/519 [=====] - 1s 1ms/step - loss: 0.3094 - accuracy: 0.8565 - val_loss: 0.3232 - val_accuracy: 0.8511

Epoch 5/15

519/519 [=====] - 1s 2ms/step - loss: 0.3074 - accuracy: 0.8586 - val_loss: 0.3206 - val_accuracy: 0.8491

Epoch 6/15

519/519 [=====] - 1s 1ms/step - loss: 0.3054 - accuracy: 0.8584 - val_loss: 0.3206 - val_accuracy: 0.8497

Epoch 7/15

519/519 [=====] - 1s 1ms/step - loss: 0.3039 - accuracy: 0.8602 - val_loss: 0.3208 - val_accuracy: 0.8503

Epoch 8/15

519/519 [=====] - 1s 1ms/step - loss: 0.3028 - accuracy: 0.8609 - val_loss: 0.3204 - val_accuracy: 0.8516

Epoch 9/15

```

519/519 [=====] - 1s 1ms/step - loss: 0.3017 -
accuracy: 0.8605 - val_loss: 0.3200 - val_accuracy: 0.8523
Epoch 10/15
519/519 [=====] - 1s 1ms/step - loss: 0.3010 -
accuracy: 0.8621 - val_loss: 0.3189 - val_accuracy: 0.8516
Epoch 11/15
519/519 [=====] - 1s 1ms/step - loss: 0.2999 -
accuracy: 0.8604 - val_loss: 0.3212 - val_accuracy: 0.8506
Epoch 12/15
519/519 [=====] - 1s 1ms/step - loss: 0.2992 -
accuracy: 0.8602 - val_loss: 0.3187 - val_accuracy: 0.8505
Epoch 13/15
519/519 [=====] - 1s 1ms/step - loss: 0.2988 -
accuracy: 0.8608 - val_loss: 0.3187 - val_accuracy: 0.8494
Epoch 14/15
519/519 [=====] - 1s 1ms/step - loss: 0.2981 -
accuracy: 0.8610 - val_loss: 0.3195 - val_accuracy: 0.8497
Epoch 15/15
519/519 [=====] - 1s 1ms/step - loss: 0.2975 -
accuracy: 0.8616 - val_loss: 0.3191 - val_accuracy: 0.8516
203/203 [=====] - 0s 727us/step - loss: 0.3191 -
accuracy: 0.8516
Accuracy: 85.156614

```

```

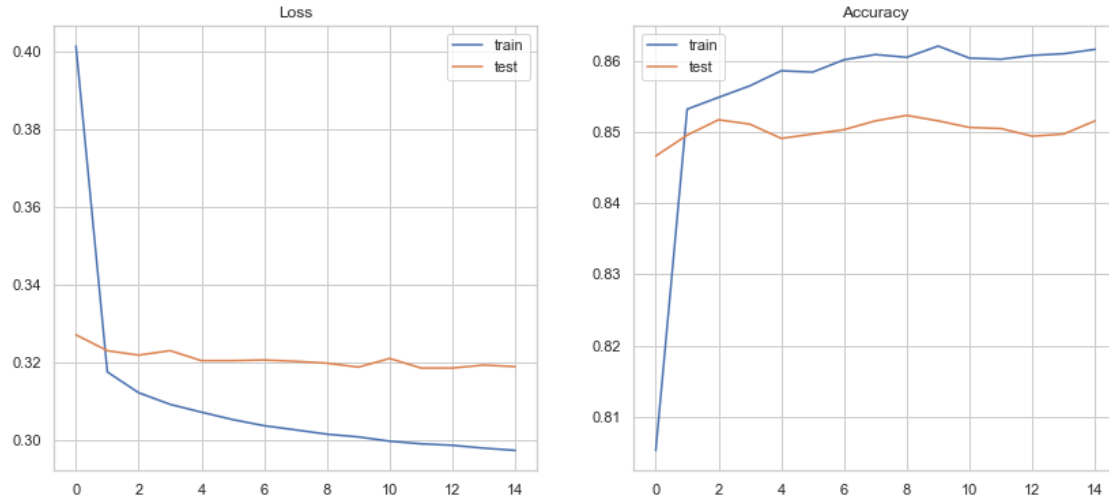
[930]: f = plt.figure(figsize=(14, 6))
plt.subplot(121)
plt.title('Loss')
plt.plot(history.history['loss'], label='train')
plt.plot(history.history['val_loss'], label='test')
plt.legend()

plt.subplot(122)
plt.title('Accuracy')
plt.plot(history.history['accuracy'], label='train')
plt.plot(history.history['val_accuracy'], label='test')
plt.legend()

print('Figure 2.18: Performance of ANN')

```

Figure 2.18: Performance of ANN



Artificial Neural Network model two

```
[931]: # Initialise ANN
model_ann2 = tf.keras.models.Sequential()
# Add a hidden layer
model_ann2.add(tf.keras.layers.Dense(units=15, activation='relu'))
# Add output layer
model_ann2.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann2.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann2.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=30, epochs=20)
loss, acc = model_ann2.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))
```

Epoch 1/20

865/865 [=====] - 1s 1ms/step - loss: 0.3661 - accuracy: 0.8298 - val_loss: 0.3272 - val_accuracy: 0.8465

Epoch 2/20

865/865 [=====] - 1s 1ms/step - loss: 0.3192 - accuracy: 0.8514 - val_loss: 0.3224 - val_accuracy: 0.8506

Epoch 3/20

865/865 [=====] - 1s 1ms/step - loss: 0.3143 - accuracy: 0.8531 - val_loss: 0.3197 - val_accuracy: 0.8519

Epoch 4/20

865/865 [=====] - 1s 1ms/step - loss: 0.3110 - accuracy: 0.8536 - val_loss: 0.3171 - val_accuracy: 0.8531

Epoch 5/20

865/865 [=====] - 1s 1ms/step - loss: 0.3086 -

```

accuracy: 0.8555 - val_loss: 0.3158 - val_accuracy: 0.8550
Epoch 6/20
865/865 [=====] - 1s 1ms/step - loss: 0.3068 -
accuracy: 0.8566 - val_loss: 0.3157 - val_accuracy: 0.8533
Epoch 7/20
865/865 [=====] - 1s 1ms/step - loss: 0.3056 -
accuracy: 0.8576 - val_loss: 0.3155 - val_accuracy: 0.8545
Epoch 8/20
865/865 [=====] - 1s 1ms/step - loss: 0.3041 -
accuracy: 0.8579 - val_loss: 0.3177 - val_accuracy: 0.8548
Epoch 9/20
865/865 [=====] - 1s 1ms/step - loss: 0.3035 -
accuracy: 0.8587 - val_loss: 0.3161 - val_accuracy: 0.8543
Epoch 10/20
865/865 [=====] - 1s 1ms/step - loss: 0.3027 -
accuracy: 0.8577 - val_loss: 0.3169 - val_accuracy: 0.8540
Epoch 11/20
865/865 [=====] - 1s 1ms/step - loss: 0.3021 -
accuracy: 0.8592 - val_loss: 0.3153 - val_accuracy: 0.8547
Epoch 12/20
865/865 [=====] - 1s 1ms/step - loss: 0.3016 -
accuracy: 0.8588 - val_loss: 0.3171 - val_accuracy: 0.8540
Epoch 13/20
865/865 [=====] - 1s 1ms/step - loss: 0.3011 -
accuracy: 0.8597 - val_loss: 0.3170 - val_accuracy: 0.8556
Epoch 14/20
865/865 [=====] - 1s 1ms/step - loss: 0.3003 -
accuracy: 0.8597 - val_loss: 0.3179 - val_accuracy: 0.8550
Epoch 15/20
865/865 [=====] - 1s 1ms/step - loss: 0.2997 -
accuracy: 0.8595 - val_loss: 0.3170 - val_accuracy: 0.8550
Epoch 16/20
865/865 [=====] - 1s 1ms/step - loss: 0.2992 -
accuracy: 0.8603 - val_loss: 0.3157 - val_accuracy: 0.8539
Epoch 17/20
865/865 [=====] - 1s 1ms/step - loss: 0.2988 -
accuracy: 0.8604 - val_loss: 0.3173 - val_accuracy: 0.8530
Epoch 18/20
865/865 [=====] - 1s 1ms/step - loss: 0.2982 -
accuracy: 0.8612 - val_loss: 0.3169 - val_accuracy: 0.8517
Epoch 19/20
865/865 [=====] - 1s 1ms/step - loss: 0.2976 -
accuracy: 0.8615 - val_loss: 0.3175 - val_accuracy: 0.8547
Epoch 20/20
865/865 [=====] - 1s 1ms/step - loss: 0.2973 -
accuracy: 0.8622 - val_loss: 0.3179 - val_accuracy: 0.8550
203/203 [=====] - 0s 695us/step - loss: 0.3179 -
accuracy: 0.8550

```

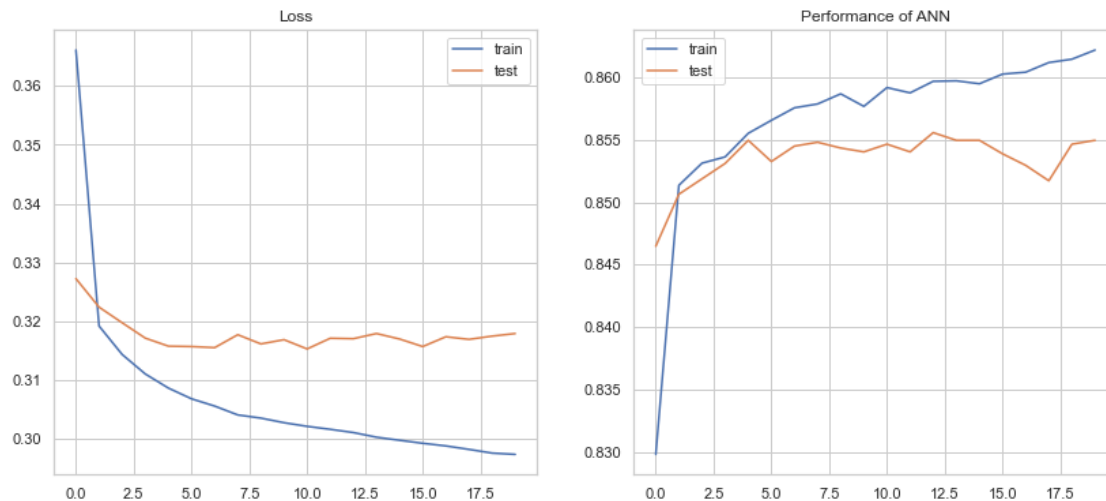
Accuracy: 85.496068

```
[932]: f = plt.figure(figsize=(14, 6))

plt.subplot(121)
plt.title('Loss')
plt.plot(history.history['loss'], label='train')
plt.plot(history.history['val_loss'], label='test')
plt.legend()

plt.subplot(122)
plt.title('Accuracy')
plt.plot(history.history['accuracy'], label='train')
plt.plot(history.history['val_accuracy'], label='test')
plt.legend()
plt.title('Performance of ANN')
print('Figure 2.19: Performance of ANN')
```

Figure 2.19: Performance of ANN



Both Artificial Neural Network (ANN) models are performing with an accuracy of 85% to 86%, which can be considered good performance for an ANN model. The accuracy of the model_ann1 oscillates between 85% and 85.5%.

1.2.4 Optimisation

- Top three models from the classification are further optimised.

Step 1 The First attempt to optimise models is made by dropping low correlated variables from the input data.

```
[933]: # Drop variables with correlation between 0.1 and -0.1 from dataset and select
↳dependent variables
x2 = df2.drop(columns=['income', 'fnlwgt', 're_Other-relative',
↳'wc_Federal-gov', 'wc_Local-gov', 'wc_Never-worked', 'wc_Self-emp-not-inc',
↳'wc_State-gov', 'wc_Without-pay',
↳'ms_Married-AF-spouse', 'ms_Married-spouse-absent',
↳'ms_Separated', 'ms_Widowed', 'country_America', 'country_Asia',
↳'country_Canada', 'country_Europe', 'country_Other',
↳'country_United-States', 'oc_Adm-clerical',
↳'oc_Armed-Forces', 'oc_Craft-repair', 'oc_Farming-fishing',
↳'oc_Handlers-cleaners', 'oc_Machine-op-inspct', 'oc_Priv-house-serv',
↳'oc_Protective-serv', 'oc_Sales', 'oc_Tech-support',
↳'oc_Transport-moving'])
y = df2.income

# Scaling dependent variables using standard scaler
ssc = StandardScaler()
x2 = ssc.fit_transform(x2)

# Separate dataset to train and test sets with 80% to train and 20% to test
x2_train, x2_test, y2_train, y2_test = train_test_split(
    x2, y2, test_size=0.2, random_state=3)
```

```
[934]: model_lr_1 = LogisticRegression(random_state=0)
model_lr_1.fit(x2_train, y2_train)
pred_lr_op = model_lr_1.predict(x2_test)

print(classification_report(y2_test, pred_lr_op))
matrix = confusion_matrix(y2_test, pred_lr_op)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for Logistic Regression')
plt.show()

print('Figure 2.20: Confusion Matrix for Logistic Regression')
```

	precision	recall	f1-score	support
0	0.87	0.93	0.90	4902
1	0.74	0.57	0.64	1579
accuracy			0.84	6481
macro avg	0.80	0.75	0.77	6481
weighted avg	0.84	0.84	0.84	6481

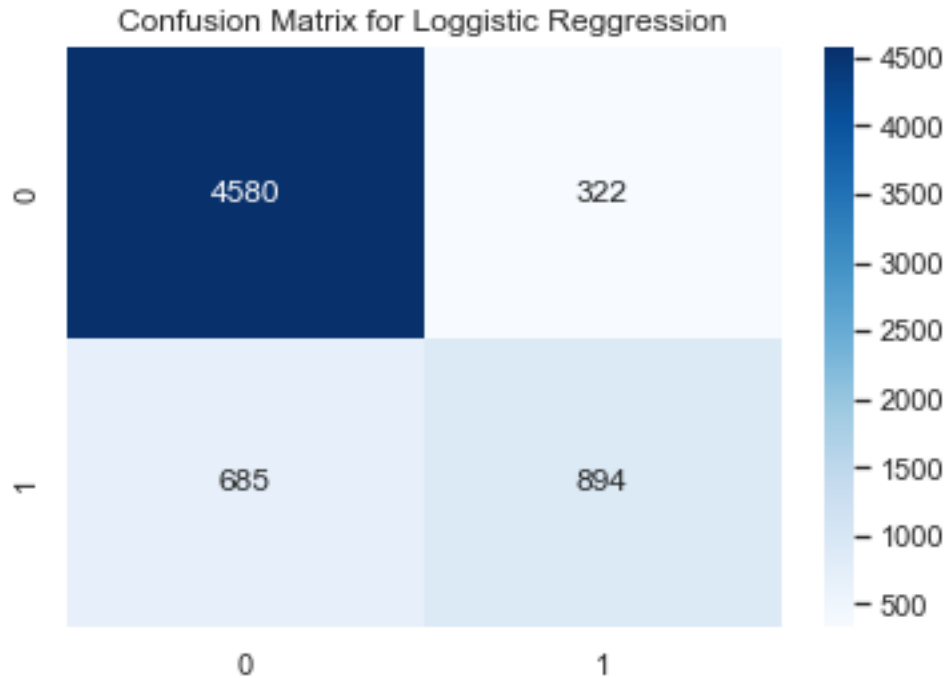


Figure 2.20: Confusion Matrix for Logistic Regression

```
[935]: model_svm_1 = svm.SVC(kernel='poly')
model_svm_1.fit(x2_train, y2_train)
pred_svm_op = model_svm_1.predict(x2_test)

print(classification_report(y2_test, pred_svm_op))
matrix = confusion_matrix(y2_test, pred_svm_op)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for SVM Classifier')
plt.show()
print('Figure 2.21: Confusion Matrix for SVM Classifier')
```

	precision	recall	f1-score	support
0	0.86	0.95	0.90	4902
1	0.77	0.54	0.63	1579
accuracy			0.85	6481
macro avg	0.81	0.74	0.77	6481
weighted avg	0.84	0.85	0.84	6481

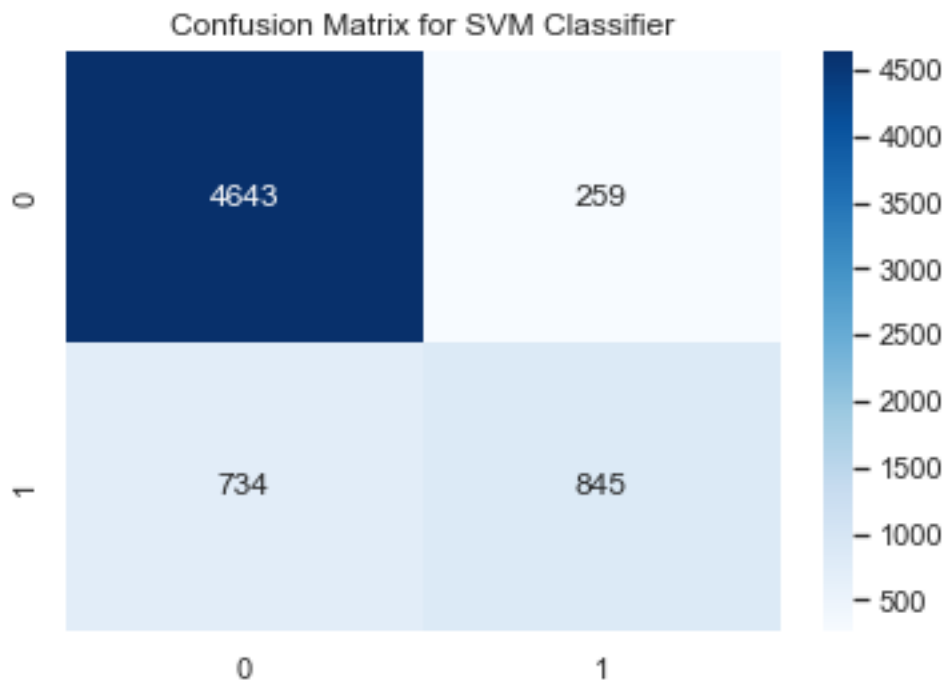


Figure 2.21: Confusion Matrix for SVM Classifier

```
[936]: model_rf_1 = RandomForestClassifier()
model_rf_1.fit(x2_train, y2_train)
pred_rf_op = model_rf_1.predict(x2_test)

print(classification_report(y2_test, pred_rf_op))
matrix = confusion_matrix(y2_test, pred_rf_op)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for Random Forest Classifier')
plt.show()
print('Figure 2.22: Confusion Matrix for Random Forest Classifier')
```

	precision	recall	f1-score	support
0	0.88	0.93	0.90	4902
1	0.72	0.60	0.66	1579
accuracy			0.85	6481
macro avg	0.80	0.76	0.78	6481
weighted avg	0.84	0.85	0.84	6481

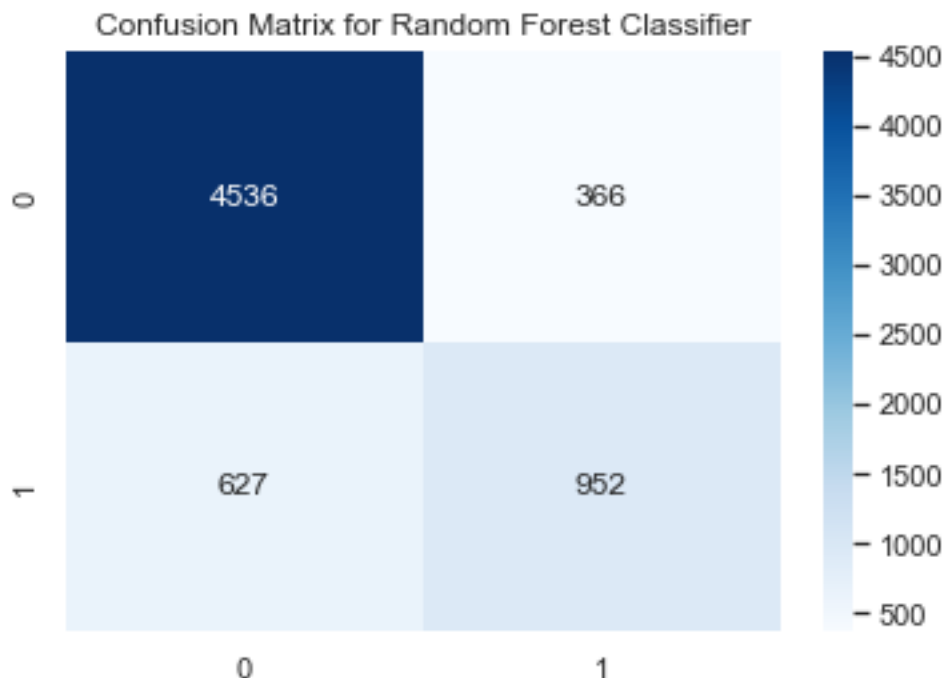


Figure 2.22: Confusion Matrix for Random Forest Classifier

```
[937]: # Initialise ANN
model_ann1 = tf.keras.models.Sequential()
# Add two hidden layers
model_ann1.add(tf.keras.layers.Dense(units=20, activation='relu'))
model_ann1.add(tf.keras.layers.Dense(units=10, activation='relu'))
# Add output layer
model_ann1.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann1.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann1.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=50, epochs=15)
loss, acc = model_ann1.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))
```

Epoch 1/15

519/519 [=====] - 1s 1ms/step - loss: 0.3873 -
accuracy: 0.8195 - val_loss: 0.3328 - val_accuracy: 0.8469

Epoch 2/15

519/519 [=====] - 1s 1ms/step - loss: 0.3227 -
accuracy: 0.8456 - val_loss: 0.3285 - val_accuracy: 0.8446

Epoch 3/15

```

519/519 [=====] - 1s 1ms/step - loss: 0.3174 -
accuracy: 0.8486 - val_loss: 0.3243 - val_accuracy: 0.8483
Epoch 4/15
519/519 [=====] - 1s 1ms/step - loss: 0.3145 -
accuracy: 0.8506 - val_loss: 0.3252 - val_accuracy: 0.8493
Epoch 5/15
519/519 [=====] - 1s 1ms/step - loss: 0.3127 -
accuracy: 0.8505 - val_loss: 0.3248 - val_accuracy: 0.8479
Epoch 6/15
519/519 [=====] - 1s 1ms/step - loss: 0.3110 -
accuracy: 0.8529 - val_loss: 0.3229 - val_accuracy: 0.8502
Epoch 7/15
519/519 [=====] - 1s 1ms/step - loss: 0.3095 -
accuracy: 0.8531 - val_loss: 0.3230 - val_accuracy: 0.8489
Epoch 8/15
519/519 [=====] - 1s 1ms/step - loss: 0.3087 -
accuracy: 0.8544 - val_loss: 0.3216 - val_accuracy: 0.8497
Epoch 9/15
519/519 [=====] - 1s 1ms/step - loss: 0.3077 -
accuracy: 0.8552 - val_loss: 0.3212 - val_accuracy: 0.8480
Epoch 10/15
519/519 [=====] - 1s 1ms/step - loss: 0.3070 -
accuracy: 0.8544 - val_loss: 0.3210 - val_accuracy: 0.8506
Epoch 11/15
519/519 [=====] - 1s 1ms/step - loss: 0.3065 -
accuracy: 0.8559 - val_loss: 0.3209 - val_accuracy: 0.8486
Epoch 12/15
519/519 [=====] - 1s 1ms/step - loss: 0.3059 -
accuracy: 0.8552 - val_loss: 0.3193 - val_accuracy: 0.8476
Epoch 13/15
519/519 [=====] - 1s 1ms/step - loss: 0.3054 -
accuracy: 0.8569 - val_loss: 0.3215 - val_accuracy: 0.8500
Epoch 14/15
519/519 [=====] - 1s 1ms/step - loss: 0.3050 -
accuracy: 0.8565 - val_loss: 0.3190 - val_accuracy: 0.8468
Epoch 15/15
519/519 [=====] - 1s 1ms/step - loss: 0.3041 -
accuracy: 0.8566 - val_loss: 0.3195 - val_accuracy: 0.8489
203/203 [=====] - 0s 702us/step - loss: 0.3195 -
accuracy: 0.8489
Accuracy: 84.894305

```

```

[938]: # Initialise ANN
model_ann2 = tf.keras.models.Sequential()
# Add a hidden layer
model_ann2.add(tf.keras.layers.Dense(units=15, activation='relu'))
# Add output layer

```



```

model_ann2.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann2.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann2.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=30, epochs=20)
loss, acc = model_ann2.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))

```

```

Epoch 1/20
865/865 [=====] - 1s 1ms/step - loss: 0.3803 -
accuracy: 0.8212 - val_loss: 0.3291 - val_accuracy: 0.8508
Epoch 2/20
865/865 [=====] - 1s 1ms/step - loss: 0.3216 -
accuracy: 0.8488 - val_loss: 0.3241 - val_accuracy: 0.8514
Epoch 3/20
865/865 [=====] - 1s 1ms/step - loss: 0.3176 -
accuracy: 0.8494 - val_loss: 0.3232 - val_accuracy: 0.8514
Epoch 4/20
865/865 [=====] - 1s 1ms/step - loss: 0.3155 -
accuracy: 0.8496 - val_loss: 0.3218 - val_accuracy: 0.8502
Epoch 5/20
865/865 [=====] - 1s 1ms/step - loss: 0.3140 -
accuracy: 0.8498 - val_loss: 0.3225 - val_accuracy: 0.8511
Epoch 6/20
865/865 [=====] - 1s 1ms/step - loss: 0.3130 -
accuracy: 0.8502 - val_loss: 0.3221 - val_accuracy: 0.8503
Epoch 7/20
865/865 [=====] - 1s 1ms/step - loss: 0.3120 -
accuracy: 0.8517 - val_loss: 0.3233 - val_accuracy: 0.8503
Epoch 8/20
865/865 [=====] - 1s 1ms/step - loss: 0.3116 -
accuracy: 0.8510 - val_loss: 0.3222 - val_accuracy: 0.8506
Epoch 9/20
865/865 [=====] - 2s 2ms/step - loss: 0.3111 -
accuracy: 0.8517 - val_loss: 0.3217 - val_accuracy: 0.8494
Epoch 10/20
865/865 [=====] - 1s 1ms/step - loss: 0.3105 -
accuracy: 0.8516 - val_loss: 0.3217 - val_accuracy: 0.8494
Epoch 11/20
865/865 [=====] - 1s 1ms/step - loss: 0.3103 -
accuracy: 0.8522 - val_loss: 0.3220 - val_accuracy: 0.8500
Epoch 12/20
865/865 [=====] - 2s 2ms/step - loss: 0.3098 -
accuracy: 0.8527 - val_loss: 0.3214 - val_accuracy: 0.8503
Epoch 13/20

```

```

865/865 [=====] - 1s 1ms/step - loss: 0.3096 -
accuracy: 0.8528 - val_loss: 0.3211 - val_accuracy: 0.8497
Epoch 14/20
865/865 [=====] - 1s 1ms/step - loss: 0.3094 -
accuracy: 0.8533 - val_loss: 0.3220 - val_accuracy: 0.8509
Epoch 15/20
865/865 [=====] - 1s 1ms/step - loss: 0.3090 -
accuracy: 0.8526 - val_loss: 0.3230 - val_accuracy: 0.8531
Epoch 16/20
865/865 [=====] - 1s 1ms/step - loss: 0.3090 -
accuracy: 0.8533 - val_loss: 0.3223 - val_accuracy: 0.8505
Epoch 17/20
865/865 [=====] - 1s 1ms/step - loss: 0.3088 -
accuracy: 0.8532 - val_loss: 0.3215 - val_accuracy: 0.8506
Epoch 18/20
865/865 [=====] - 1s 1ms/step - loss: 0.3086 -
accuracy: 0.8534 - val_loss: 0.3226 - val_accuracy: 0.8506
Epoch 19/20
865/865 [=====] - 1s 1ms/step - loss: 0.3087 -
accuracy: 0.8543 - val_loss: 0.3220 - val_accuracy: 0.8493
Epoch 20/20
865/865 [=====] - 1s 1ms/step - loss: 0.3085 -
accuracy: 0.8537 - val_loss: 0.3223 - val_accuracy: 0.8511
203/203 [=====] - 0s 1ms/step - loss: 0.3223 -
accuracy: 0.8511
Accuracy: 85.110325

```

This step did not increase the performance of the models, and for Random Forest and ANN models, it decreased the accuracy slightly. Therefore, this step is not carried forward. All the features are used in the model training.

Step 2 Different scaling methods are used to transform data to check whether the performance can be increased.

```

[939]: # RobustScaler, MinMaxScaler, Normalizer was tried
#x2 = StandardScaler().fit_transform(x2)
#x2 = MinMaxScaler().fit_transform(x2)
#x2 = Normalizer().fit_transform(x2)

# Scaling dependent variables using minmax scaler
x2 = MinMaxScaler().fit_transform(x2)

# Separate dataset to train and test sets with 80% to train and 20% to test
x2_train, x2_test, y2_train, y2_test = train_test_split(
    x2, y2, test_size=0.2, random_state=3)

```

```

[940]: model_lr = LogisticRegression(random_state=0, max_iter=1000)
model_lr.fit(x2_train, y2_train)

```

```

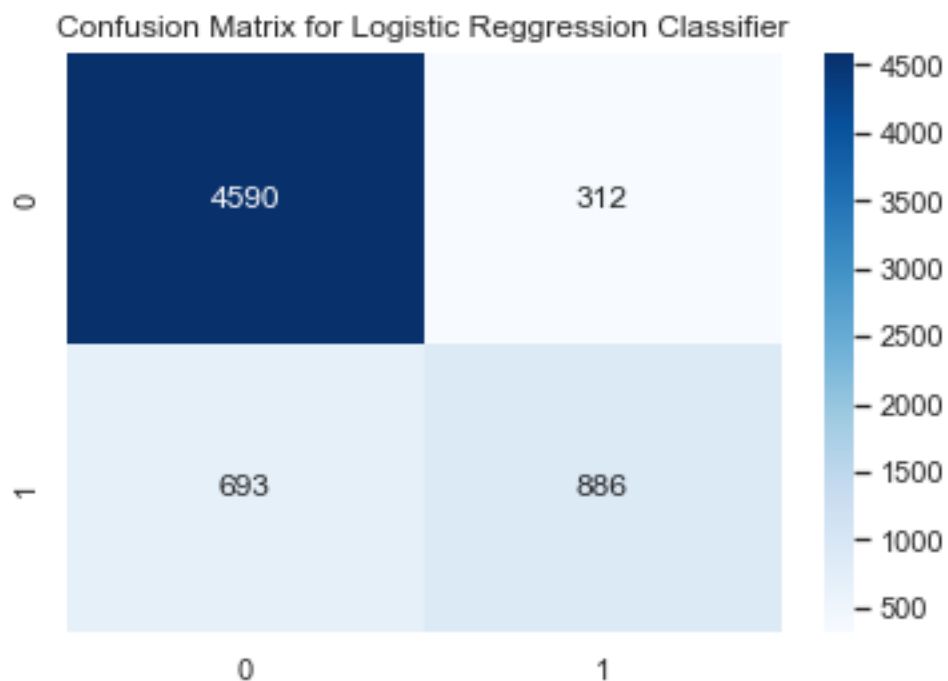
pred_lr_op = model_lr.predict(x2_test)

print(classification_report(y2_test, pred_lr_op))
matrix = confusion_matrix(y2_test, pred_lr_op)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for Logistic Regression Classifier')
print('Figure 2.23: Confusion Matrix for Logistic Regression Classifier')

```

	precision	recall	f1-score	support
0	0.87	0.94	0.90	4902
1	0.74	0.56	0.64	1579
accuracy			0.84	6481
macro avg	0.80	0.75	0.77	6481
weighted avg	0.84	0.84	0.84	6481

Figure 2.23: Confusion Matrix for Logistic Regression Classifier



```

[941]: model_svm = svm.SVC(kernel='poly')
model_svm.fit(x2_train, y2_train)
pred_svm_op = model_svm.predict(x2_test)

print(classification_report(y2_test, pred_svm_op))

```

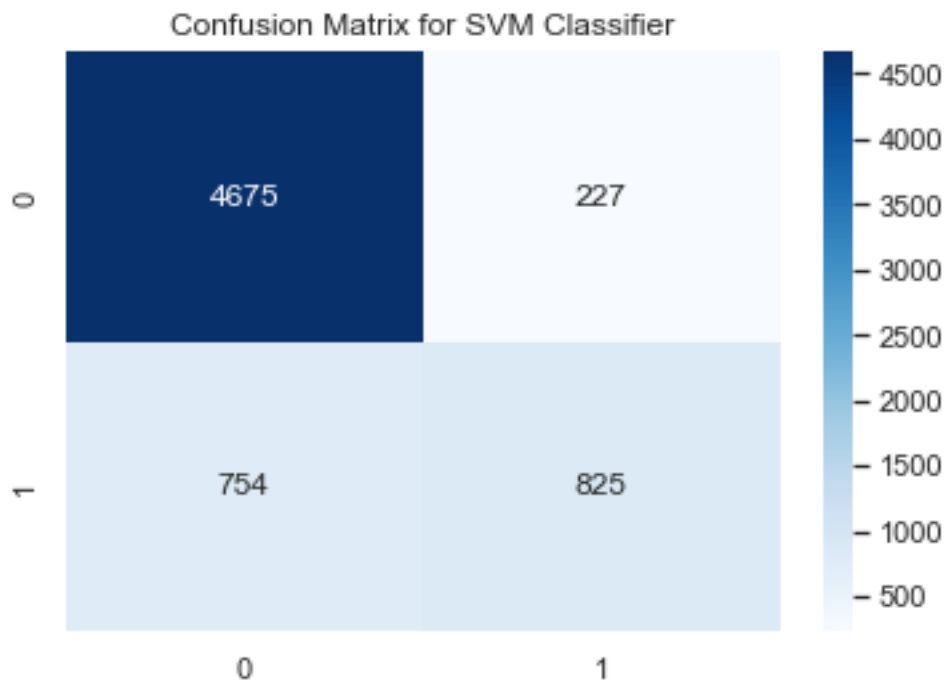
```

matrix = confusion_matrix(y2_test, pred_svm_op)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for SVM Classifier')
print('Figure 2.24: Confusion Matrix for SVM Classifier')

```

	precision	recall	f1-score	support
0	0.86	0.95	0.91	4902
1	0.78	0.52	0.63	1579
accuracy			0.85	6481
macro avg	0.82	0.74	0.77	6481
weighted avg	0.84	0.85	0.84	6481

Figure 2.24: Confusion Matrix for SVM Classifier



```

[942]: model_rf = RandomForestClassifier()
model_rf.fit(x2_train, y2_train)
pred_rf_op = model_rf.predict(x2_test)

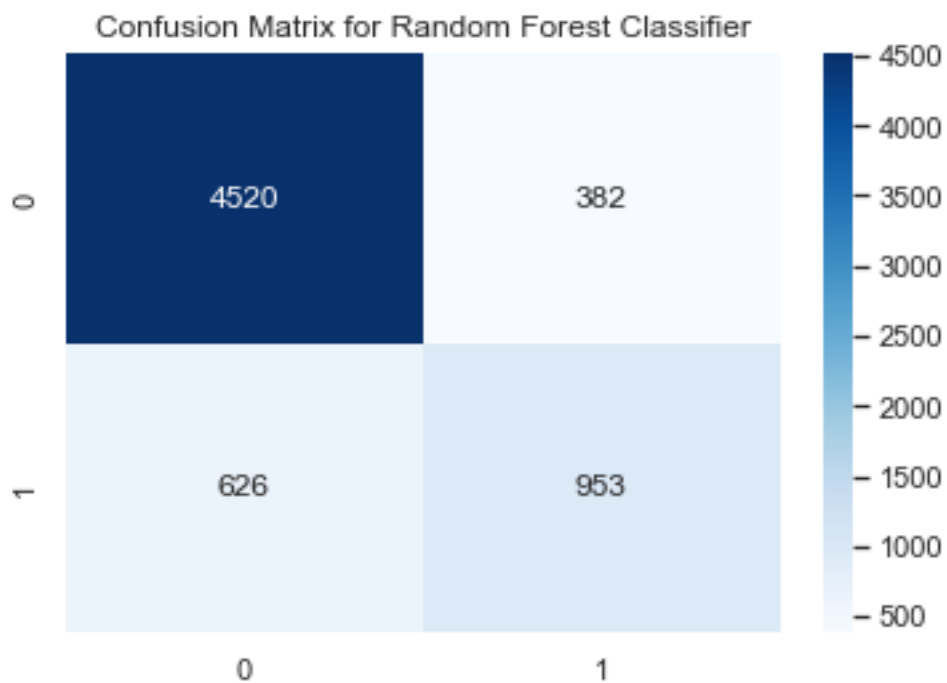
print(classification_report(y2_test, pred_rf_op))
matrix = confusion_matrix(y2_test, pred_rf_op)
sns.heatmap(matrix, annot=True, fmt='d', cmap="Blues")
plt.title('Confusion Matrix for Random Forest Classifier')

```

```
print('Figure 2.25: Confusion Matrix for Random Forest Classifier')
```

	precision	recall	f1-score	support
0	0.88	0.92	0.90	4902
1	0.71	0.60	0.65	1579
accuracy			0.84	6481
macro avg	0.80	0.76	0.78	6481
weighted avg	0.84	0.84	0.84	6481

Figure 2.25: Confusion Matrix for Random Forest Classifier



```
[943]: # Initialise ANN
model_ann1 = tf.keras.models.Sequential()
# Add two hidden layers
model_ann1.add(tf.keras.layers.Dense(units=20, activation='relu'))
model_ann1.add(tf.keras.layers.Dense(units=10, activation='relu'))
# Add output layer
model_ann1.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann1.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
```

```
history = model_ann1.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=50, epochs=15)
loss, acc = model_ann1.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))
```

Epoch 1/15

519/519 [=====] - 1s 1ms/step - loss: 0.4155 -
accuracy: 0.8023 - val_loss: 0.3723 - val_accuracy: 0.8331

Epoch 2/15

519/519 [=====] - 1s 2ms/step - loss: 0.3505 -
accuracy: 0.8372 - val_loss: 0.3463 - val_accuracy: 0.8432

Epoch 3/15

519/519 [=====] - 1s 2ms/step - loss: 0.3353 -
accuracy: 0.8446 - val_loss: 0.3351 - val_accuracy: 0.8468

Epoch 4/15

519/519 [=====] - 1s 2ms/step - loss: 0.3305 -
accuracy: 0.8459 - val_loss: 0.3324 - val_accuracy: 0.8463

Epoch 5/15

519/519 [=====] - 1s 2ms/step - loss: 0.3268 -
accuracy: 0.8462 - val_loss: 0.3344 - val_accuracy: 0.8496

Epoch 6/15

519/519 [=====] - 1s 2ms/step - loss: 0.3255 -
accuracy: 0.8477 - val_loss: 0.3322 - val_accuracy: 0.8446

Epoch 7/15

519/519 [=====] - 1s 3ms/step - loss: 0.3241 -
accuracy: 0.8470 - val_loss: 0.3308 - val_accuracy: 0.8434

Epoch 8/15

519/519 [=====] - 1s 2ms/step - loss: 0.3231 -
accuracy: 0.8470 - val_loss: 0.3286 - val_accuracy: 0.8452

Epoch 9/15

519/519 [=====] - 1s 2ms/step - loss: 0.3219 -
accuracy: 0.8497 - val_loss: 0.3290 - val_accuracy: 0.8477

Epoch 10/15

519/519 [=====] - 1s 1ms/step - loss: 0.3218 -
accuracy: 0.8485 - val_loss: 0.3282 - val_accuracy: 0.8471

Epoch 11/15

519/519 [=====] - 1s 1ms/step - loss: 0.3208 -
accuracy: 0.8484 - val_loss: 0.3273 - val_accuracy: 0.8457

Epoch 12/15

519/519 [=====] - 1s 1ms/step - loss: 0.3204 -
accuracy: 0.8490 - val_loss: 0.3270 - val_accuracy: 0.8480

Epoch 13/15

519/519 [=====] - 1s 2ms/step - loss: 0.3194 -
accuracy: 0.8497 - val_loss: 0.3285 - val_accuracy: 0.8491

Epoch 14/15

519/519 [=====] - 1s 1ms/step - loss: 0.3187 -
accuracy: 0.8488 - val_loss: 0.3291 - val_accuracy: 0.8485

```
Epoch 15/15
519/519 [=====] - 1s 1ms/step - loss: 0.3195 -
accuracy: 0.8489 - val_loss: 0.3332 - val_accuracy: 0.8415
203/203 [=====] - 0s 1ms/step - loss: 0.3332 -
accuracy: 0.8415
Accuracy: 84.153682
```

```
[944]: # Initialise ANN
model_ann2 = tf.keras.models.Sequential()
# Add a hidden layer
model_ann2.add(tf.keras.layers.Dense(units=15, activation='relu'))
# Add output layer
model_ann2.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann2.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann2.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=30, epochs=20)
loss, acc = model_ann2.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))
```

```
Epoch 1/20
865/865 [=====] - 2s 2ms/step - loss: 0.4251 -
accuracy: 0.7854 - val_loss: 0.3894 - val_accuracy: 0.8222
Epoch 2/20
865/865 [=====] - 1s 1ms/step - loss: 0.3703 -
accuracy: 0.8264 - val_loss: 0.3624 - val_accuracy: 0.8395
Epoch 3/20
865/865 [=====] - 1s 1ms/step - loss: 0.3502 -
accuracy: 0.8368 - val_loss: 0.3452 - val_accuracy: 0.8472
Epoch 4/20
865/865 [=====] - 1s 1ms/step - loss: 0.3393 -
accuracy: 0.8405 - val_loss: 0.3397 - val_accuracy: 0.8488
Epoch 5/20
865/865 [=====] - 1s 1ms/step - loss: 0.3337 -
accuracy: 0.8439 - val_loss: 0.3362 - val_accuracy: 0.8472
Epoch 6/20
865/865 [=====] - 1s 1ms/step - loss: 0.3303 -
accuracy: 0.8462 - val_loss: 0.3321 - val_accuracy: 0.8454
Epoch 7/20
865/865 [=====] - 1s 1ms/step - loss: 0.3280 -
accuracy: 0.8474 - val_loss: 0.3313 - val_accuracy: 0.8454
Epoch 8/20
865/865 [=====] - 1s 1ms/step - loss: 0.3267 -
accuracy: 0.8474 - val_loss: 0.3344 - val_accuracy: 0.8483
Epoch 9/20
865/865 [=====] - 1s 1ms/step - loss: 0.3257 -
```

```

accuracy: 0.8473 - val_loss: 0.3298 - val_accuracy: 0.8463
Epoch 10/20
865/865 [=====] - 1s 1ms/step - loss: 0.3246 -
accuracy: 0.8488 - val_loss: 0.3325 - val_accuracy: 0.8477
Epoch 11/20
865/865 [=====] - 1s 1ms/step - loss: 0.3233 -
accuracy: 0.8488 - val_loss: 0.3286 - val_accuracy: 0.8469
Epoch 12/20
865/865 [=====] - 1s 1ms/step - loss: 0.3225 -
accuracy: 0.8486 - val_loss: 0.3305 - val_accuracy: 0.8488
Epoch 13/20
865/865 [=====] - 1s 1ms/step - loss: 0.3217 -
accuracy: 0.8486 - val_loss: 0.3283 - val_accuracy: 0.8486
Epoch 14/20
865/865 [=====] - 1s 1ms/step - loss: 0.3212 -
accuracy: 0.8488 - val_loss: 0.3281 - val_accuracy: 0.8451
Epoch 15/20
865/865 [=====] - 1s 1ms/step - loss: 0.3207 -
accuracy: 0.8480 - val_loss: 0.3276 - val_accuracy: 0.8459
Epoch 16/20
865/865 [=====] - 1s 1ms/step - loss: 0.3203 -
accuracy: 0.8488 - val_loss: 0.3282 - val_accuracy: 0.8483
Epoch 17/20
865/865 [=====] - 1s 1ms/step - loss: 0.3197 -
accuracy: 0.8487 - val_loss: 0.3301 - val_accuracy: 0.8429
Epoch 18/20
865/865 [=====] - 1s 1ms/step - loss: 0.3195 -
accuracy: 0.8491 - val_loss: 0.3283 - val_accuracy: 0.8485
Epoch 19/20
865/865 [=====] - 1s 1ms/step - loss: 0.3193 -
accuracy: 0.8489 - val_loss: 0.3270 - val_accuracy: 0.8465
Epoch 20/20
865/865 [=====] - 1s 1ms/step - loss: 0.3192 -
accuracy: 0.8488 - val_loss: 0.3275 - val_accuracy: 0.8460
203/203 [=====] - 0s 685us/step - loss: 0.3275 -
accuracy: 0.8460
Accuracy: 84.601140

```

In this step, it is clear the initial data transform method, Standard Scaler, is the best way to scale data as other scaling methods did not increase performance. Moreover, some scaling methods have decreased model performance.

1.2.5 Hyper parameter tuning

The exhaustive search method Grid Search is used to find the best parameters for an estimator from the specified parameter values. These parameters are defined in the model and not directly learnt with the estimator. Here Grid Search is used to avoid missing out on any good values from the specified parameters. In the GridSearchCV, cross-validation is also used to find the best values

from the parameter grid.

Tuning the hyper-parameters of Logistic Regression For Penalty, l1, l2, and a combination of the two methods, elastic-net is used as parameters. Solvers lbfgs, newton-CG, sag, saga, and liblinear is used with supported penalty methods. Max iter values 1000 and 200, tolerance values of 0.001 and 0.01 and C values of 2, 4 and 5 are used to make the parameter space.

```
[945]: # Separating dependent and independent variables
x2 = df2.drop(columns=['income'])
y2 = df2.income

# Scaling dependent variables using standard scaler
x2 = StandardScaler().fit_transform(x2)

# Separate dataset to train and test sets with 80% to train and 20% to test
x2_train, x2_test, y2_train, y2_test = train_test_split(
    x2, y2, test_size=0.2, random_state=3)

[946]: # Depending on the supported solvers for penalty parameter, different set of
    ↪parameter grids are defined
param_grid = [
    {'penalty': ['l2'],
     'solver': ['lbfgs', 'newton-cg', 'sag', 'saga'],
     'max_iter': [1000, 2000],
     'tol': [0.001, 0.01],
     'C': [2.0, 4.0, 0.5]
    },
    {'penalty': ['l1'],
     'solver': ['saga', 'liblinear'],
     'max_iter': [1000, 2000],
     'tol': [0.001, 0.01],
     'C': [2.0, 4.0, 0.5]
    },
    {'penalty': ['elasticnet'],
     'solver': ['saga'],
     'max_iter': [1000, 2000],
     'tol': [0.001, 0.01],
     'C': [2.0, 4.0, 5.0, ]
    }
]
clf = GridSearchCV(estimator=model_lr, param_grid=param_grid)
best_model = clf.fit(x2_train, y2_train)
print('The best score across ALL searched params:\n', best_model.best_score_)
print('The best parameters across ALL searched params:\n', best_model.
    ↪best_params_)
```

The best score across ALL searched params:
0.8514716894650999

The best parameters across ALL searched params:

```
{'C': 0.5, 'max_iter': 1000, 'penalty': 'l1', 'solver': 'saga', 'tol': 0.01}
```

```
[947]: best_predicted_values = best_model.predict(x2_test)
accuracy_score(best_predicted_values, y2_test)
```

```
[947]: 0.8503317389291776
```

The accuracy of the Logistic regression is not improved after hyper-parameter tuning. The default parameters also have the same accuracy of 85% as the best model.

Tuning the hyper-parameters of Supported Vector Machine Here, linear, rbf and poly kernels and C values of 1 and 10 are used to make the parameter grid.

```
[948]: parameters = {'kernel': ('linear', 'rbf'), 'C': [1, 10]}
svc = svm.SVC()
# Run the grid search
clf = GridSearchCV(estimator=svc, param_grid=parameters)
best_model = clf.fit(x2_train, y2_train)
print('The best score across ALL searched params:\n', clf.best_score_)
print('The best parameters across ALL searched params:\n', clf.best_params_)
```

The best score across ALL searched params:

```
0.8523207004416825
```

The best parameters across ALL searched params:

```
{'C': 1, 'kernel': 'rbf'}
```

```
[949]: best_predicted_values = best_model.predict(x2_test)
accuracy_score(best_predicted_values, y2_test)
```

```
[949]: 0.852029007869156
```

Similar to Logistic Regression, the Supported vector machine also achieved higher accuracy after hyper-parameter tuning.

Tuning the hyper-parameters of Random Forest Classifier The number of estimators, Selection criterion Gini and entropy, and different values of max depth and minimum sample split is used to make the parameter grid.

```
[950]: # Hyperparameter Optimization
parameters = {
    'n_estimators': [50, 100, 300, 400],
    'criterion': ['entropy', 'gini'],
    'max_depth': [30, 40, 50],
    'min_samples_split': [20, 25, 50]
}

# Run the grid search
```

```

grid_obj = GridSearchCV(estimator=model_rf, param_grid=parameters)
grid_obj = grid_obj.fit(x2_train, y2_train)

# Set the clf to the best combination of parameters
clf = grid_obj.best_estimator_

# Train the model using the training sets
clf.fit(x2_train, y2_train)

print('The best score across ALL searched params:\n', grid_obj.best_score_)
print('The best parameters across ALL searched params:\n', grid_obj.
      ↪best_params_)

```

The best score across ALL searched params:

0.8654761405169232

The best parameters across ALL searched params:

```
{'criterion': 'gini', 'max_depth': 30, 'min_samples_split': 25, 'n_estimators':
100}
```

```
[951]: best_predicted_values = clf.predict(x2_test)
accuracy_score(best_predicted_values, y2_test)
```

```
[951]: 0.8645270791544515
```

The Random Forest model has improved its accuracy after the hyper-parameter tuning from 85 to 86.

Manual hyper-parameters tuning the for Artificial Neural Network Models

```

[952]: # Initialise ANN
model_ann1 = tf.keras.models.Sequential()
# Add two hidden layers
model_ann1.add(tf.keras.layers.Dense(units=35, activation='softmax'))
model_ann1.add(tf.keras.layers.Dropout(.1, input_shape=(2,)))
# Add output layer
model_ann1.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann1.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann1.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=50, epochs=15)
loss, acc = model_ann1.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))

```

Epoch 1/15

519/519 [=====] - 1s 1ms/step - loss: 0.5583 -
accuracy: 0.7684 - val_loss: 0.4655 - val_accuracy: 0.8364

Epoch 2/15
519/519 [=====] - 1s 1ms/step - loss: 0.4228 - accuracy: 0.8383 - val_loss: 0.3937 - val_accuracy: 0.8477
Epoch 3/15
519/519 [=====] - 1s 1ms/step - loss: 0.3796 - accuracy: 0.8431 - val_loss: 0.3661 - val_accuracy: 0.8517
Epoch 4/15
519/519 [=====] - 1s 1ms/step - loss: 0.3587 - accuracy: 0.8463 - val_loss: 0.3522 - val_accuracy: 0.8526
Epoch 5/15
519/519 [=====] - 1s 1ms/step - loss: 0.3499 - accuracy: 0.8465 - val_loss: 0.3445 - val_accuracy: 0.8514
Epoch 6/15
519/519 [=====] - 1s 1ms/step - loss: 0.3433 - accuracy: 0.8463 - val_loss: 0.3385 - val_accuracy: 0.8514
Epoch 7/15
519/519 [=====] - 1s 1ms/step - loss: 0.3392 - accuracy: 0.8458 - val_loss: 0.3357 - val_accuracy: 0.8514
Epoch 8/15
519/519 [=====] - 1s 1ms/step - loss: 0.3349 - accuracy: 0.8471 - val_loss: 0.3323 - val_accuracy: 0.8520
Epoch 9/15
519/519 [=====] - 1s 1ms/step - loss: 0.3307 - accuracy: 0.8476 - val_loss: 0.3299 - val_accuracy: 0.8513
Epoch 10/15
519/519 [=====] - 1s 1ms/step - loss: 0.3281 - accuracy: 0.8480 - val_loss: 0.3275 - val_accuracy: 0.8519
Epoch 11/15
519/519 [=====] - 1s 1ms/step - loss: 0.3259 - accuracy: 0.8479 - val_loss: 0.3260 - val_accuracy: 0.8528
Epoch 12/15
519/519 [=====] - 1s 1ms/step - loss: 0.3229 - accuracy: 0.8499 - val_loss: 0.3249 - val_accuracy: 0.8531
Epoch 13/15
519/519 [=====] - 1s 1ms/step - loss: 0.3211 - accuracy: 0.8499 - val_loss: 0.3239 - val_accuracy: 0.8537
Epoch 14/15
519/519 [=====] - 1s 1ms/step - loss: 0.3205 - accuracy: 0.8489 - val_loss: 0.3231 - val_accuracy: 0.8536
Epoch 15/15
519/519 [=====] - 1s 1ms/step - loss: 0.3191 - accuracy: 0.8500 - val_loss: 0.3221 - val_accuracy: 0.8526
203/203 [=====] - 0s 711us/step - loss: 0.3221 - accuracy: 0.8526
Accuracy: 85.264617

Results

- Using different optimisers resulted accuracy:
 - sgd ~ 75
 - Adadelata ~ 67
 - Ftrl ~ 75
 - Nadam ~ 85
- Using tanh, selu, and exponential activation functions resulted accuracy around 85

Try	Layer 1	Layer 2	Accuracy
1	units=15 activation = relu	units=5 activation = relu	85.0
2	units=25 activation = relu	units=15 activation = relu	85.1
3	units=30 activation = relu	units=10 activation = relu	85.1
4	units=30 activation = softmax	units=10 activation = softmax	85.3
5	units=35 activation = softmax	units=15 activation = softmax	85.4
6	units=35 activation = softmax	units=10 activation = softmax	85.7
7	units=35 activation = softmax	units=10 activation = softmax	85.7

All the different parameter changes only increased accuracy slightly for this model. Even one layer changing to **dropout** layer did not help to increase accuracy.

```
[953]: # Initialise ANN
model_ann2 = tf.keras.models.Sequential()
# Add a hidden layer
model_ann2.add(tf.keras.layers.Dense(units=35, activation='softmax'))
# Add output layer
model_ann2.add(tf.keras.layers.Dense(units=1, activation='sigmoid'))

model_ann2.compile(
    optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

history = model_ann2.fit(x2_train, y2_train, validation_data=(
    x2_test, y2_test), batch_size=25, epochs=20)
loss, acc = model_ann2.evaluate(x2_test, y2_test)
print('Accuracy: %f' % (acc*100))
```

Epoch 1/20

1037/1037 [=====] - 2s 1ms/step - loss: 0.4910 - accuracy: 0.7933 - val_loss: 0.3936 - val_accuracy: 0.8472

Epoch 2/20

1037/1037 [=====] - 1s 1ms/step - loss: 0.3619 - accuracy: 0.8489 - val_loss: 0.3525 - val_accuracy: 0.8522

Epoch 3/20

1037/1037 [=====] - 1s 1ms/step - loss: 0.3369 - accuracy: 0.8526 - val_loss: 0.3413 - val_accuracy: 0.8519

Epoch 4/20

1037/1037 [=====] - 1s 1ms/step - loss: 0.3262 - accuracy: 0.8546 - val_loss: 0.3346 - val_accuracy: 0.8520

Epoch 5/20

```

1037/1037 [=====] - 1s 1ms/step - loss: 0.3197 -
accuracy: 0.8549 - val_loss: 0.3298 - val_accuracy: 0.8534
Epoch 6/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3151 -
accuracy: 0.8567 - val_loss: 0.3275 - val_accuracy: 0.8533
Epoch 7/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3118 -
accuracy: 0.8578 - val_loss: 0.3262 - val_accuracy: 0.8525
Epoch 8/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3095 -
accuracy: 0.8588 - val_loss: 0.3247 - val_accuracy: 0.8526
Epoch 9/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3075 -
accuracy: 0.8586 - val_loss: 0.3237 - val_accuracy: 0.8528
Epoch 10/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3057 -
accuracy: 0.8594 - val_loss: 0.3224 - val_accuracy: 0.8543
Epoch 11/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3043 -
accuracy: 0.8606 - val_loss: 0.3216 - val_accuracy: 0.8537
Epoch 12/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3029 -
accuracy: 0.8606 - val_loss: 0.3206 - val_accuracy: 0.8530
Epoch 13/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3014 -
accuracy: 0.8612 - val_loss: 0.3208 - val_accuracy: 0.8526
Epoch 14/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.3003 -
accuracy: 0.8622 - val_loss: 0.3209 - val_accuracy: 0.8530
Epoch 15/20
1037/1037 [=====] - 2s 2ms/step - loss: 0.2990 -
accuracy: 0.8616 - val_loss: 0.3205 - val_accuracy: 0.8525
Epoch 16/20
1037/1037 [=====] - 2s 2ms/step - loss: 0.2980 -
accuracy: 0.8625 - val_loss: 0.3213 - val_accuracy: 0.8526
Epoch 17/20
1037/1037 [=====] - 2s 2ms/step - loss: 0.2971 -
accuracy: 0.8629 - val_loss: 0.3208 - val_accuracy: 0.8517
Epoch 18/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.2962 -
accuracy: 0.8634 - val_loss: 0.3213 - val_accuracy: 0.8514
Epoch 19/20
1037/1037 [=====] - 2s 1ms/step - loss: 0.2954 -
accuracy: 0.8643 - val_loss: 0.3206 - val_accuracy: 0.8513
Epoch 20/20
1037/1037 [=====] - 1s 1ms/step - loss: 0.2946 -
accuracy: 0.8644 - val_loss: 0.3212 - val_accuracy: 0.8514
203/203 [=====] - 0s 731us/step - loss: 0.3212 -

```

accuracy: 0.8514
Accuracy: 85.141182

Results

- Using different optimisers resulted accuracy:
 - sgd ~ 85
 - Adadelat ~ 72
 - Ftrl ~ 85
 - Nadam ~ 85
- Using tanh, selu, and exponential activation functions resulted accuracy around 83 ~ 85

Try	Layer 1	Accuracy
1	units=15 activation = relu	85.0
2	units=25 activation = relu	85.3
3	units=30 activation = relu	85.1
4	units=30 activation = softmax	85.3
5	units=35 activation = softmax	85.3
6	units=25 activation = softmax	85.4

All the different parameter changes only increased accuracy slightly for this model

1.2.6 Conclusion

Five classification models and two Artificial Neural Network models were used to predict individuals' annual income based on US census data. Then the first three classification models and two ANN models were chosen based on the performance of predicting data to further tuning. Those five selected models are further tuned using feature selection, different methods of data cleaning and hyperparameter tuning. The highest accuracy is 86% from the Random Forest Classifier. Most of the other models also performed around 85% at their best.

Artificial Neural Network models did not show a difference in accuracy when changing the input features, data transformation or even with the different number of hidden layers. The only difference observed is from hyperparameter testing, where for some optimisers, accuracy was reduced to seventies or sixties.

Overall, there is no significant difference when considering the best performance for the top five models. However, the Random Forest Classifier is more accurate in predicting if an individual gets an annual income of \$50000 or more. The Random Forest model is robust to outliers, and it has shown unchanging accuracy of over 85% despite changes to the model parameters, scaling methods and feature selection. In comparison, other models had an accuracy range from ~50% to 85%.

1.2.7 Reference

NHS (2022), Understanding your health and weight: Body mass index (BMI). Available at: <https://www.nhsinform.scot/healthy-living/food-and-nutrition/healthy-eating-and-weight-loss/understanding-your-health-and-weight-body-mass-index-bmi> (July 18, 2022).

scikit-learn (2022), 6.3. Preprocessing data. Available at: <https://scikit-learn.org/stable/modules/preprocessing.html#preprocessing-data>(July 20, 2022).

scikit-learn (2022), sklearn.linear_model.LogisticRegression. Available at: https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LogisticRegression.html#sklearn.linear_model.LogisticRegression(July 15, 2022).

scikit-learn (2022) 3.3.2. Classification metrics. Available at: <https://scikit-learn.org/stable/modules/classes.html#module-sklearn.metrics>(July 15, 2022)

scikit-learn (2022), sklearn.model_selection.GridSearchCV. Available at: https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html (July 21, 2022). Keras(2022),Keras API reference. Available at: <https://keras.io/api/>(July 22, 2022)