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MSDS 422 Practical Machine Learning

9 February 2025

Module 05: Titanic

In 1912, the Titanic shipwreck resulted in the loss of about 1,502 lives out of the 2,224 passengers on board. This analysis used Kaggle's Titanic dataset to study survival rates based on factors such as age, gender, ticket price, and passenger class. The main goal within the research was to predict the number of survived through the help of machine learning models. The machine learning models that were focused on this fifth module were: Random Forest Regressor, Gradient Boosted Trees, and last but not least Extra Trees Regressor.

Before heading onto modeling and training, the first requirement was that the dataset be analyzed and prepared. Missing values were noticed in the dataset. The columns that had missing values were Age, Cabin, and Embarked. The missing values for Age were handled with the median value, as it was believed to be the most appropriate approach instead of replacing them with 0. Cabin was replaced with "unknown" wherever missing values were shown. Lastly, the column Embarked was replaced with the most common port (mode) based on the passenger's class.

A few feature engineering techniques were applied to achieve one mission—to improve the model's performance. A new column called Title was extracted from the Name. For example, in "Ms. Thomas," "Ms" was extracted using regex (regular expressions), which was learned in an NLP course taken previously. A column, Family Size, was created to understand the number of members in the family to incorporate the understanding of whether the passenger was traveling alone or not. Age and Fare, which were numerical features, used Standard Scaling to maintain a consistent organization across the different variables.

Outliers in the dataset were further investigated with the help of a built-in method called the Interquartile Range (IQR), and the extreme values were removed so that they would not affect the models. Following that, the dataset was visualized to better understand its characteristics. A histogram was created to analyze the distribution of the Age column. It was noticeable that the distribution was right-skewed. Some observations from the visualization include: there were more young passengers compared to older ones, most passengers were adults around the median age, and no severe outliers were present. This suggests that age is a crucial factor and may help distinguish survival rates. Moreover, bar plots were created, revealing that passengers in first class had the highest chance of survival, followed by second class, with third class having the lowest survival rate. A box plot of Fare by passenger class was also generated, demonstrating that first-class tickets were the most expensive. Lastly, a heatmap was created to examine feature correlations, which revealed that Pclass and Fare were strongly related to the number of survivors.

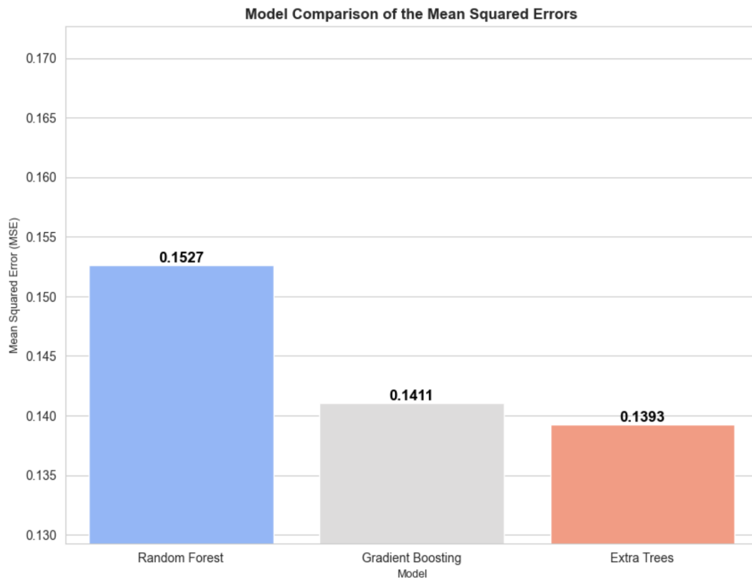
Next, for evaluating the model, the dataset was divided into training and validation sets using the 5-fold cross-validation method, which was chosen to prevent overfitting. The models (Random Forest Regressor, Gradient Boosted Trees, and Extra Trees Regressor) were trained using Grid Search CV, which helped optimize the hyperparameters. The main hyperparameters used throughout the research were:

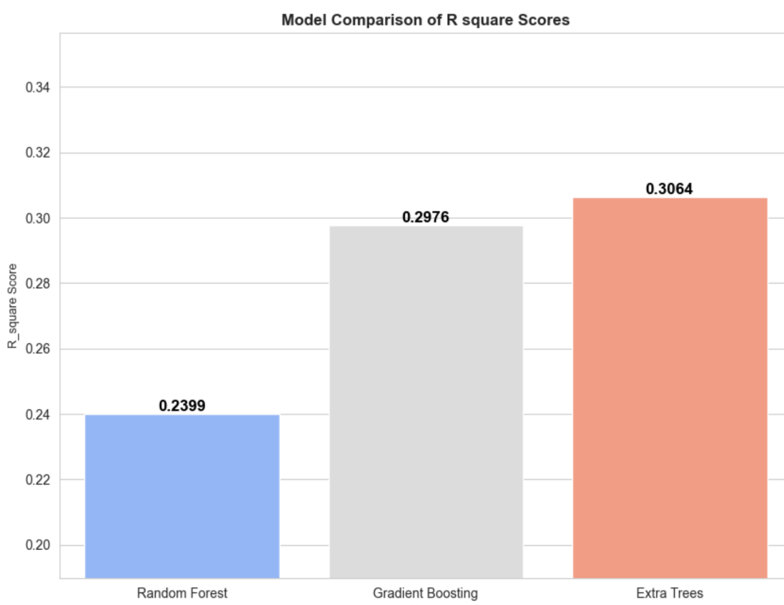
- number of trees within the model → n_estimators
- maximum depth of each tree → max_depth
- number of features that was considered per split → max_features
- minimum samples that are required in order to split a node → min_samples_split
- minimum samples in a lead node → min_samples_leaf
- step size per iteration → learning_rate
- fraction of data used for boosting → subsample

For the assignment, one of the requirements was to use loss functions. For regression models, squared_error and absolute_error were used, as they are more suitable for regression tasks rather than classification methods. The models were also evaluated using Mean Squared Error (MSE) and R-Squared.

MODEL	MSE	R-SQUARED
RANDOM FOREST	0.152650	0.239911
GRADIENT BOOSTING	0.141070	0.297572
EXTRA TREES	0.139291	0.306430

Overall, according to the table created above, it is shown that the Extra Trees Regressor performed the best and most accurately, achieving the lowest MSE of 0.139291 and the highest R-squared value of 0.306430. The Gradient Boosting Regressor performed slightly worse than the Extra Trees Regressor but was comparatively better than the Random Forest Regressor. Unfortunately, the Random Forest Regressor performed the worst, with the highest MSE and the lowest R-squared value. To improve this, further hyperparameter tuning could be beneficial. Initially, I explored a wide range of hyperparameters, including more values for max_depth and min_samples_split. However, I realized that this approach was taking over 30 minutes, so I decided to select a smaller range instead. Additionally, bar plots were also created to understand the MSE and R-squared which is similar to the table above but in graphical perspective.





Overall, from this research we can understand that the Extra Trees Regression was the best output and have performed the best primarily. For improvement, feature engineering or better hypermeters is necessary.

References

"Extratreesclassifier." scikit. Accessed February 10, 2025.
https://scikit- learn.org/stable/modules/generated/sklearn.ensemble.ExtraTreesClassifier.html.

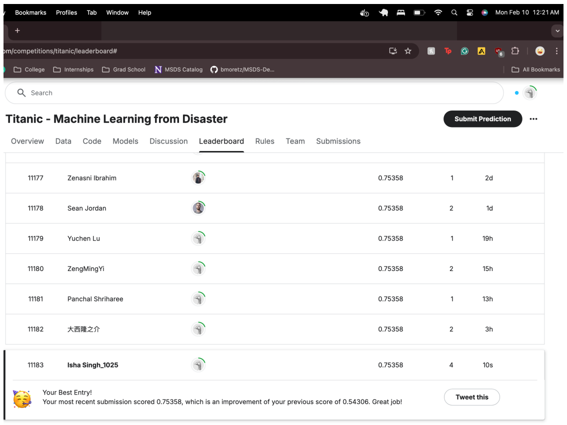
"Gradientboostingclassifier." scikit. Accessed February 10, 2025. https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.GradientBoostingClassifier.html.

"Randomforestclassifier." scikit. Accessed February 9, 2025. https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html.

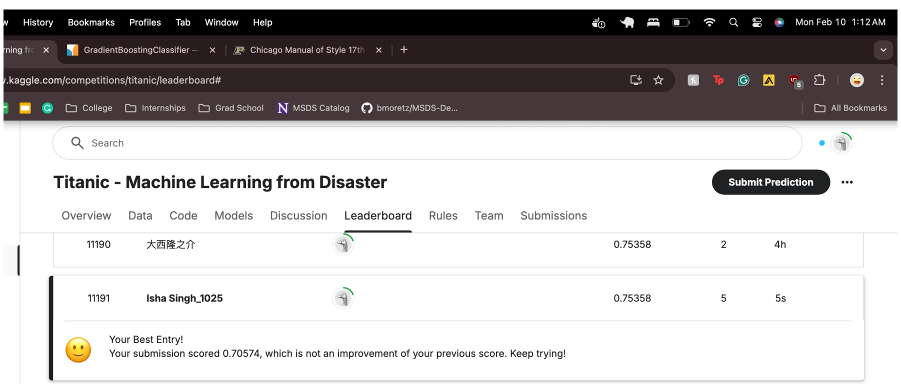
"Titanic - Machine Learning from Disaster." Kaggle. Accessed February 9, 2025. https://www.kaggle.com/competitions/titanic.

Kaggle Submissions

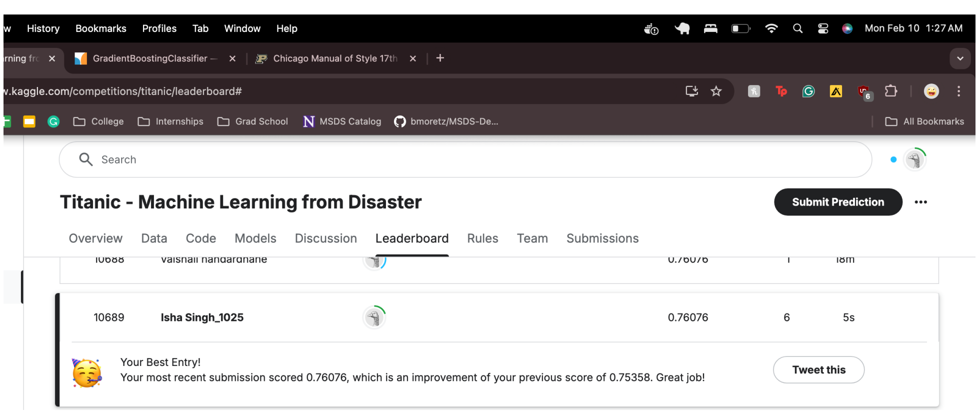
Random Forest Regressor



Gradient Boosting



Extra Trees



titanic_ml module_05

February 10, 2025

1 Titanic - Machine Learning from Disaster

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File Load In

[205]:
```
from scipy.stats import shapiro
from statsmodels.stats.outliers_influence import variance_inflation_factor
```

[206]:
```
import numpy as np
```

[207]:
```
import matplotlib.pyplot as plt
```

[208]:
```
import seaborn as sns
```

[209]:
```
import pandas as pd
```

[210]:
```
from sklearn.ensemble import RandomForestRegressor
```

[254]:
```
from scipy.stats import shapiro
```

[211]:
```
from sklearn.model_selection import GridSearchCV, KFold, train_test_split
```

[270]:
```
from sklearn.metrics import mean_squared_error, r2_score
```

[319]:
```
from sklearn.ensemble import GradientBoostingRegressor
```

[348]:
```
from sklearn.ensemble import ExtraTreesRegressor
```

SECTION 01: Descriptive Statistics

TRAINING DATA

[212]:
```
titanic_train_dataframe = pd.read_csv("/Users/isingh/Desktop/titanic/train.csv")
```

TESTING DATA

[213]:
```python
titanic_test_dataframe = pd.read_csv("/Users/isingh/Desktop/titanic/test.csv")
```

[214]:
```python
titanic_test_dataframe.columns
```

[214]:
```
Index(['PassengerId', 'Pclass', 'Name', 'Sex', 'Age', 'SibSp', 'Parch',
       'Ticket', 'Fare', 'Cabin', 'Embarked'],
      dtype='object')
```

[215]:
```python
titanic_train_dataframe.describe()
```

[215]:
```
       PassengerId    Survived      Pclass         Age       SibSp  \
count   891.000000  891.000000  891.000000  714.000000  891.000000
mean    446.000000    0.383838    2.308642   29.699118    0.523008
std     257.353842    0.486592    0.836071   14.526497    1.102743
min       1.000000    0.000000    1.000000    0.420000    0.000000
25%     223.500000    0.000000    2.000000   20.125000    0.000000
50%     446.000000    0.000000    3.000000   28.000000    0.000000
75%     668.500000    1.000000    3.000000   38.000000    1.000000
max     891.000000    1.000000    3.000000   80.000000    8.000000

            Parch        Fare
count  891.000000  891.000000
mean     0.381594   32.204208
std      0.806057   49.693429
min      0.000000    0.000000
25%      0.000000    7.910400
50%      0.000000   14.454200
75%      0.000000   31.000000
max      6.000000  512.329200
```

[216]:
```python
missing_values = titanic_train_dataframe.isnull().sum()
```

[217]:
```python
missing_values
```

[217]:
```
PassengerId      0
Survived         0
Pclass           0
Name             0
Sex              0
Age            177
SibSp            0
Parch            0
Ticket           0
Fare             0
Cabin          687
Embarked         2
dtype: int64
```

Outlier

[218]:
```python
titanic_train_dataframe["Age"].fillna(
    titanic_train_dataframe["Age"].median(), inplace=True
)
```

```
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/2219488372.py:1
: FutureWarning: A value is trying to be set on a copy of a DataFrame or Series
through chained assignment using an inplace method.
The behavior will change in pandas 3.0. This inplace method will never work
because the intermediate object on which we are setting values always behaves as
a copy.

For example, when doing 'df[col].method(value, inplace=True)', try using
'df.method({col: value}, inplace=True)' or df[col] = df[col].method(value)
instead, to perform the operation inplace on the original object.


  titanic_train_dataframe['Age'].fillna(titanic_train_dataframe['Age'].median(),
inplace=True)
```

[219]:
```python
titanic_train_dataframe["Cabin"].fillna("Unknown", inplace=True)
titanic_train_dataframe["Embarked"].fillna(
    titanic_train_dataframe.groupby("Pclass")["Embarked"].transform(
        lambda x: x.mode().iloc[0]
    ),
    inplace=True,
)
```

```
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/2013883459.py:1
: FutureWarning: A value is trying to be set on a copy of a DataFrame or Series
through chained assignment using an inplace method.
The behavior will change in pandas 3.0. This inplace method will never work
because the intermediate object on which we are setting values always behaves as
a copy.

For example, when doing 'df[col].method(value, inplace=True)', try using
'df.method({col: value}, inplace=True)' or df[col] = df[col].method(value)
instead, to perform the operation inplace on the original object.


  titanic_train_dataframe['Cabin'].fillna('Unknown', inplace=True)
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/2013883459.py:2
: FutureWarning: A value is trying to be set on a copy of a DataFrame or Series
through chained assignment using an inplace method.
The behavior will change in pandas 3.0. This inplace method will never work
because the intermediate object on which we are setting values always behaves as
a copy.
```

```
For example, when doing 'df[col].method(value, inplace=True)', try using
'df.method({col: value}, inplace=True)' or df[col] = df[col].method(value)
instead, to perform the operation inplace on the original object.


  titanic_train_dataframe['Embarked'].fillna(titanic_train_dataframe.groupby('Pc
lass')['Embarked'].transform(lambda x: x.mode().iloc[0]), inplace=True)
```

Title

[220]:
```python
titanic_train_dataframe["Title"] = titanic_train_dataframe["Name"].str.extract(
    " ([A-Za-z]+)\.", expand=False
)
```

Family Size

[221]:
```python
titanic_train_dataframe["FamilySize"] = (
    titanic_train_dataframe["SibSp"] + titanic_train_dataframe["Parch"] + 1
)
```

Whether a family member was alone or not

[222]:
```python
titanic_train_dataframe["IsAlone"] = (
    titanic_train_dataframe["FamilySize"] == 1
).astype(int)
```

Feature Scaling

[223]:
```python
from sklearn.preprocessing import StandardScaler
```

[224]:
```python
scaler = StandardScaler()
titanic_train_dataframe[["Age", "Fare"]] = scaler.fit_transform(
    titanic_train_dataframe[["Age", "Fare"]]
)
```

[225]:
```python
titanic_train_dataframe.duplicated().sum()
```

[225]:
```
0
```

[226]:
```python
missing_values = titanic_train_dataframe.isnull().sum()
print("Missing Values:")
print(missing_values)
```

```
Missing Values:
PassengerId    0
Survived       0
Pclass         0
Name           0
Sex            0
Age            0
SibSp          0
```

```
Parch          0
Ticket         0
Fare           0
Cabin          0
Embarked       0
Title          0
FamilySize     0
IsAlone        0
dtype: int64
```

Outlier IQR

[227]:
```
titanic_train_dataframe
```

[227]:
```
     PassengerId  Survived  Pclass  \
0              1         0       3
1              2         1       1
2              3         1       3
3              4         1       1
4              5         0       3
..           …         …     …
886          887         0       2
887          888         1       1
888          889         0       3
889          890         1       1
890          891         0       3

                                                  Name     Sex       Age  \
0                              Braund, Mr. Owen Harris    male -0.565736
1    Cumings, Mrs. John Bradley (Florence Briggs Th…  female  0.663861
2                               Heikkinen, Miss. Laina  female -0.258337
3         Futrelle, Mrs. Jacques Heath (Lily May Peel)  female  0.433312
4                             Allen, Mr. William Henry    male  0.433312
..                                                 …     …       …
886                              Montvila, Rev. Juozas    male -0.181487
887                       Graham, Miss. Margaret Edith  female -0.796286
888           Johnston, Miss. Catherine Helen "Carrie"  female -0.104637
889                              Behr, Mr. Karl Howell    male -0.258337
890                                Dooley, Mr. Patrick    male  0.202762

     SibSp  Parch            Ticket      Fare    Cabin Embarked Title  \
0        1      0         A/5 21171 -0.502445  Unknown        S    Mr
1        1      0          PC 17599  0.786845      C85        C   Mrs
2        0      0  STON/O2. 3101282 -0.488854  Unknown        S  Miss
3        1      0            113803  0.420730     C123        S   Mrs
4        0      0            373450 -0.486337  Unknown        S    Mr
..     …    …               …       …      …   …
886      0      0            211536 -0.386671  Unknown        S   Rev
```

```
887      0      0           112053 -0.044381      B42         S  Miss
888      1      2       W./C. 6607 -0.176263  Unknown         S  Miss
889      0      0           111369 -0.044381     C148         C    Mr
890      0      0           370376 -0.492378  Unknown         Q    Mr

     FamilySize  IsAlone
0             2        0
1             2        0
2             1        1
3             2        0
4             1        1
..          …      …
886           1        1
887           1        1
888           4        0
889           1        1
890           1        1

[891 rows x 15 columns]
```

[228]:

```
numeric_cols = titanic_train_dataframe.select_dtypes(
    include=[np.number]
).columns.tolist()
Q1 = titanic_train_dataframe[numeric_cols].quantile(0.25)
Q3 = titanic_train_dataframe[numeric_cols].quantile(0.75)
IQR = Q3 - Q1

lower_bound = Q1 - 1.5 * IQR
upper_bound = Q3 + 1.5 * IQR

# Filtering out outliers
titanic_train_dataframe1 = titanic_train_dataframe[
    ~(
        (titanic_train_dataframe[numeric_cols] < lower_bound)
        | (titanic_train_dataframe[numeric_cols] > upper_bound)
    ).any(axis=1)
]
```

[229]:

```
titanic_train_dataframe1
```

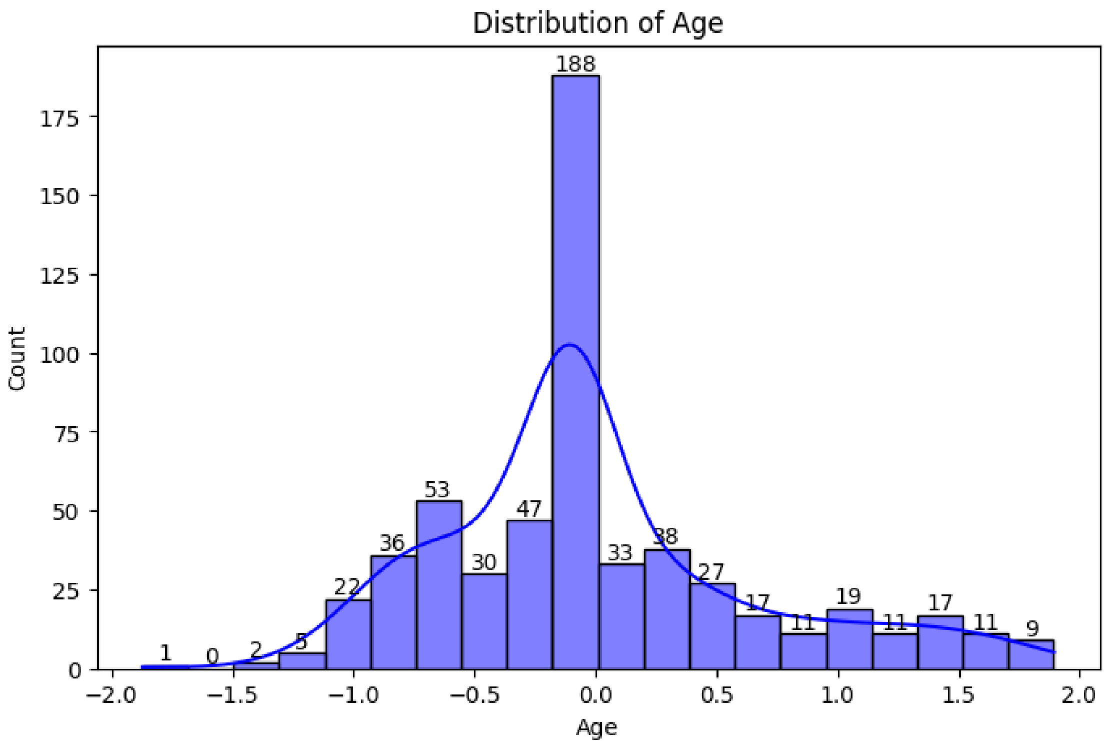
[229]:

```
     PassengerId  Survived  Pclass  \
0              1         0       3
2              3         1       3
3              4         1       1
4              5         0       3
5              6         0       3
..           …       …     …
```

```
884          885         0       3
886          887         0       2
887          888         1       1
889          890         1       1
890          891         0       3

                                                  Name     Sex       Age  SibSp  \
0                              Braund, Mr. Owen Harris    male -0.565736      1
2                               Heikkinen, Miss. Laina  female -0.258337      0
3         Futrelle, Mrs. Jacques Heath (Lily May Peel)  female  0.433312      1
4                             Allen, Mr. William Henry    male  0.433312      0
5                                     Moran, Mr. James    male -0.104637      0
..                                                 …       …         …      …
884                             Sutehall, Mr. Henry Jr    male -0.335187      0
886                              Montvila, Rev. Juozas    male -0.181487      0
887                       Graham, Miss. Margaret Edith  female -0.796286      0
889                              Behr, Mr. Karl Howell    male -0.258337      0
890                                Dooley, Mr. Patrick    male  0.202762      0

     Parch            Ticket      Fare    Cabin Embarked Title  FamilySize  \
0        0         A/5 21171 -0.502445  Unknown        S    Mr           2
2        0  STON/O2. 3101282 -0.488854  Unknown        S  Miss           1
3        0            113803  0.420730     C123        S   Mrs           2
4        0            373450 -0.486337  Unknown        S    Mr           1
5        0            330877 -0.478116  Unknown        Q    Mr           1
..     …               …       …      …      …   …         …
884      0   SOTON/OQ 392076 -0.506472  Unknown        S    Mr           1
886      0            211536 -0.386671  Unknown        S   Rev           1
887      0            112053 -0.044381      B42        S  Miss           1
889      0            111369 -0.044381     C148        C    Mr           1
890      0            370376 -0.492378  Unknown        Q    Mr           1

     IsAlone
0          0
2          1
3          0
4          1
5          1
..       …
884        1
886        1
887        1
889        1
890        1

[577 rows x 15 columns]
```

Visualizations - Exploratory Data Analysis

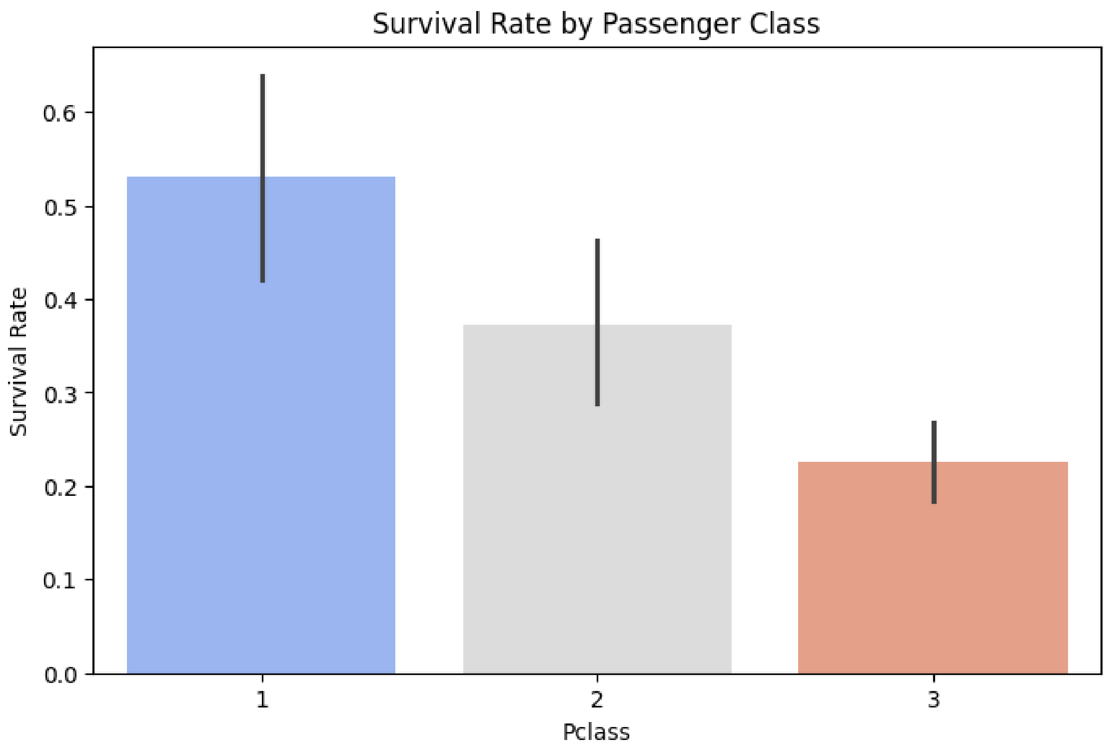
[231]:
```
plt.figure(figsize=(8, 5))
sns.histplot(titanic_train_dataframe1["Age"], bins=20, kde=True, color="blue")
plt.title("Distribution of Age")
for p in plt.gca().patches:
    plt.gca().annotate(
        f"{int(p.get_height())}",
        (p.get_x() + p.get_width() / 2, p.get_height()),
        ha="center",
        va="bottom",
        fontsize=10,
        color="black",
    )
plt.show()
```



[232]:
```
plt.figure(figsize=(8, 5))
sns.barplot(
    x="Pclass",
    y="Survived",
    data=titanic_train_dataframe1,
    palette="coolwarm",
    estimator=np.mean,
)
plt.title("Survival Rate by Passenger Class")
```

```
plt.ylabel("Survival Rate")
plt.show()
```

```
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/3739617002.py:2
: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same
effect.

  sns.barplot(x='Pclass', y='Survived', data=titanic_train_dataframe1,
palette='coolwarm', estimator=np.mean)
```

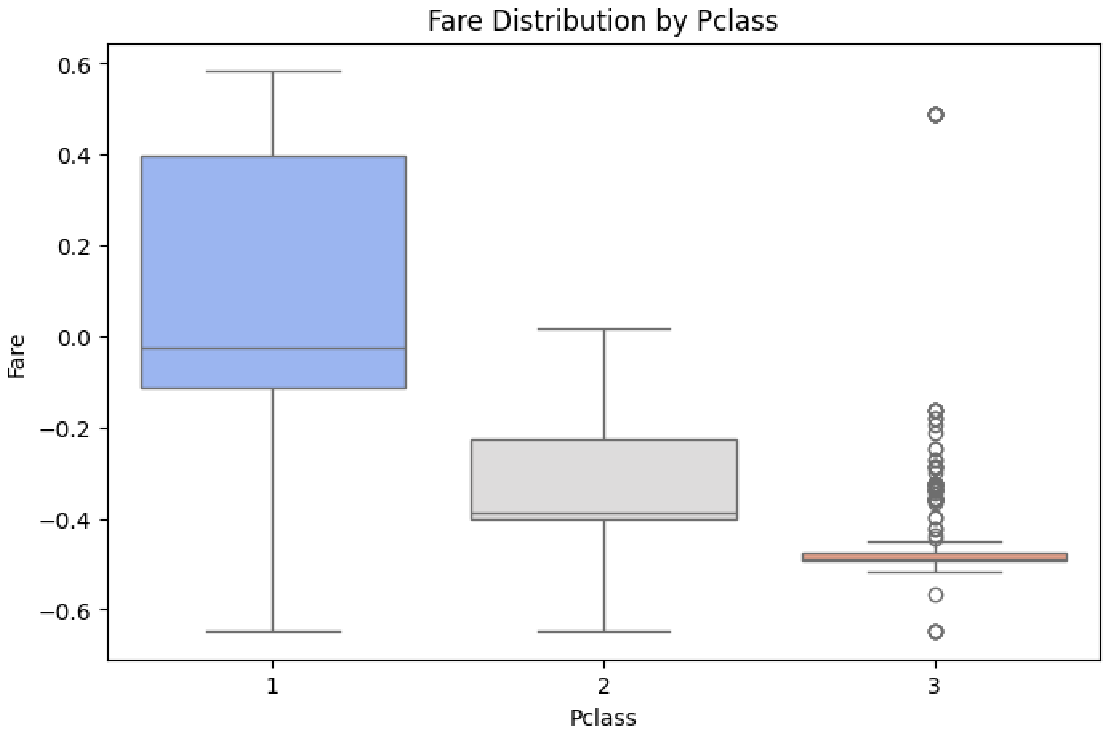


[233]:
```
plt.figure(figsize=(8, 5))
sns.boxplot(x="Pclass", y="Fare", data=titanic_train_dataframe1,␣
  ↪palette="coolwarm")
plt.title("Fare Distribution by Pclass")
plt.show()
```

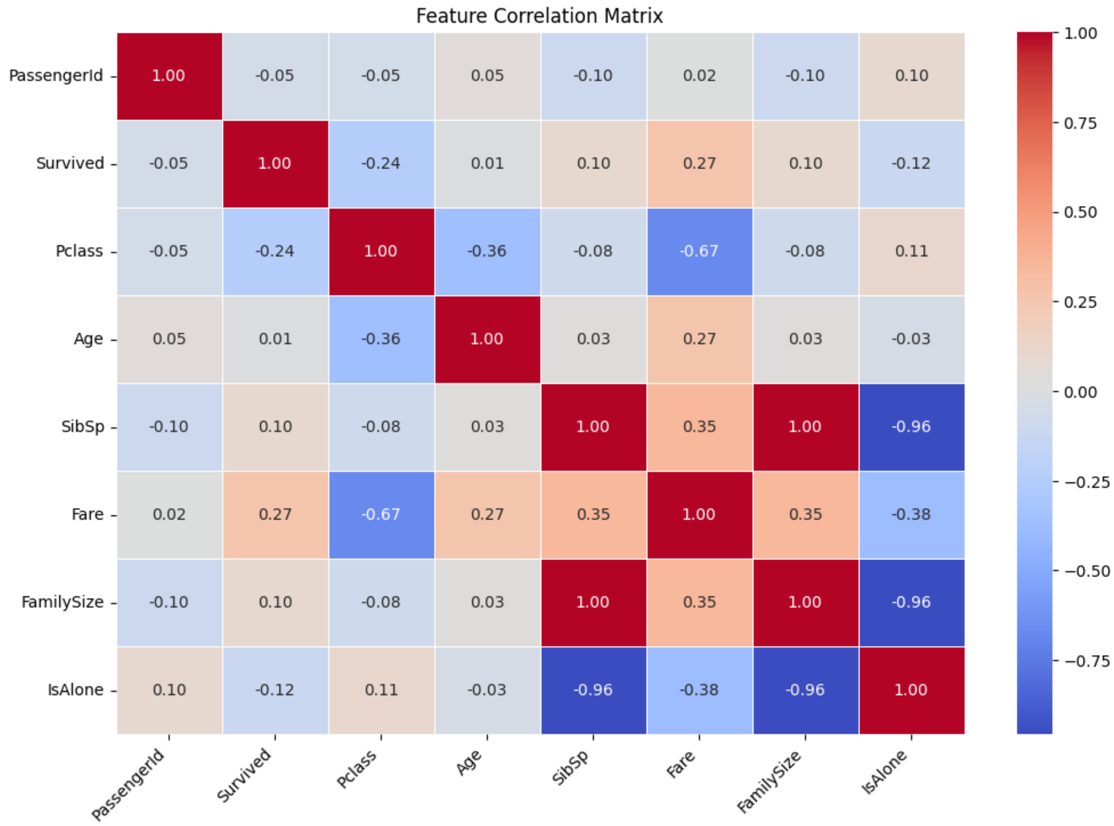
```
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/2735142903.py:2
: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same
```

effect.

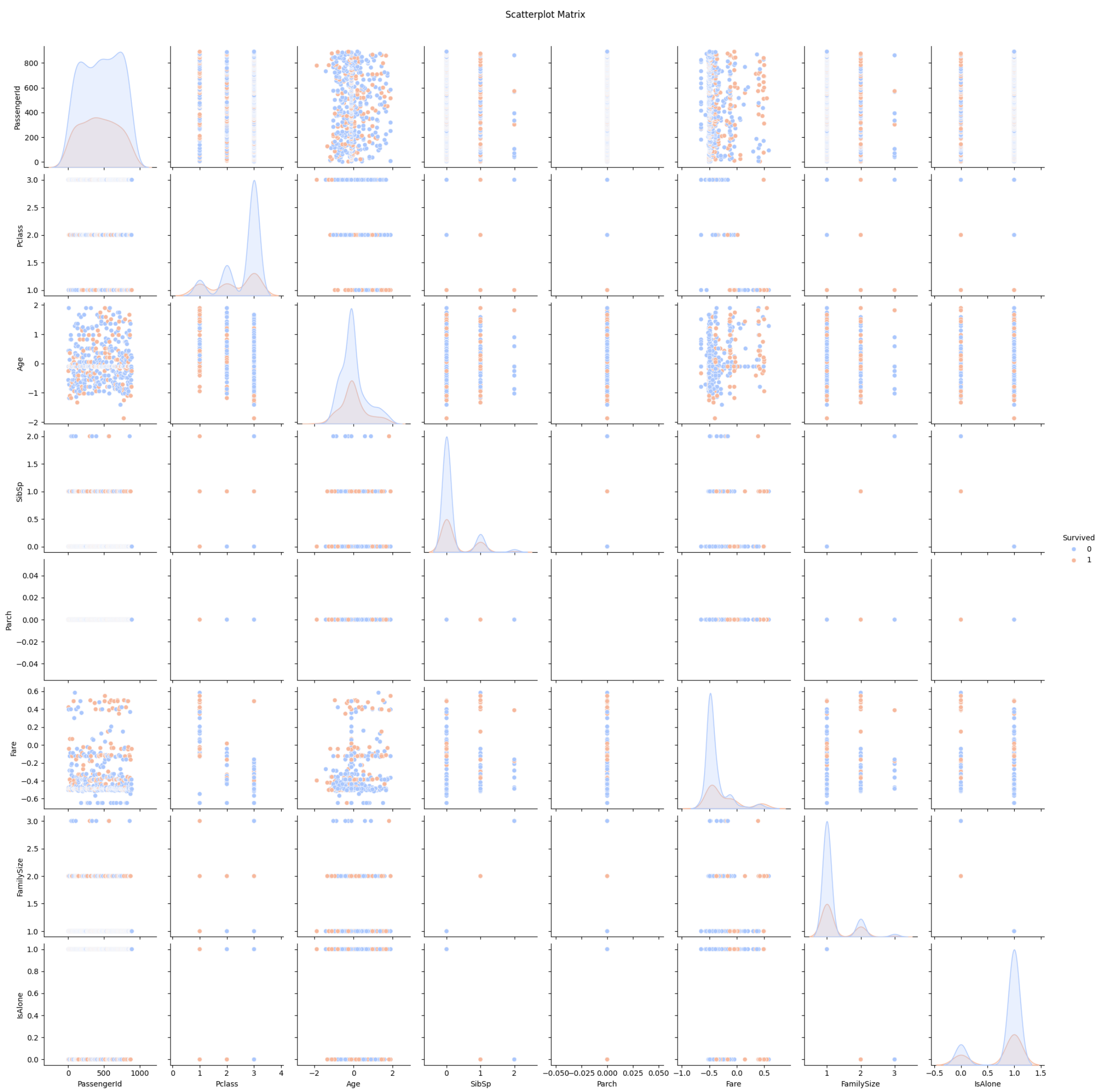
```
  sns.boxplot(x='Pclass', y='Fare', data=titanic_train_dataframe1,
palette='coolwarm')
```



[234]:
```
numeric_df = titanic_train_dataframe1.select_dtypes(include=[np.number])
numeric_df = numeric_df.loc[:, (numeric_df.var() > 0)]
plt.figure(figsize=(12, 8))  # Larger figure size
sns.heatmap(numeric_df.corr(), annot=True, cmap="coolwarm", fmt=".2f",␣
 ↪linewidths=0.5)
plt.xticks(rotation=45, ha="right")
plt.yticks(rotation=0)
plt.title("Feature Correlation Matrix")

plt.show()
```



[ ]:
```
numeric_cols = titanic_train_dataframe1.select_dtypes(include=[np.number])
sns.pairplot(numeric_cols, hue="Survived", palette="coolwarm")
plt.suptitle("Scatterplot Matrix", y=1.02)
plt.show()
```



[236]:
```python
print(titanic_train_dataframe1.isnull().sum())
```

```
PassengerId    0
Survived       0
Pclass         0
Name           0
Sex            0
Age            0
SibSp          0
Parch          0
Ticket         0
Fare           0
Cabin          0
Embarked       0
```

```
Title         0
FamilySize    0
IsAlone       0
dtype: int64
```

Train Test Split

[238]:
```python
from sklearn.model_selection import train_test_split

X = titanic_train_dataframe1.drop(columns=["Survived"])  # Features
y = titanic_train_dataframe1["Survived"]  # Target
```

[239]:
```python
X = X.drop(columns=["Name", "Ticket", "Cabin", "PassengerId"], errors="ignore")
```

[240]:
```python
print(X.columns)
X.head()
```

```
Index(['Pclass', 'Sex', 'Age', 'SibSp', 'Parch', 'Fare', 'Embarked', 'Title',
       'FamilySize', 'IsAlone'],
      dtype='object')
```

[240]:
```
   Pclass     Sex       Age  SibSp  Parch      Fare Embarked Title  \
0       3    male -0.565736      1      0 -0.502445        S    Mr
2       3  female -0.258337      0      0 -0.488854        S  Miss
3       1  female  0.433312      1      0  0.420730        S   Mrs
4       3    male  0.433312      0      0 -0.486337        S    Mr
5       3    male -0.104637      0      0 -0.478116        Q    Mr

   FamilySize  IsAlone
0           2        0
2           1        1
3           2        0
4           1        1
5           1        1
```

[ ]:
```python
X = pd.get_dummies(X, columns=["Sex", "Embarked", "Title"], drop_first=True)
```

[242]:
```python
X.head()
```

[242]:
```
   Pclass       Age  SibSp  Parch      Fare  FamilySize  IsAlone  Sex_male  \
0       3 -0.565736      1      0 -0.502445           2        0      True
2       3 -0.258337      0      0 -0.488854           1        1     False
3       1  0.433312      1      0  0.420730           2        0     False
4       3  0.433312      0      0 -0.486337           1        1      True
5       3 -0.104637      0      0 -0.478116           1        1      True

   Embarked_Q  Embarked_S  …  Title_Lady  Title_Major  Title_Master  \
0       False        True  …       False        False         False
2       False        True  …       False        False         False
```

```
3       False        True  ...      False        False         False
4       False        True  ...      False        False         False
5        True       False  ...      False        False         False

   Title_Miss  Title_Mlle  Title_Mr  Title_Mrs  Title_Ms  Title_Rev  Title_Sir
0       False       False      True      False     False      False      False
2        True       False     False      False     False      False      False
3       False       False     False       True     False      False      False
4       False       False      True      False     False      False      False
5       False       False      True      False     False      False      False

[5 rows x 22 columns]
```

[244]:
```python
X = X.astype(int)
X.head()
```

[244]:
```
   Pclass  Age  SibSp  Parch  Fare  FamilySize  IsAlone  Sex_male  Embarked_Q  \
0       3    0      1      0     0           2        0         1           0
2       3    0      0      0     0           1        1         0           0
3       1    0      1      0     0           2        0         0           0
4       3    0      0      0     0           1        1         1           0
5       3    0      0      0     0           1        1         1           1

   Embarked_S  ...  Title_Lady  Title_Major  Title_Master  Title_Miss  \
0           1  ...           0            0             0           0
2           1  ...           0            0             0           1
3           1  ...           0            0             0           0
4           1  ...           0            0             0           0
5           0  ...           0            0             0           0

   Title_Mlle  Title_Mr  Title_Mrs  Title_Ms  Title_Rev  Title_Sir
0           0         1          0         0          0          0
2           0         0          0         0          0          0
3           0         0          1         0          0          0
4           0         1          0         0          0          0
5           0         1          0         0          0          0

[5 rows x 22 columns]
```

Cross Validation

[245]:
```python
from sklearn.model_selection import KFold

kf = KFold(n_splits=5, shuffle=True, random_state=42)
```

[246]:
```python
kf = KFold(n_splits=5, shuffle=True, random_state=42)

for train_index, test_index in kf.split(X, y):
```

```
    X_train, X_val = X.iloc[train_index], X.iloc[test_index]
    y_train, y_val = y.iloc[train_index], y.iloc[test_index]
```

[247]:
```
print(X.dtypes)
print(X.head())
```

```
Pclass            int64
Age               int64
SibSp             int64
Parch             int64
Fare              int64
FamilySize        int64
IsAlone           int64
Sex_male          int64
Embarked_Q        int64
Embarked_S        int64
Title_Dr          int64
Title_Jonkheer    int64
Title_Lady        int64
Title_Major       int64
Title_Master      int64
Title_Miss        int64
Title_Mlle        int64
Title_Mr          int64
Title_Mrs         int64
Title_Ms          int64
Title_Rev         int64
Title_Sir         int64
dtype: object
   Pclass  Age  SibSp  Parch  Fare  FamilySize  IsAlone  Sex_male  Embarked_Q  \
0       3    0      1      0     0           2        0         1           0
2       3    0      0      0     0           1        1         0           0
3       1    0      1      0     0           2        0         0           0
4       3    0      0      0     0           1        1         1           0
5       3    0      0      0     0           1        1         1           1

   Embarked_S  …  Title_Lady  Title_Major  Title_Master  Title_Miss  \
0           1  …           0            0             0           0
2           1  …           0            0             0           1
3           1  …           0            0             0           0
4           1  …           0            0             0           0
5           0  …           0            0             0           0

   Title_Mlle  Title_Mr  Title_Mrs  Title_Ms  Title_Rev  Title_Sir
0           0         1          0         0          0          0
2           0         0          0         0          0          0
3           0         0          1         0          0          0
4           0         1          0         0          0          0
```

```
5            0          1           0          0           0           0

[5 rows x 22 columns]
```

[248]:
```
print("Current columns in X:", X.columns)
```

```
Current columns in X: Index(['Pclass', 'Age', 'SibSp', 'Parch', 'Fare',
'FamilySize', 'IsAlone',
       'Sex_male', 'Embarked_Q', 'Embarked_S', 'Title_Dr', 'Title_Jonkheer',
       'Title_Lady', 'Title_Major', 'Title_Master', 'Title_Miss', 'Title_Mlle',
       'Title_Mr', 'Title_Mrs', 'Title_Ms', 'Title_Rev', 'Title_Sir'],
      dtype='object')
```

Model Assumptions

[ ]:
```
X_copy = X.copy()
vif_data = pd.DataFrame()
vif_data["Feature"] = X_copy.columns
vif_data["VIF"] = [
    variance_inflation_factor(X_copy.values, i) for i in range(X_copy.shape[1])
]

print("VIF Values for Multicollinearity Check:")
print(vif_data.sort_values(by="VIF", ascending=False))
```

```
VIF Values for Multicollinearity Check:
           Feature          VIF
5       FamilySize  2271.694262
2            SibSp   376.023709
15      Title_Miss   176.818976
7         Sex_male   135.673565
17        Title_Mr   116.933276
18       Title_Mrs    99.053525
6          IsAlone    12.621587
10        Title_Dr     6.224177
20       Title_Rev     5.063031
12      Title_Lady     3.268537
19        Title_Ms     3.263391
16      Title_Mlle     3.255726
13     Title_Major     3.045242
14    Title_Master     2.038888
21       Title_Sir     2.030270
11  Title_Jonkheer     2.012673
8       Embarked_Q     1.820930
9       Embarked_S     1.747054
0           Pclass     1.240012
1              Age     1.194009
3            Parch          NaN
4             Fare          NaN
```

```
/Users/isingh/opt/miniconda3/lib/python3.9/site-
packages/statsmodels/regression/linear_model.py:1736: RuntimeWarning: invalid
value encountered in scalar divide
  return 1 - self.ssr/self.centered_tss
```

[ ]:
```
numerical_cols = X_copy.select_dtypes(include=[np.number]).columns.tolist()

print("\nShapiro-Wilk Normality Test for LDA:")
for col in numerical_cols:
    try:
        stat, p = shapiro(X_copy[col])
        print(f"- {col}: p-value={p:.4f} {'(Normal)' if p > 0.05 else '(Not␣
↪Normal)'}")
    except ValueError:
        print(f"- {col}: Skipped (Shapiro test failed due to large sample␣
↪size)")
```

```
Shapiro-Wilk Normality Test for LDA:
- Pclass: p-value=0.0000 (Not Normal)
- Age: p-value=0.0000 (Not Normal)
- SibSp: p-value=0.0000 (Not Normal)
- Parch: p-value=1.0000 (Normal)
- Fare: p-value=1.0000 (Normal)
- FamilySize: p-value=0.0000 (Not Normal)
- IsAlone: p-value=0.0000 (Not Normal)
- Sex_male: p-value=0.0000 (Not Normal)
- Embarked_Q: p-value=0.0000 (Not Normal)
- Embarked_S: p-value=0.0000 (Not Normal)
- Title_Dr: p-value=0.0000 (Not Normal)
- Title_Jonkheer: p-value=0.0000 (Not Normal)
- Title_Lady: p-value=0.0000 (Not Normal)
- Title_Major: p-value=0.0000 (Not Normal)
- Title_Master: p-value=0.0000 (Not Normal)
- Title_Miss: p-value=0.0000 (Not Normal)
- Title_Mlle: p-value=0.0000 (Not Normal)
- Title_Mr: p-value=0.0000 (Not Normal)
- Title_Mrs: p-value=0.0000 (Not Normal)
- Title_Ms: p-value=0.0000 (Not Normal)
- Title_Rev: p-value=0.0000 (Not Normal)
- Title_Sir: p-value=0.0000 (Not Normal)
```

```
/Users/isingh/opt/miniconda3/lib/python3.9/site-
packages/scipy/stats/_axis_nan_policy.py:531: UserWarning: scipy.stats.shapiro:
Input data has range zero. The results may not be accurate.
  res = hypotest_fun_out(*samples, **kwds)
```

Random Forest Regression

[279]:
```
param_grid = {
    "n_estimators": [50, 100, 150, 200, 250, 300],  # Number of trees
    "max_features": ["sqrt", "log2", 5, 7],  # Maximum features per split
    "max_depth": [10, 20, 30, None],  # Maximum depth of each tree
    "criterion": ["squared_error", "absolute_error"],  # Valid criteria for␣
 ↪regression
}
```

Gini and entropy are only valid for classification

Random Forest Regressor is a regression model, which uses different splitting criteria.

"Randomforestclassifier." scikit. Accessed February 9, 2025. https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html.

[280]:
```
rf_regressor = RandomForestRegressor(random_state=42)
```

[281]:
```
grid_search_randomforest_regressor = GridSearchCV(
    estimator=rf_regressor,
    param_grid=param_grid,
    cv=5,  # 5-fold cross-validation
    scoring="neg_mean_squared_error",  # Minimize MSE
)
```

[282]:
```
grid_search_randomforest_regressor.fit(X_train, y_train)
```

[282]:
```
GridSearchCV(cv=5, estimator=RandomForestRegressor(random_state=42),
             param_grid={'criterion': ['squared_error', 'absolute_error'],
                         'max_depth': [10, 20, 30, None],
                         'max_features': ['sqrt', 'log2', 5, 7],
                         'n_estimators': [50, 100, 150, 200, 250, 300]},
             scoring='neg_mean_squared_error')
```

[283]:
```
best_params_random_forest_regressor = grid_search_randomforest_regressor.
 ↪best_params_
print(
    "Best parameters -- Random Forest Regressor:",␣
 ↪best_params_random_forest_regressor
)
```

```
Best parameters -- Random Forest Regressor: {'criterion': 'squared_error',
'max_depth': 10, 'max_features': 'sqrt', 'n_estimators': 100}
```

[284]:
```
best_model_with_randomforest = grid_search_randomforest_regressor.
 ↪best_estimator_
print("Best model with Random Forest Regressor:", best_model_with_randomforest)
```

```
Best model with Random Forest Regressor: RandomForestRegressor(max_depth=10,
max_features='sqrt', random_state=42)
```

[285]:
```
y_pred_random_forest = best_model_with_randomforest.predict(X_val)
```

[286]:
```
mse_random_forest_regressor = mean_squared_error(y_val, y_pred_random_forest)
print("The mse for Random Forest Regressor is:", mse_random_forest_regressor)
```

```
The mse for Random Forest Regressor is: 0.1526500802481171
```

[289]:
```
r_squared_random_forest_regressor = r2_score(y_val, y_pred_random_forest)
print(
    "The r-squared for Random Forest Regressor is:",␣
 ↪r_squared_random_forest_regressor
)
```

```
The r-squared for Random Forest Regressor is: 0.23991065087298635
```

Kaggle Submission for Random Forest Regressor

[ ]:
```
X_test = titanic_test_dataframe.drop(
    columns=["Name", "Ticket", "Cabin", "PassengerId"], errors="ignore"
)
```

[307]:
```
X_test = pd.get_dummies(X_test, drop_first=True)
```

[310]:
```
for col in X_copy.columns:
    if col not in X_test.columns:
        X_test[col] = 0


X_test = X_test[X_copy.columns]
```

[311]:
```
X_test.fillna(X_test.median(), inplace=True)
```

[312]:
```
print(" X test columns:", X_test.columns)
```

```
 X test columns: Index(['Pclass', 'Age', 'SibSp', 'Parch', 'Fare', 'FamilySize',
'IsAlone',
       'Sex_male', 'Embarked_Q', 'Embarked_S', 'Title_Dr', 'Title_Jonkheer',
       'Title_Lady', 'Title_Major', 'Title_Master', 'Title_Miss', 'Title_Mlle',
       'Title_Mr', 'Title_Mrs', 'Title_Ms', 'Title_Rev', 'Title_Sir'],
      dtype='object')
```

[315]:
```
y_pred_kaggle_randomforest_regression = best_model_with_randomforest.
 ↪predict(X_test)
```

[ ]:
```
y_pred_kaggle_binary_conversion_rdf = (
    y_pred_kaggle_randomforest_regression > 0.5
).astype(int)
```

[317]:
```
submission_df = pd.DataFrame(
    {
        "PassengerId": titanic_test_dataframe["PassengerId"],
        "Survived": y_pred_kaggle_binary_conversion_rdf,
    }
)
```

[318]:
```
submission_file_path = "random_forest_submission.csv"
submission_df.to_csv(submission_file_path, index=False)
```

Gradident Boosting

"Gradientboostingclassifier." scikit. Accessed February 10, 2025. https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.GradientBoostingClassifier.html.

[372]:
```
param_grid_gradient_boosting = {
    "n_estimators": [50, 150, 300],  # number of trees
    "learning_rate": [0.05, 0.1, 0.2],  ## Step size per iteration
    "max_depth": [3, 7],  # maximum number of levels in each tree
    "subsample": [0.6, 1.0],  # Fraction of data used
    "min_samples_split": [2, 10],  # Min samples to split
    "min_samples_leaf": [1, 5],  # Min samples in leaf
    "max_features": ["sqrt", "log2"],  # Features per split
}
```

[327]:
```
gradient_boosting_regressor = GradientBoostingRegressor(random_state=42)
```

[328]:
```
grid_search_gradient_boosting_regressor = GridSearchCV(
    estimator=gradient_boosting_regressor,
    param_grid=param_grid_gradient_boosting,
    cv=5,  # 5-fold cross-validation
    scoring="neg_mean_squared_error",
)
```

[329]:
```
grid_search_gradient_boosting_regressor.fit(X_train, y_train)
```

[329]:
```
GridSearchCV(cv=5, estimator=GradientBoostingRegressor(random_state=42),
             param_grid={'learning_rate': [0.05, 0.1, 0.2], 'max_depth': [3, 7],
                         'max_features': ['sqrt', 'log2'],
                         'min_samples_leaf': [1, 5],
                         'min_samples_split': [2, 10],
                         'n_estimators': [50, 150, 300],
                         'subsample': [0.6, 1.0]},
             scoring='neg_mean_squared_error')
```

[330]:
```
best_params_gradient_boosting = grid_search_gradient_boosting_regressor.
 ↪best_params_
print("Best parameters -- Gradient Boosting:", best_params_gradient_boosting)
```

```
Best parameters -- Gradient Boosting: {'learning_rate': 0.1, 'max_depth': 3,
'max_features': 'sqrt', 'min_samples_leaf': 5, 'min_samples_split': 2,
'n_estimators': 50, 'subsample': 1.0}
```

[331]:
```python
best_model_with_gradient_boosting_regressor = (
    grid_search_gradient_boosting_regressor.best_estimator_
)
```

[334]:
```python
y_pred_gradient_boosting = best_model_with_gradient_boosting_regressor.
 ↪predict(X_val)
```

[335]:
```python
mse_gradient_boosting = mean_squared_error(y_val, y_pred_gradient_boosting)
print("The mse for Gradient Boosting Regressor is:", mse_gradient_boosting)
```

```
The mse for Gradient Boosting Regressor is: 0.1410699424712798
```

[337]:
```python
r_squared_gradient_boosting = r2_score(y_val, y_pred_gradient_boosting)
print("The r-squared for Gradient Boosting Regressor is:",␣
 ↪r_squared_gradient_boosting)
```

```
The r-squared for Gradient Boosting Regressor is: 0.2975715402173664
```

Kaggle Submission for Gradient Boosting

[340]:
```python
X_test_gradient_boosting = titanic_test_dataframe.drop(
    columns=["Name", "Ticket", "Cabin", "PassengerId"], errors="ignore"
)
```

[341]:
```python
X_test_gradient_boosting = pd.get_dummies(X_test_gradient_boosting,␣
 ↪drop_first=True)
```

[342]:
```python
for col in X_copy.columns:
    if col not in X_test_gradient_boosting.columns:
        X_test_gradient_boosting[col] = 0

X_test_gradient_boosting = X_test_gradient_boosting[X_copy.columns]
```

[343]:
```python
X_test_gradient_boosting.fillna(X_test_gradient_boosting.median(), inplace=True)
```

[344]:
```python
y_pred_kaggle_gradient_boosting = best_model_with_gradient_boosting_regressor.
 ↪predict(
    X_test_gradient_boosting
)
```

[345]:
```python
y_pred_kaggle_gradient_boosting = (y_pred_kaggle_gradient_boosting > 0.5).
 ↪astype(int)
```

[346]:
```python
submission_df_gb = pd.DataFrame(
    {
```

```
        "PassengerId": titanic_test_dataframe["PassengerId"],
        "Survived": y_pred_kaggle_gradient_boosting,
    }
)
```

[347]:
```
submission_file_path_gb = "gradient_boosting_submission.csv"
submission_df_gb.to_csv(submission_file_path_gb, index=False)
```

Extra Trees

"Extratreesclassifier." scikit. Accessed February 10, 2025. https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.ExtraTreesClassifier.html.

[349]:
```
param_grid_extra_trees = {
    "n_estimators": [50, 150, 300],
    "max_features": ["sqrt", "log2", 0.5],
    "max_depth": [None, 10, 30],
    "min_samples_split": [2, 10],
    "min_samples_leaf": [1, 5],
    "criterion": ["squared_error", "absolute_error"],
}
```

[351]:
```
extra_trees_regressor = ExtraTreesRegressor(random_state=42)
```

[ ]:
```
grid_search_extra_trees = GridSearchCV(
    estimator=extra_trees_regressor,
    param_grid=param_grid_extra_trees,
    cv=5,  # 5-fold cross-validation
    scoring="neg_mean_squared_error",  # Minimize MSE
)
```

[355]:
```
grid_search_extra_trees.fit(X_train, y_train)
```

[355]:
```
GridSearchCV(cv=5, estimator=ExtraTreesRegressor(random_state=42),
             param_grid={'criterion': ['squared_error', 'absolute_error'],
                         'max_depth': [None, 10, 30],
                         'max_features': ['sqrt', 'log2', 0.5],
                         'min_samples_leaf': [1, 5],
                         'min_samples_split': [2, 10],
                         'n_estimators': [50, 150, 300]},
             scoring='neg_mean_squared_error')
```

[356]:
```
best_params_extra_trees = grid_search_extra_trees.best_params_
print("Best parameters for Extra Trees Regressor:", best_params_extra_trees)
```

```
Best parameters for Extra Trees Regressor: {'criterion': 'squared_error',
'max_depth': 10, 'max_features': 0.5, 'min_samples_leaf': 5,
'min_samples_split': 2, 'n_estimators': 50}
```

[358]:
```python
best_model_with_extra_trees = grid_search_extra_trees.best_estimator_
```

[359]:
```python
y_pred_extra_trees = best_model_with_extra_trees.predict(X_val)
```

[360]:
```python
mse_extra_trees = mean_squared_error(y_val, y_pred_extra_trees)
print("The mse for Extra Trees Regressor is:", mse_extra_trees)
```

```
The mse for Extra Trees Regressor is: 0.13929092580937663
```

[361]:
```python
r2_extra_trees = r2_score(y_val, y_pred_extra_trees)
print("The r-squared for Extra Trees Regressor is:", r2_extra_trees)
```

```
The r-squared for Extra Trees Regressor is: 0.3064297839499226
```

[362]:
```python
X_test_extra_trees = titanic_test_dataframe.drop(
    columns=["Name", "Ticket", "Cabin", "PassengerId"], errors="ignore"
)
```

[363]:
```python
X_test_extra_trees = pd.get_dummies(X_test_extra_trees, drop_first=True)
```

[365]:
```python
for col in X_copy.columns:
    if col not in X_test_extra_trees.columns:
        X_test_extra_trees[col] = 0

X_test_extra_trees = X_test_extra_trees[X_copy.columns]
```

[366]:
```python
X_test_extra_trees.fillna(X_test_extra_trees.median(), inplace=True)
```

[368]:
```python
y_pred_kaggle_extra_trees = best_model_with_extra_trees.
 ↪predict(X_test_extra_trees)
```

[369]:
```python
y_pred_kaggle_binary_extra_trees = (y_pred_kaggle_extra_trees > 0.5).astype(int)
```

[370]:
```python
submission_df_extra_trees = pd.DataFrame(
    {
        "PassengerId": titanic_test_dataframe["PassengerId"],
        "Survived": y_pred_kaggle_binary_extra_trees,
    }
)
```

[371]:
```python
submission_file_path_extra_trees = "extra_trees_submission.csv"
submission_df_extra_trees.to_csv(submission_file_path_extra_trees, index=False)
```

Evaluation of Models

[383]:
```python
model_results = pd.DataFrame(
    {
        "Model": ["Random Forest", "Gradient Boosting", "Extra Trees"],
```

```
        "MSE": [mse_random_forest_regressor, mse_gradient_boosting,␣
↪mse_extra_trees],
        "R_square Score": [
            r_squared_random_forest_regressor,
            r_squared_gradient_boosting,
            r2_extra_trees,
        ],
    }
)

print("Model Performance Summary")
print(model_results.to_string(index=False))
```

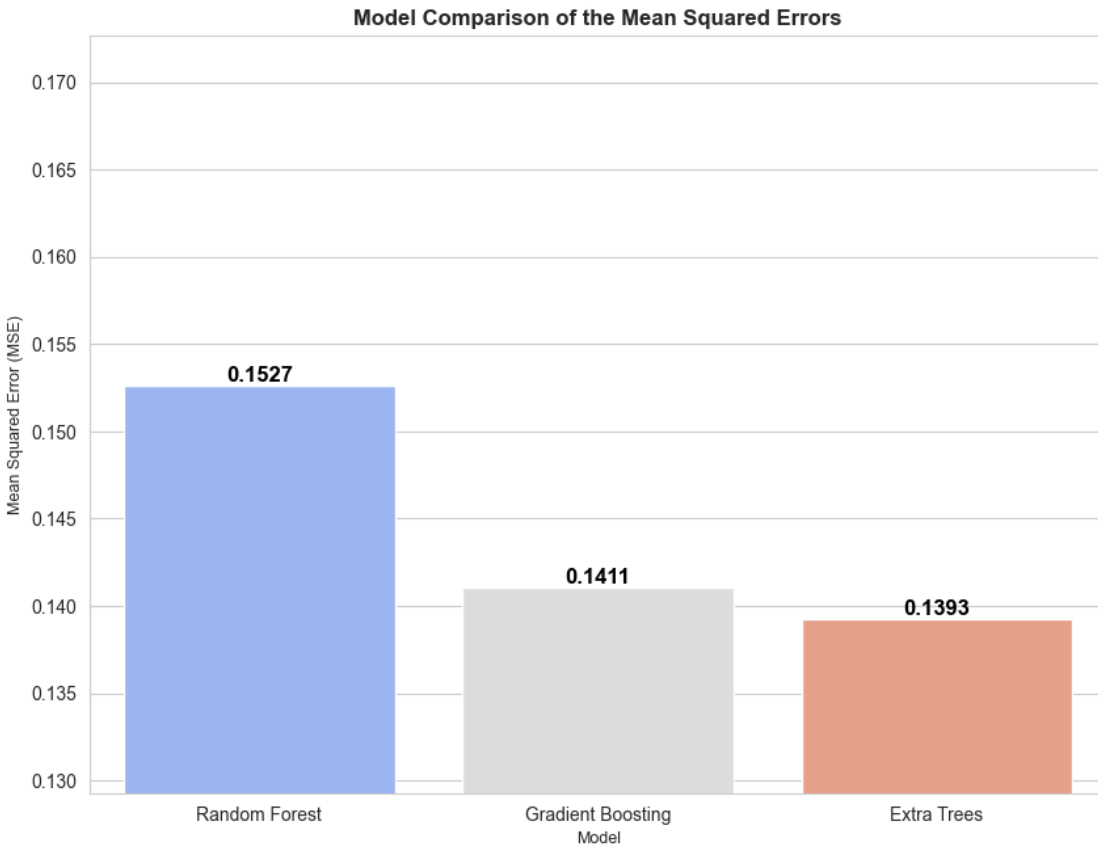
```
Model Performance Summary
            Model      MSE  R_square Score
    Random Forest 0.152650        0.239911
Gradient Boosting 0.141070        0.297572
      Extra Trees 0.139291        0.306430
```

MSE COMPARISON

[384]:
```
plt.figure(figsize=(10, 7.5))
ax = sns.barplot(x="Model", y="MSE", data=model_results, palette="coolwarm")

for p in ax.patches:
    ax.annotate(
        f"{p.get_height():.4f}",
        (p.get_x() + p.get_width() / 2, p.get_height()),
        ha="center",
        va="bottom",
        fontsize=12,
        color="black",
        fontweight="bold",
    )

plt.ylim(model_results["MSE"].min() - 0.01, model_results["MSE"].max() + 0.02)


# Labels and title
plt.xlabel("Model", fontsize=9)
plt.ylabel("Mean Squared Error (MSE)", fontsize=9)
plt.title("Model Comparison of the Mean Squared Errors", fontsize=12,␣
↪fontweight="bold")

plt.show()
```

```
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/632806412.py:2:
FutureWarning:
```

```
Passing `palette` without assigning `hue` is deprecated and will be removed in
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same
effect.

  ax = sns.barplot(x="Model", y="MSE", data=model_results, palette="coolwarm")
```

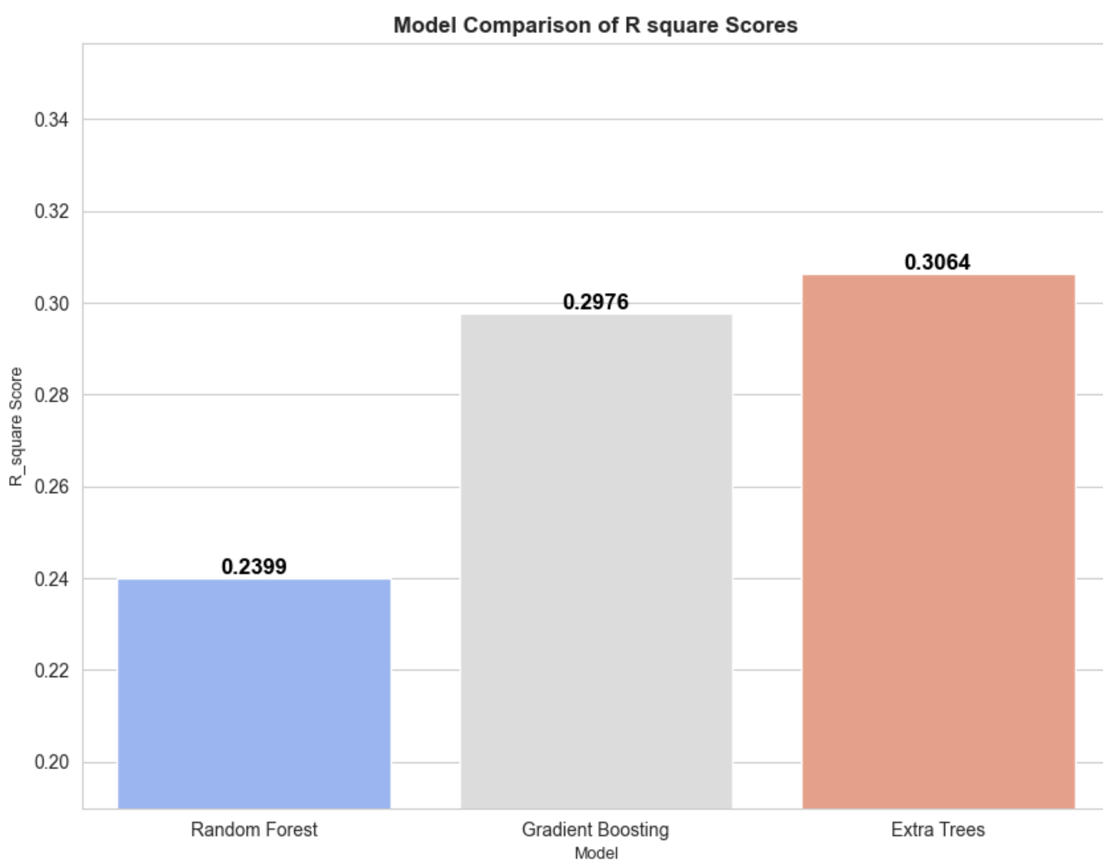


R_Squared

[387]:
```python
plt.figure(figsize=(10, 7.5))
ax = sns.barplot(x="Model", y="R_square Score", data=model_results,
 palette="coolwarm")

for p in ax.patches:
    ax.annotate(
        f"{p.get_height():.4f}",
        (p.get_x() + p.get_width() / 2, p.get_height()),
        ha="center",
        va="bottom",
        fontsize=12,
        color="black",
        fontweight="bold",
```

```
    )

plt.ylim(
    model_results["R_square Score"].min() - 0.05,
    model_results["R_square Score"].max() + 0.05,
)

plt.xlabel("Model", fontsize=9)
plt.ylabel("R_square Score", fontsize=9)
plt.title("Model Comparison of R square Scores", fontsize=12, fontweight="bold")

# Show plot
plt.show()
```

```
/var/folders/qx/htthbr0s1bx5ncc2f9j6j1qc0000gn/T/ipykernel_16658/679450378.py:2:
FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same
effect.

  ax = sns.barplot(x="Model", y="R_square Score", data=model_results,
palette="coolwarm")
```



```
[ ]:
```