# Titanic - Machine Learning from Disaster

#### Michael Berger

#!conda install -y matplotlib numpy seaborn plotly scikit-learn pandasql scipy

## Overview

The data has been split into two groups:

* training set (train.csv)
* test set (test.csv)

The training set should be used to build your machine learning models. For the training set, we provide the outcome (also known as the “ground truth”) for each passenger. Your model will be based on “features” like passengers’ gender and class. You can also use feature engineering to create new features.

The test set should be used to see how well your model performs on unseen data. For the test set, we do not provide the ground truth for each passenger. It is your job to predict these outcomes. For each passenger in the test set, use the model you trained to predict whether or not they survived the sinking of the Titanic.

We also include gender\_submission.csv, a set of predictions that assume all and only female passengers survive, as an example of what a submission file should look like.

**Data Dictionary**

| Variable | Definition | Key |
| --- | --- | --- |
| survival | Survival | 0 = No, 1 = Yes |
| pclass | Ticket class | 1 = 1st, 2 = 2nd, 3 = 3rd |
| sex | Sex |  |
| Age | Age in years |  |
| sibsp | # of siblings / spouses aboard the Titanic |  |
| parch | # of parents / children aboard the Titanic |  |
| ticket | Ticket number |  |
| fare | Passenger fare |  |
| cabin | Cabin number |  |
| embarked | Port of Embarkation | C = Cherbourg, Q = Queenstown, S = Southampton |

**Variable Notes**

**pclass**: A proxy for socio-economic status (SES)
1st = Upper
2nd = Middle
3rd = Lower

**age**: Age is fractional if less than 1. If the age is estimated, is it in the form of xx.5

**sibsp**: The dataset defines family relations in this way...
Sibling = brother, sister, stepbrother, stepsister
Spouse = husband, wife (mistresses and fiancés were ignored)

**parch**: The dataset defines family relations in this way...
Parent = mother, father
Child = daughter, son, stepdaughter, stepson
Some children travelled only with a nanny, therefore parch=0 for them.

## Libraries

# @title

import pandas as pd

import matplotlib.pyplot as plt

import numpy as np

import re

import seaborn as sns

import plotly.express as px

import plotly.subplots as subplots

from plotly.subplots import make\_subplots

import plotly.io as pio

import plotly.graph\_objects as go

# sklearn imports

from sklearn import metrics

from sklearn import pipeline

from sklearn import linear\_model

from sklearn import preprocessing

from sklearn import model\_selection

from sklearn.model\_selection import train\_test\_split, cross\_val\_predict, GridSearchCV, cross\_val\_score

from sklearn.linear\_model import Lasso, Ridge, LogisticRegression

from sklearn.svm import SVC

from sklearn.ensemble import GradientBoostingClassifier, RandomForestClassifier, RandomForestRegressor, AdaBoostRegressor, GradientBoostingRegressor

from sklearn.metrics import accuracy\_score, confusion\_matrix, precision\_score, recall\_score, f1\_score

from sklearn.tree import DecisionTreeClassifier

import pandasql as ps

from datetime import datetime

import json

import scipy.stats as st

## Reading Train Data

#delete me

passenger\_df\_train = pd.read\_csv(pref+"train.csv", index\_col="PassengerId")

passenger\_df\_test = pd.read\_csv(pref+"test.csv", index\_col="PassengerId")

passenger\_df\_test["Survived"] = -1

passenger\_df = pd.concat([passenger\_df\_train, passenger\_df\_test])

passenger\_df.vu()

| Survived | Pclass | Name | Sex | Age | SibSp | Parch | Ticket | Fare | Cabin | Embarked |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| -1 | 3 | Niklasson, Mr. Samuel | male | 28.00 | 0 | 0 | 363611 | 8.05 | nan | S |
| -1 | 1 | Borebank, Mr. John James | male | 42.00 | 0 | 0 | 110489 | 26.55 | D22 | S |
| -1 | 3 | Pedersen, Mr. Olaf | male | nan | 0 | 0 | 345498 | 7.78 | nan | S |
| 0 | 2 | Meyer, Mr. August | male | 39.00 | 0 | 0 | 248723 | 13.00 | nan | S |
| -1 | 3 | McCarthy, Miss. Catherine Katie"" | female | nan | 0 | 0 | 383123 | 7.75 | nan | Q |
| 0 | 3 | Zabour, Miss. Thamine | female | nan | 1 | 0 | 2665 | 14.45 | nan | C |
| -1 | 3 | McNeill, Miss. Bridget | female | nan | 0 | 0 | 370368 | 7.75 | nan | Q |
| 1 | 2 | Leitch, Miss. Jessie Wills | female | nan | 0 | 0 | 248727 | 33.00 | nan | S |
| -1 | 3 | Johnston, Mrs. Andrew G (Elizabeth Lily" Watson)" | female | nan | 1 | 2 | W./C. 6607 | 23.45 | nan | S |
| 1 | 3 | Moubarek, Master. Gerios | male | nan | 1 | 1 | 2661 | 15.25 | nan | C |

**Which features are categorical?**

These values classify the samples into sets of similar samples. Within categorical features are the values nominal, ordinal, ratio, or interval based? Among other things this helps us select the appropriate plots for visualization.

* Categorical: Survived, Sex, and Embarked. Ordinal: Pclass.

**Which features are numerical?**

Which features are numerical? These values change from sample to sample. Within numerical features are the values discrete, continuous, or timeseries based? Among other things this helps us select the appropriate plots for visualization.

* Continous: Age, Fare. Discrete: SibSp, Parch.

**Which features may contain errors or typos?**

* Name feature may contain errors or typos as there are several ways used to describe a name including titles, round brackets, and quotes used for alternative or short names.

**Check if there any null values**

print(passenger\_df\_train.isna().any())

print('\_'\*40)

passenger\_df\_test.isna().any()

Survived False

Pclass False

Name False

Sex False

Age True

SibSp False

Parch False

Ticket False

Fare False

Cabin True

Embarked True

dtype: bool

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Pclass False

Name False

Sex False

Age True

SibSp False

Parch False

Ticket False

Fare True

Cabin True

Embarked False

Survived False

dtype: bool

## Explatory Data Analysis (EDA) and Data Visualization

### Part 1 - Data Visualization

#### Describe Data

passenger\_df\_train.info()

print('\_'\*40)

passenger\_df\_test.info()

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

Index: 891 entries, 1 to 891

Data columns (total 11 columns):

# Column Non-Null Count Dtype

--- ------ -------------- -----

0 Survived 891 non-null int64

1 Pclass 891 non-null int64

2 Name 891 non-null object

3 Sex 891 non-null object

4 Age 714 non-null float64

5 SibSp 891 non-null int64

6 Parch 891 non-null int64

7 Ticket 891 non-null object

8 Fare 891 non-null float64

9 Cabin 204 non-null object

10 Embarked 889 non-null object

dtypes: float64(2), int64(4), object(5)

memory usage: 83.5+ KB

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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

Index: 418 entries, 892 to 1309

Data columns (total 11 columns):

# Column Non-Null Count Dtype

--- ------ -------------- -----

0 Pclass 418 non-null int64

1 Name 418 non-null object

2 Sex 418 non-null object

3 Age 332 non-null float64

4 SibSp 418 non-null int64

5 Parch 418 non-null int64

6 Ticket 418 non-null object

7 Fare 417 non-null float64

8 Cabin 91 non-null object

9 Embarked 418 non-null object

10 Survived 418 non-null int64

dtypes: float64(2), int64(4), object(5)

memory usage: 39.2+ KB

passenger\_df\_train.describe()

print(f'Train: There are {len(passenger\_df\_train["Ticket"].unique())} unique Ticket names and {len(passenger\_df\_train["Cabin"].unique())} unique Cabins.')

print(f'Test: There are {len(passenger\_df\_test["Ticket"].unique())} unique Ticket names and {len(passenger\_df\_test["Cabin"].unique())} unique Cabins.')

Train: There are 681 unique Ticket names and 148 unique Cabins.

Test: There are 363 unique Ticket names and 77 unique Cabins.

**Which features contain blank, null or empty values?**

These will require correcting.

* Cabin > Age > Embarked features contain a number of null values in that order for the training dataset.
* Cabin > Age are incomplete in case of test dataset.

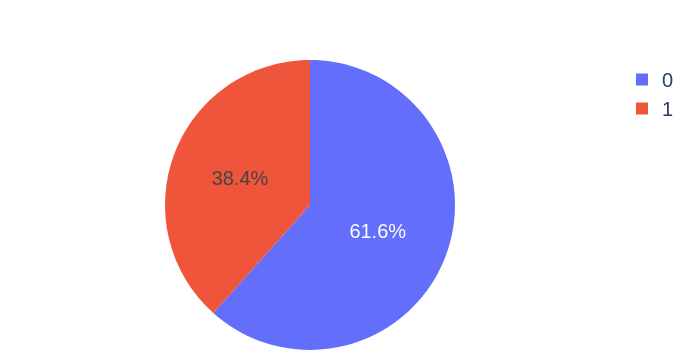
**What are the data types for various features?**

Helping us during converting goal.

* Seven features are integer or floats. Six in case of test dataset.
* Five features are strings (object).

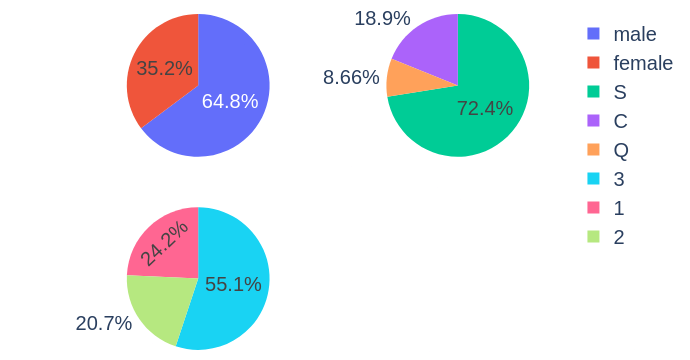
#### Amount of Survivors

create\_pie\_chart\_of\_count(passenger\_df\_train, 'Survived')



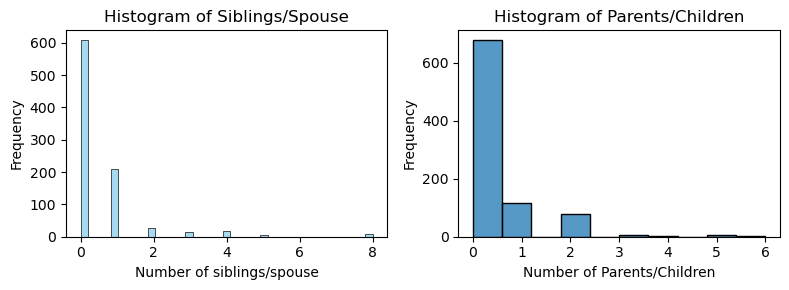
#### Pie Charts for Embark, Sex and Pclass

create\_pie\_chart\_subplot\_of\_count(passenger\_df\_train, ['Sex', 'Embarked', 'Pclass'])



#### Histograms for Siblings/Spouse and Parents/Children

fig



### Observations in a Nutshell for all features separately:

**passengers**:

1. There were 891 passengers in the data, with 681 unique tickets and 148 Cabins
2. Most passengers did not stay at a Cabin.

**sex**:

1. 65% of passengers are male and the rest female

**survived**:

1. 38% of passengers survived the disaster

**embarked**:

1. The majority of the passengers embarked from Southampton (makes sense because assumed higher population)
2. small amount of passengers have an unknown embarkment

**pclass**:

1. Most of the passengers are 3rd Class

**age**:

1. There are 177 passengers that have an unknown age
2. The average age is 23 and most of the passengers were in their 20’s

**sibsp**:

1. 600+ passengers were without siblings/spouses
2. 1 Outlier of 8 siblings/spouse (probably the family members as each index)

**parch**:

1. The big majority of the passengers are without parents/children
2. No big outlier (max=6)
3. Mainly between 0-2

### Assumptions based on the data

***Correlating***

We want to know how well does each feature correlate with Survival.

***Completing***

1. We may want to complete Age feature as it is definitely correlated to survival.
2. We may want to complete the Embarked feature as it may also correlate with survival or another important feature.

***Filtering***

1. Ticket feature may be dropped from our analysis as it contains high ratio of duplicates (22%) and there may not be a correlation between Ticket and survival.
2. Cabin feature may be dropped as it is highly incomplete or contains many null values both in training and test dataset.
3. PassengerId may be dropped from training dataset as it does not contribute to survival.
4. Name feature is relatively non-standard, may not contribute directly to survival, so maybe dropped.

***Engineering***

1. We may want to create a new feature called Family based on Parch and SibSp to get total count of family members on board.
2. We may want to engineer the Name feature to extract Title as a new feature.
3. We may want to create new feature for Age bands. This turns a continous numerical feature into an ordinal categorical feature.
4. We may also want to create a Fare range feature if it helps our analysis.
5. We may want to divide the Cabin into Letter and number of cabin instead of filtering the feature completely to get further information.

***Classifying***

We may also add to our assumptions based on the problem description noted earlier.

1. Women (Sex=female) were more likely to have survived.
2. Children (Age<?) were more likely to have survived.
3. The upper-class passengers (Pclass=1) were more likely to have survived.

### Data Exploration

To confirm some of our observations and assumptions, we can quickly analyze our feature correlations by pivoting features against each other. We can only do so at this stage for features which do not have any empty values. It also makes sense doing so only for features which are categorical (Sex), ordinal (Pclass) or discrete (SibSp, Parch) type.

* **Pclass** We observe significant correlation (>0.5) among Pclass=1 and Survived (classifying #3). We decide to include this feature in our model.
* **Sex** We confirm the observation during problem definition that Sex=female had very high survival rate at 74% (classifying #1).
* **SibSp and Parch** These features have zero correlation for certain values. It may be best to derive a feature or a set of features from these individual features (engineering #1).

#### Comparing non-null features to survived

fig.show()

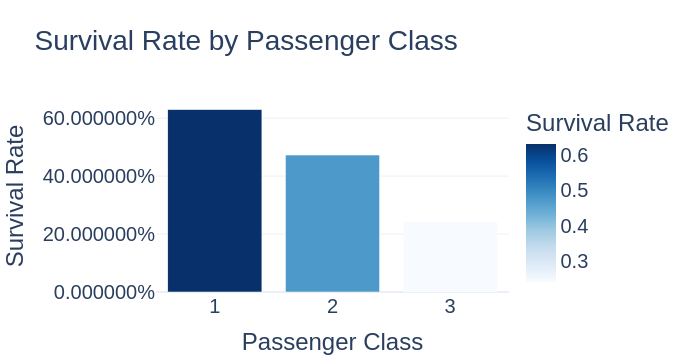


fig.show()

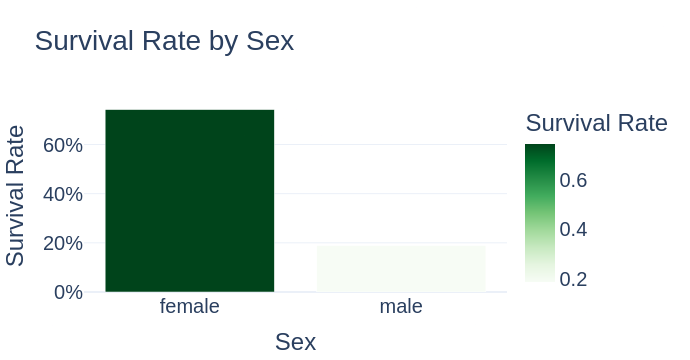


fig.show()

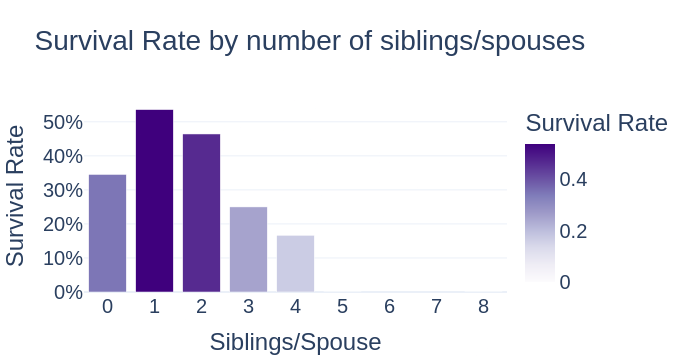


fig.show()

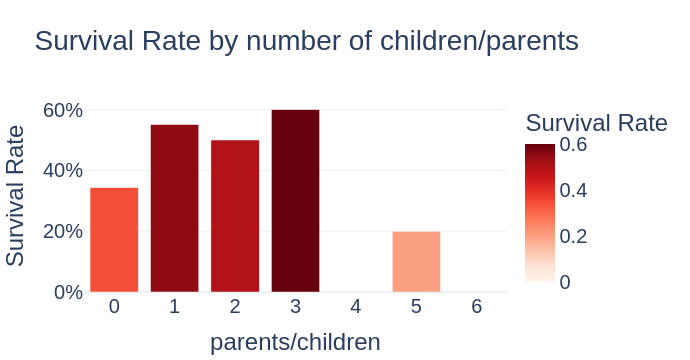
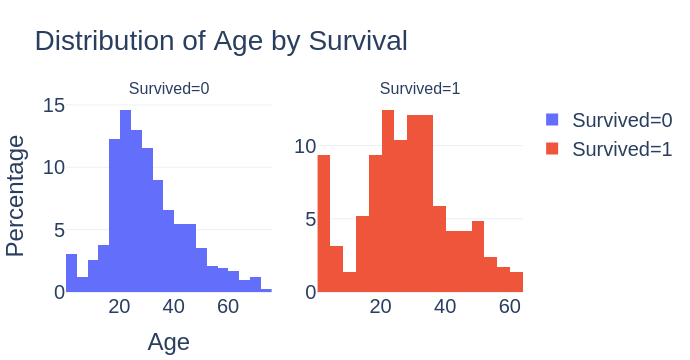


fig.show()



#### Based on the Age vs Survived Histograms:

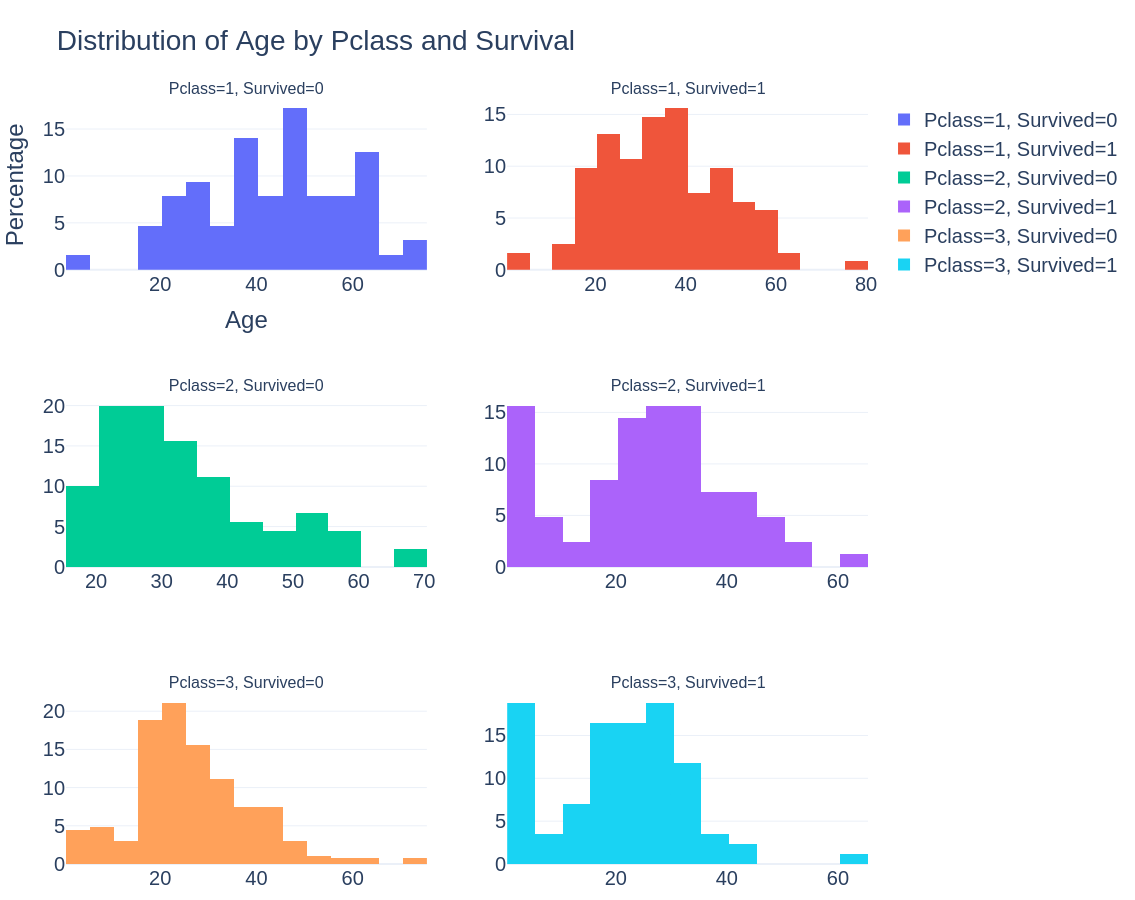
***Observations***

* Infants (Age <=4) had high survival rate.
* Large number of 15-25 year olds did not survive.
* Most passengers are in 15-35 age range.

***Decisions***

* We should consider Age (classifying #2) in our model training.
* Complete the Age feature for null values (completing #1).
* We should band age groups (engineering #3).

fig.show()



#### Based on the Pclass vs Survived Histograms:

***Observations***

* Pclass=3 had most passengers, however most did not survive. Confirms our classifying assumption #2.
* Oldest passengers (Age = 80) survived.
* Infant passengers in Pclass=2 and Pclass=3 mostly survived. Further qualifies our classifying assumption #2.
* Most passengers in Pclass=1 survived. Confirms our classifying assumption #3.
* Pclass varies in terms of Age distribution of passengers.

***Decisions***

* Consider Pclass for model training.

#### Based on the Pclass vs Survived vs Sex based on Embarked pointplots:

***Observations***

* Female passengers had much better survival rate than males. Confirms classifying (#1).
* Exception in Embarked=C where males had higher survival rate. This could be a correlation between Pclass and Embarked and in turn Pclass and Survived, not necessarily direct correlation between Embarked and Survived.
* Males had better survival rate in Pclass=3 when compared with Pclass=2 for C and Q ports. Completing (#2).
* Ports of embarkation have varying survival rates for Pclass=3 and among male passengers. Correlating (#1).

***Decisions***

* Add Sex feature to model training.
* Complete and add Embarked feature to model training.

#### Based on the Sex vs Fare vs Embarked vs Survived Barplots:

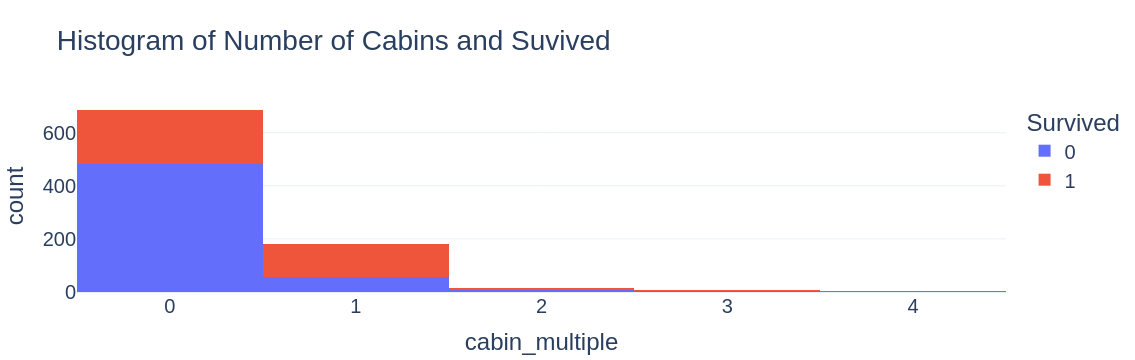
***Observations***

* Higher fare paying passengers had better survival. Confirms our assumption for creating (#4) fare ranges.
* Port of embarkation correlates with survival rates. Confirms correlating (#1) and completing (#2).

***Decisions***

* Consider banding Fare feature.

px.histogram(data\_frame= cabin\_divide, x="cabin\_multiple", color="Survived",title='Histogram of Number of Cabins and Suvived')



Create categories based on the cabin letter (n stands for null). In this case we will treat null values like it’s own category

pd.pivot\_table(cabin\_divide,index='Survived',

columns='cabin\_deck', values = 'Name',

aggfunc='count')

#### Based on the Cabins Pivot Tables:

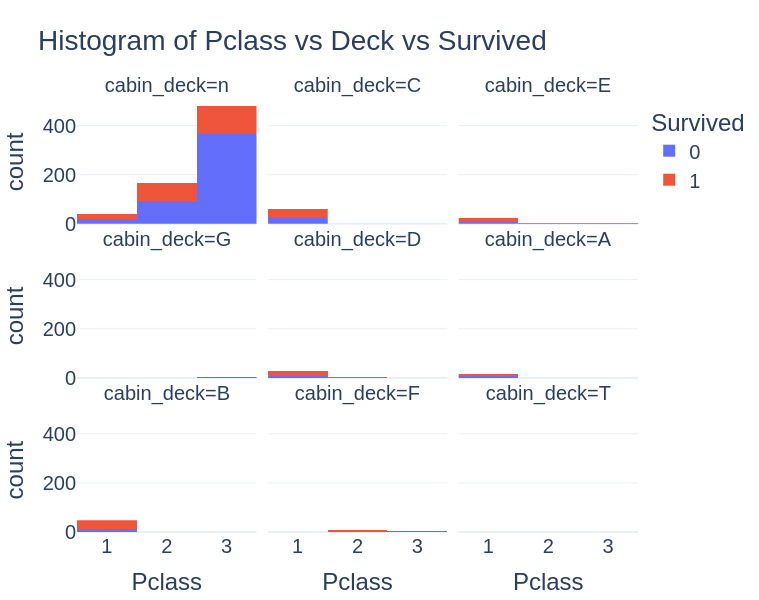
***Observations***

* Passengers with at least a Cabin listed to there ticket have a higher chance of surviving. Confirms engineering (#5)
* Cabin titles B,C,D,E and F have a higher chance of survival. Confirms engineering (#5) and debunks Filtering (#2)

***Decisions***

* Consider Seperating the cabin feature into only cabin letters.
* Consider creating a number of Cabins feature.

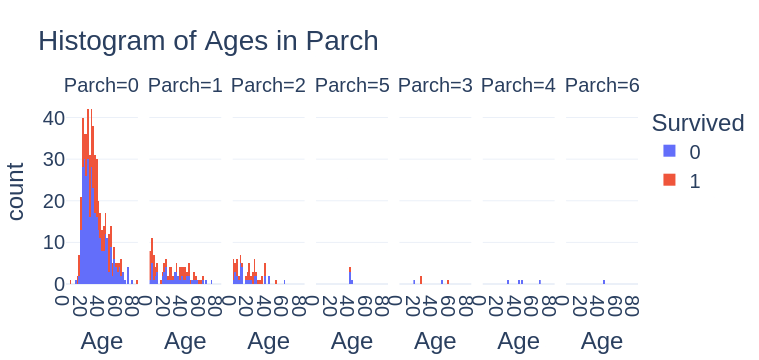
fig.show()



**Ages vs ParCh**

px.histogram(data\_frame= passenger\_df\_train, facet\_col="Parch",

x="Age", color="Survived",title='Histogram of Ages in Parch')



### Exploration with no regard to Survival

For the purpose of this exploration and feature engineering we will unite training and testing data. The advantage of this is that we can perform same transformations on both datasets at the same time.
Since test set has all NaNs in Survived, we will mark it with “-1”. This will later allow for splitting them back easily.  
During this exploration we will not touch “Survived” feature.

passenger\_df.loc[passenger\_df.Survived.isna(),"Survived"] = -1

passenger\_df.sample(10)

#### Cabin

passenger\_df["HasCabin"] = ~passenger\_df.Cabin.isnull() \*1

px.histogram(passenger\_df, x = "Pclass", color="HasCabin")

interesting\_passengers = [823, 831, 829, 828, 827, 826, 825, 822, 833,

584, 938, 600, 285, 24, 1266, 1185, 648,

1001, 129, 1180, 1213, 873, 1114, 67, 517, 346]

passenger\_df.loc[interesting\_passengers].sample(10)

Some cabins seem to not have splitted correctly. However, upon examining these cabins we can conclude that these are families occupying several cabins. Since the families occupies cabins very close to each other, our splitting is good enough. Those are only in 1st class.

#### Ticket/placement

Explore what we can find from ticket/ placement data.  
Columns involved:  
[“Fare”, “Cabin”, “Pclass”, “Embarked”, “Ticket”]

passenger\_df.drop("tPref tNum".split(" "),axis=1, inplace=True, errors='ignore')

rx = r'(?P<tPref>[A-Za-z/.\d]+\s(?:[A-Za-z.\d]+\s)?)?(?P<tNum>\d+)$'

tspl = passenger\_df.Ticket.str.extract(rx)

passenger\_df = passenger\_df.join(tspl)

Validate: all tickets got split correctly?

passenger\_df["tCheck"] = (passenger\_df['tPref']).fillna('') + "" +passenger\_df['tNum'].astype(str)

passenger\_df[passenger\_df['Ticket'] != passenger\_df["tCheck"]]

##### Analyzing ticket prefixes

q = """

Select tPref, count(Ticket) as tickets

from passenger\_df

group by tPref

order by tickets desc

limit 13

"""

ps.sqldf(q)

q = """

select Pclass, tPrefTr, tPref, count(\*) as cnt

from passenger\_df

group by Pclass, tPrefTr, tPref

order by Pclass, tPrefTr, cnt desc

limit 13

"""

ps.sqldf(q)

Unfortunately, I could not guess what most of these mean, and no clues was found on internet

##### Hypothesis: ticket number has meaning

During exploration I had an hipothesis that ticket number could somehow contain an encoding to placement of the passenger on the ship.
To explore this hypothesis, I created various plots of features that might be involved, such as:

* Ticket number
* Ticket prefix
* Fare
* Class
* Deck
* cabin number

Ticket numbers seem to be concentrated into several groups. Interet seems to suggest that these groups come from individual stores from which the tickets were purchased. The order inside group is probably the order in which the tickets were purchased, so probably not very relevant to current research.

For now I could not identify any interaction pattern of tickets numbers with other features.

Zooming down to only 2, 3 classes, I was wondering if cabin deck, number or side might somehow be “encoded” in Fare and ticket number. But the data is too sparse to make any judjement on that.

fig = px.scatter(passenger\_df, x = "tNum", y = "Fare", color="ClassDeck", facet\_col="HasCabin", \

color\_discrete\_sequence= px.colors.sequential.Rainbow, category\_orders=co ,

height=600, range\_x= [-10000, 4.1e5], range\_y=[-10,100]) #, facet\_col= "Survived")

fig

#### Age

passenger\_df[passenger\_df.Age.isna()].shape[0] / passenger\_df.shape[0]

0.20091673032849502

We see that about 20% of passengers have no age registered. Maybe it could be estimated from other features?

#### Name

There appears to be a lot of information that can be extracted from passengers names.  
First, let’s see what tokens beside names we can expect to see in this column

tokens.head(20)

tokens.loc[tokens.word.str.contains("\.", ),"count"].sum()/ passenger\_df.shape[0]

0.6814362108479756

We see that people titles have high token frequencies, suggesting that lots of people have them. Specifically, 68% of the people have them.  
Moreover, the Name column appears to have a very consistent structure:  
Last\_name, Title. First\_Name (Second\_Name)  
This allows to relatively easy split the Name column into its components.

passenger\_df.drop("lName Title fName sName".split(" "),axis=1, inplace=True, errors='ignore')

rx = r"^(?P<lName>[A-Za-z\s'-]+),\s(?P<Title>[A-Za-z\s]+)\.(?:\s(?P<fName>[A-Za-z\s\/\"]+))?(?:\s\((?P<sName>[A-Za-z\s\"'\.-]+)\).\*)?$"

nspl = passenger\_df.Name.str.extract(rx)

passenger\_df = passenger\_df.join(nspl)

cols = ['Pclass', 'Name', 'Sex', 'Age', 'lName', 'Title', 'fName', 'sName']

passenger\_df[cols].sample(10)

##### Title

q = """

select Title, count(\*) as cnt

from passenger\_df

group by Title

order by cnt desc

"""

ps.sqldf(q)

**Most titles are Mr, Mrs, Miss and Master. This may be used to estimate age where it’s unknown**

There are several military titles, as well as other relarted to person’s occupation. These can be joined into a single category Rare:

* Col, Major, Jonkeer, Capt.
* Rev is Reverend - a member of clergy
* Dr is Doctor

Some titles are the equivalent of Mr, Mrs... in other languages or alternative spelling:

* Ms, Mlle = Miss
* Mme = Mrs

Several people have a noble title. But since they are few, they can be joined into Mr, Mrs category.

* the Countess, Lady, Dona = Mrs
* Don, Sir = Mr

passenger\_df.loc[passenger\_df.Title.isin(["Col", "Major", "Jonkheer", "Capt", "Dr", "Rev"]),show].sort\_values("Age")

After the replacing we have just 5 categories in title:

q = """

select Title, count(\*) as cnt

from passenger\_df

group by Title

order by cnt desc

"""

ps.sqldf(q)

##### Second name

Let’s explore the second name:

passenger\_df.loc[~passenger\_df.sName.isna(),show].sample(10)

We perform a similar token analysis with these as before

names = passenger\_df.sName.astype(str).apply(func=spl).values.tolist()

words = sum(names,[])

unique, counts = np.unique(words, return\_counts=True)

wc = pd.DataFrame({"word":unique, "count": counts})

tokens = wc.sort\_values("count",ascending=False)

tokens.head(20)

passenger\_df.loc[passenger\_df.sName.astype(str).str.contains("Mr"),show]

Seems like majority of these contain full/maiden names of women travelling with ticket under their husbands’ names.  
Maybe this property could be used for Age estimation...

#### Family composition data

px.scatter(passenger\_df, x = "Age", y = "Parch", color="Title", hover\_data=["Fare"], \

category\_orders=co, height= 600 )

We clearly see that the titles Master and Miss, along with the amount of parents and siblings, can serve as a good indicator for people’s age

#### Some interaction variables

### Part 2 - Data Engineering + Encoding Categorical Values

### Data Imputation

As discussed in Exploration section, about 20% of passengers have no Are registered. We would like to impute the null values of Age with an estimation based on other variables.

But first, there is one person without Fare. We’ll just put a number manually there.

passenger\_df.loc[passenger\_df.Fare.isna(), "Fare"] = 7.2500

Prepare dataset for training and imputation

Cx = ["Fare", "Sex", "SibSp", "Parch", "Pclass", "Title"]

Cy = "Age"

categorical\_columns = ["Sex", "Title"]

# Convert categorical variables into dummy variables using one-hot encoding

X = pd.get\_dummies(passenger\_df[Cx], columns=categorical\_columns)

y = passenger\_df[Cy]

X.head(7)

Select rows with missing values for ‘Age’ in target. Those will be imputed

Ximp = X[y.isna()]

yimp = y[y.isna()]

Ximp.head(7)

Select rows with existing values for ‘Age’ in target. Those will be used to learn the pattern for imputation

X = X[~y.isna()]

y = y[~y.isna()]

X.head(7)

Train, validation, test split

#### Cross-validate ensemble models

This convenience function will be used for training, evaluation and summarization of various ML models.  
At this stage we will concentrate on ensemble family of models

Random Forest

#deleteme

rfr = RandomForestRegressor()

param\_grid ={'max\_depth': st.randint(6, 20),

'n\_estimators': st.randint(10, 500),

'max\_features': np.arange(5, 12),

'max\_leaf\_nodes': st.randint(6, 30)}

grid = model\_selection.RandomizedSearchCV(rfr,

param\_grid, cv=10,

verbose=1, n\_iter=iterations, n\_jobs=16 )

Run\_and\_Report(grid, X, y)

Fitting 10 folds for each of 2 candidates, totalling 20 fits

Elapsed Time: 00:00:01

====================

Best Score: 0.433

Best Parameters: {'max\_depth': 6, 'max\_features': 9, 'max\_leaf\_nodes': 27, 'n\_estimators': 334}

AdaBoost

abr = AdaBoostRegressor()

abr.get\_params()

param\_grid ={

'learning\_rate': st.randint(1, 10),

'n\_estimators': st.randint(10, 500),

}

grid = model\_selection.RandomizedSearchCV(abr,

param\_grid, cv=10,

verbose=1, n\_iter=iterations, n\_jobs=16 )

Run\_and\_Report(grid, X, y)

Fitting 10 folds for each of 2 candidates, totalling 20 fits

Elapsed Time: 00:00:00

====================

Best Score: 0.294

Best Parameters: {'learning\_rate': 3, 'n\_estimators': 173}

GradientBoosting

gbr = GradientBoostingRegressor()

param\_grid ={'max\_depth': st.randint(6, 20),

'n\_estimators': st.randint(10, 500),

'max\_features': np.arange(5,12),

'max\_leaf\_nodes': st.randint(6, 30)}

grid = model\_selection.RandomizedSearchCV(gbr,

param\_grid, cv=10,

verbose=1, n\_iter=iterations, n\_jobs=16 )

Run\_and\_Report(grid, X, y)

Fitting 10 folds for each of 2 candidates, totalling 20 fits

Elapsed Time: 00:00:00

====================

Best Score: 0.430

Best Parameters: {'max\_depth': 10, 'max\_features': 6, 'max\_leaf\_nodes': 8, 'n\_estimators': 149}

CV\_df = pd.DataFrame(CV\_Runs)

CV\_df[['elapsed', 'estimator', 'best\_params', 'train\_score',

'val\_score', 'cv', 'n\_iter']]

fig = px.scatter(CV\_df, x="timestamp", y="train\_score", color="estimator")

fig.show()

fig.add\_trace( go.Scatter(x=CV\_df["timestamp"], y=CV\_df["val\_score"], name="val\_score", )) #, fill=CV\_df["estimator"]))

fig.show()

#### Estimate missing ages

Based on the benchmarking results above, we decided to choose model 3 (GradientBoostingRegressor)

best\_params = {'max\_depth': 13, 'max\_features': 5, 'max\_leaf\_nodes': 29, 'n\_estimators': 435}

rfc = GradientBoostingRegressor( \*\*best\_params)

rfc.fit(X,y)

y\_hat = rfc.predict(Ximp)

y\_hat = pd.Series(rfc.predict(Ximp), index=Ximp.index)

y\_hat.head(7)

PassengerId

6 22.482209

18 32.216009

20 44.775079

27 27.427907

29 21.672006

30 27.910477

32 45.170013

dtype: float64

Impute the new predicted age values into original dataset and visually compare distributions of existing and estimated ages

px.histogram(passenger\_df, x="Age", facet\_col = "AgeEstimated")

px.scatter(passenger\_df, x = "Age", y = "Parch", color="Title", facet\_col= "AgeEstimated",

hover\_data=["SibSp", "Fare", "Name"],

category\_orders=co, height= 600)

It seems that imputation went quite well.

### Construct More features

# Gives the length of the name

passenger\_df['Words\_Count'] = passenger\_df['Name'].apply(lambda x: len(x.split()))

print(passenger\_df.Words\_Count.value\_counts())

Words\_Count

4 558

3 449

5 144

6 81

7 59

8 16

14 1

9 1

Name: count, dtype: int64

fig.show()

Create new features cabin\_multiple and cabin\_deck that shows number of cabins each passenger had.  
Create new feature FamilySize as a combination of SibSp and Parch  
Create new feature IsAlone from FamilySize

display(df1), display(df2)

(None, None)

Remove all NULLS in the Fare column and Create new feature CategoricalFare

df

Create a New feature CategoricalAge

df.head(8)

### Mapping Categorical and High Ordinal Features

passenger\_df.loc[:, ['Age\*Class', 'Age', 'Pclass']].head(10)

### Feature Selection

passenger\_df.head(10)

passenger\_df\_train = passenger\_df[passenger\_df.Survived != -1]

passenger\_df\_train.head(10)

passenger\_df\_test = passenger\_df[passenger\_df.Survived == -1].drop("Survived", axis=1)

passenger\_df\_test.head(10)

passenger\_df\_corr=passenger\_df\_train.astype(float).corr()

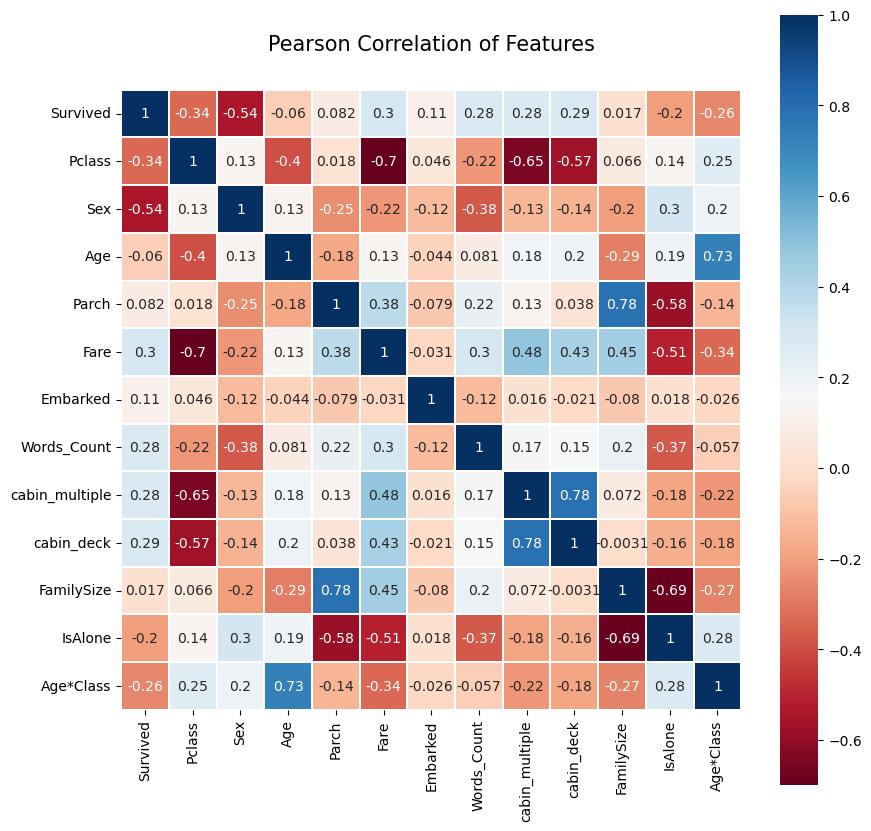
colormap=plt.cm.RdBu

plt.figure(figsize=(10,10))

plt.title('Pearson Correlation of Features', y=1.05, size=15)

sns.heatmap(passenger\_df\_corr,linewidths=0.1,vmax=1.0, square=True, cmap=colormap, linecolor='white', annot=True)

plt.show()



### Takeaway from the Heatmap

There aren’t many features strongly correlated with one another (highest is 0.78 between Parch and FamilySize and between the two cabin features. We’ll still leave both features.) This is good from a point of view of feeding these features into your learning model because there isn’t much redundant or superfluous data in our training set and we accept that each feature carries data with some unique information.

## Model Learning

### Splitting the passenger data 80/20

X = passenger\_df\_train.drop('Survived', axis=1)

y = passenger\_df\_train['Survived']

# Splitting data into train and validation sets

X\_train, X\_val, y\_train, y\_val = train\_test\_split(X, y, test\_size=0.2, random\_state=42)

### Model Functions

#### Train and Evaluate models

#### Visualize Results

#### Confusion Matrix for Best Model

### Classical models

Initialize models with Hyperparameters

# Define models

models = {

'Logistic Regression': LogisticRegression(),

'Random Forest': RandomForestClassifier(),

'SVM': SVC(),

#'Lasso': Lasso(),

#'Ridge': Ridge(),

'Gradient Boosting': GradientBoostingClassifier(),

'Decision Tree': DecisionTreeClassifier()

}

# Define hyperparameter grids for each model

param\_grids = {

'Logistic Regression': {'C': [0.001, 0.01, 0.1, 1, 10, 100]},

'Random Forest': {'n\_estimators': [10, 50, 100, 200, 500], 'max\_depth': [None, 10, 20, 30, 50]},

'SVM': {'C': [0.01, 0.1, 1, 10, 100], 'gamma': [0.01, 0.1, 1, 10, 100]},

'Gradient Boosting': {'n\_estimators': [10, 50, 100, 200, 500], 'learning\_rate': [0.001, 0.01, 0.1, 1]},

'Decision Tree': {'max\_depth': [None, 10, 20, 30, 50, 100]}

#'Lasso': {'alpha': [0.01, 0.1, 1]},

#'Ridge': {'alpha': [0.01, 0.1, 1]},

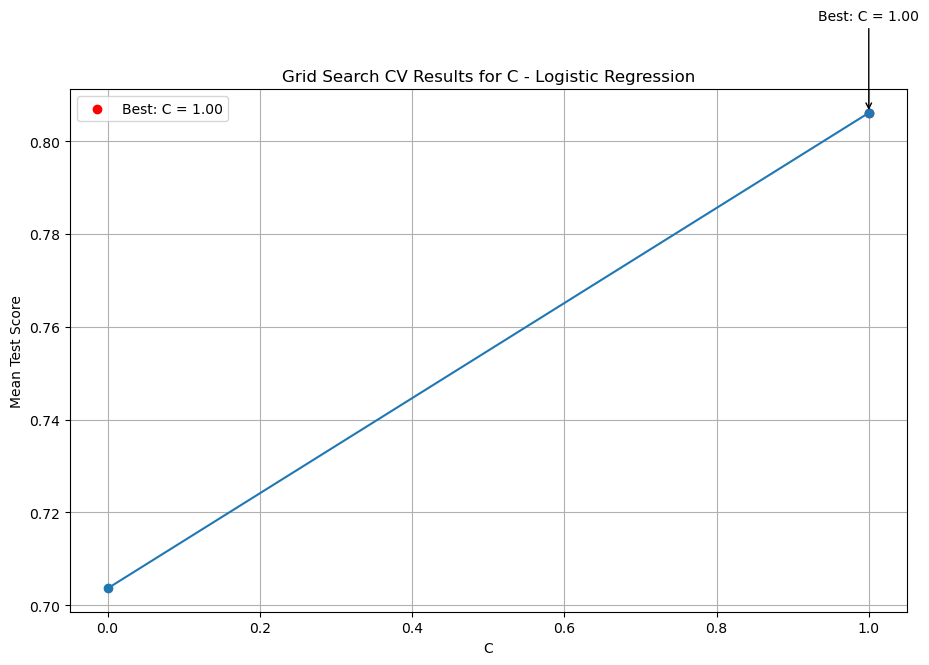
}

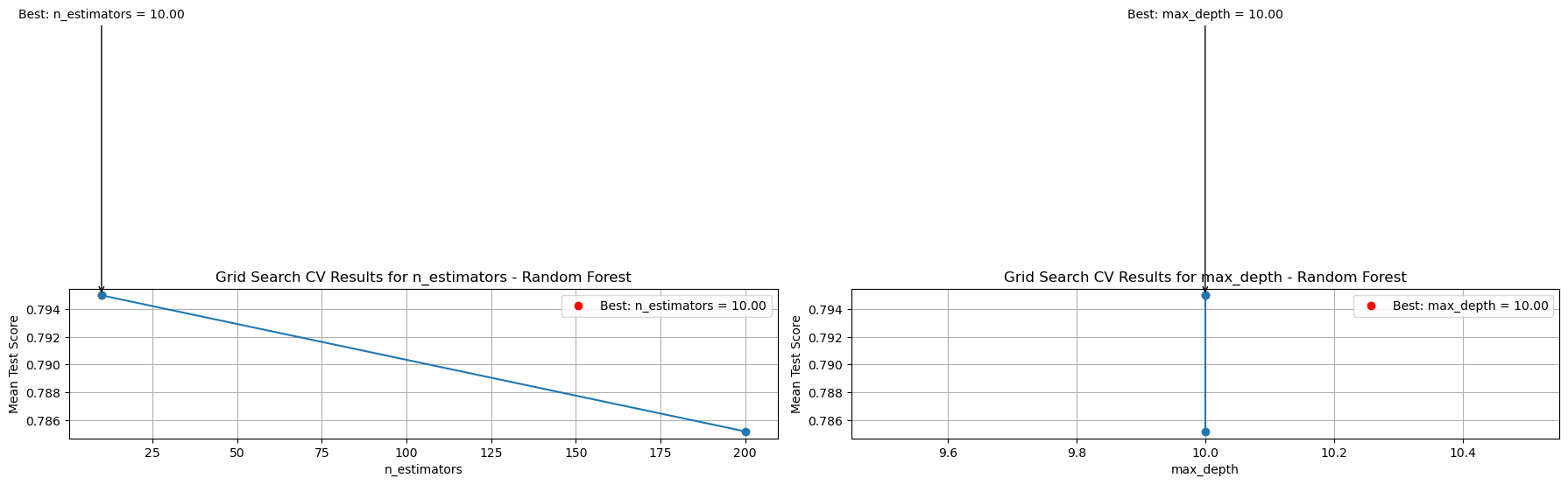
# Train and evaluate models

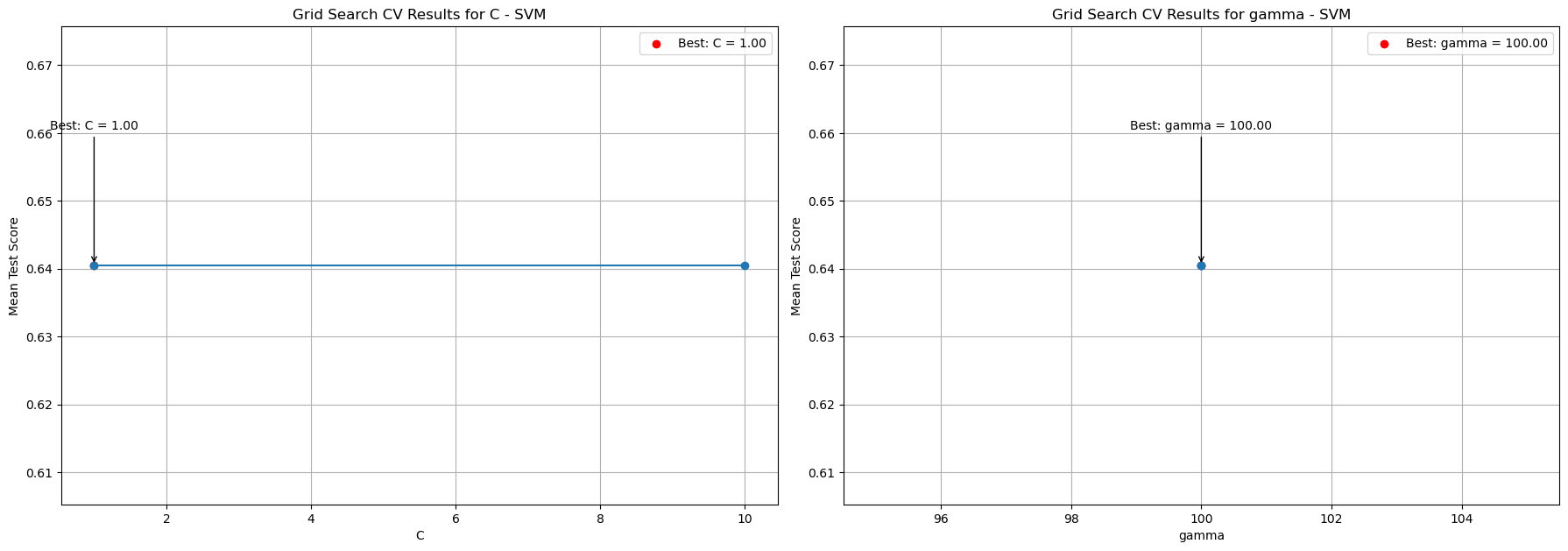
results, evaluation\_df = train\_and\_evaluate\_models(models, X\_train, y\_train, X\_val, y\_val,

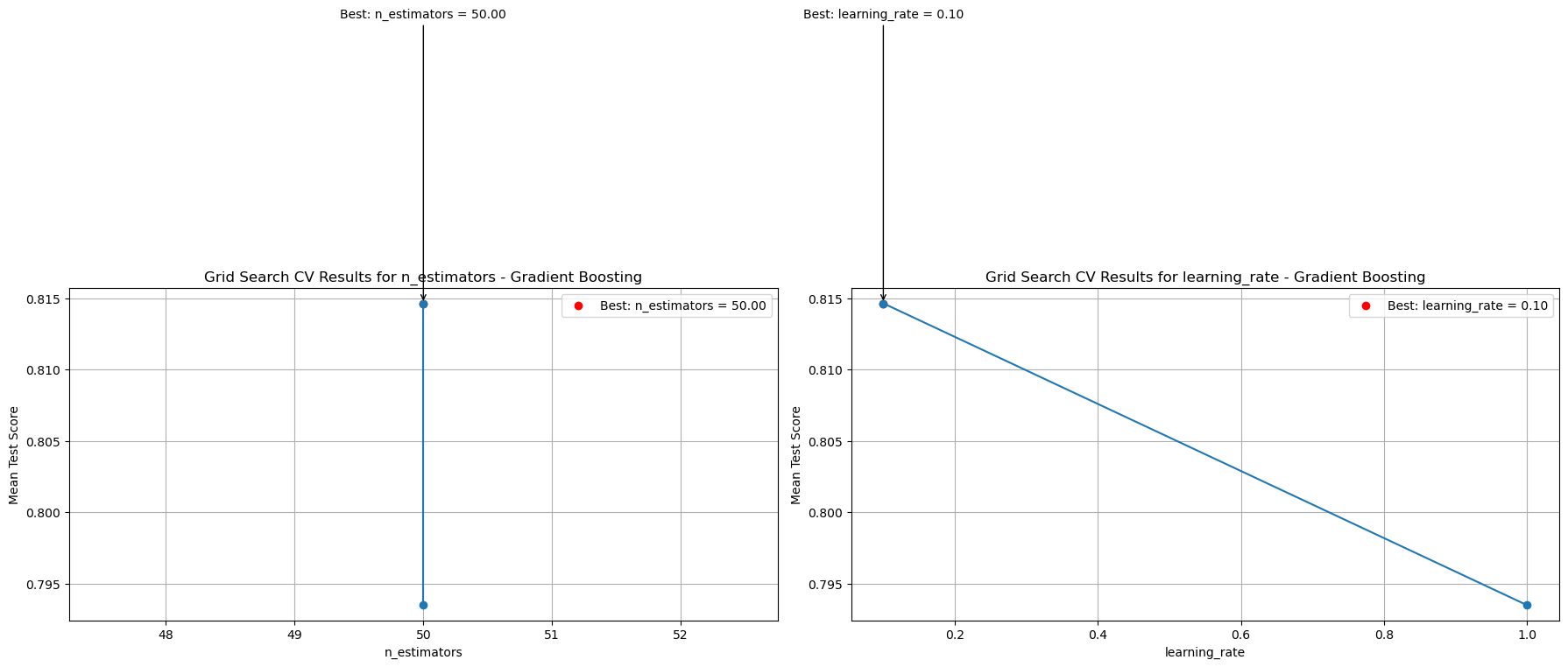
param\_grids, scoring='accuracy', cv=10)

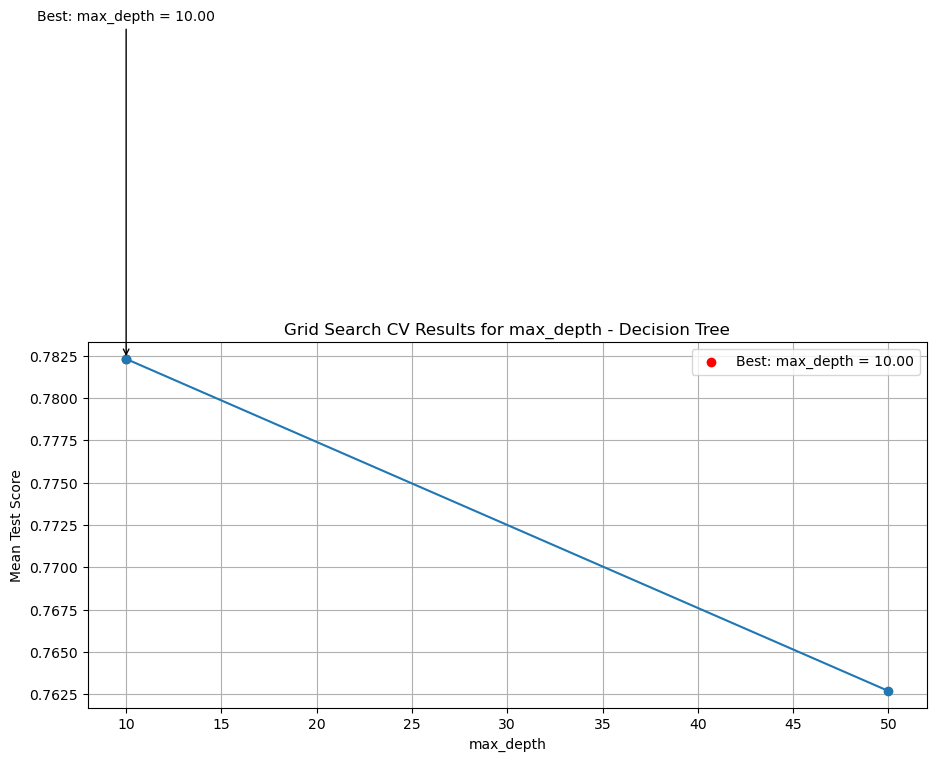
evaluation\_df











We can see that SVM gives us the best Validation score, meaning SVM works best with new Data.

best\_model\_row = evaluation\_df.loc[evaluation\_df['Validation Score'].idxmax()]

best\_model\_name = best\_model\_row['Model']

best\_validation\_score = best\_model\_row['Validation Score']

best\_model = models[best\_model\_name]

print("Best Model: ", best\_model\_name)

print("Best Validation Score: {:.4f}" .format(best\_validation\_score))

best\_model

Best Model: Gradient Boosting

Best Validation Score: 0.8324

evaluate\_best\_model(best\_model, X\_train, y\_train, X\_val, y\_val)

---------------------------------------------------------------------------

AttributeError Traceback (most recent call last)

Cell In[159], line 1

----> 1 evaluate\_best\_model(best\_model, X\_train, y\_train, X\_val, y\_val)

Cell In[155], line 22, in evaluate\_best\_model(best\_model, X\_train, y\_train, X\_val, y\_val)

18 plt.subplot(1, 2, 1)

19 sns.heatmap(conf\_matrix, annot=True, fmt="d", cmap="Greens", cbar=False,

20 xticklabels=['Predicted Negative', 'Predicted Positive'],

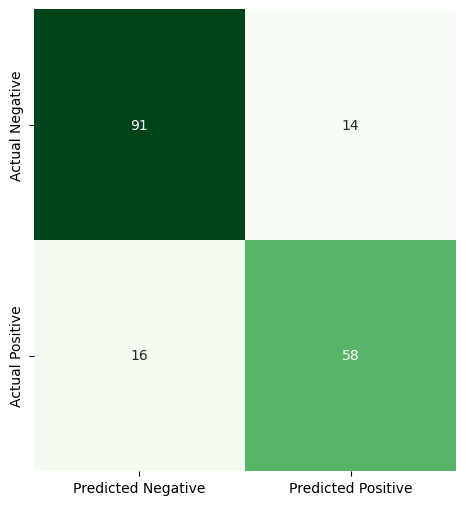
21 yticklabels=['Actual Negative', 'Actual Positive'])

---> 22 plt.title(f"Confusion Matrix for {str(best\_model.estimator)} model")

23 plt.xlabel("Predicted label")

24 plt.ylabel("True label")

AttributeError: 'GradientBoostingClassifier' object has no attribute 'estimator'



### Lasso and Ridge Regularization

# Creating a Lasso Regularization model

lasso\_model = Lasso(alpha=0.1)

# Creating a Ridge Regularization model

ridge\_model = Ridge(alpha=0.1)

# Cross-validation to plot the cost function

alphas = np.logspace(-4, 4, 100) # Range of alpha values for cross-validation

scores\_lasso = []

scores\_ridge = []

#### 10-fold Cross Validation using initial Hyper Parameters

In order to tune Performance in every model, we’ll have multiple values of the hyper paramaters and find the values that give us the best cross validation score, which in this case is accuracy scores:

for alpha in alphas:

lasso\_model.alpha = alpha

cv\_scores\_lasso = cross\_val\_score(lasso\_model, X\_train, y\_train, cv=10) # 10-fold cross-validation

scores\_lasso.append(np.mean(cv\_scores\_lasso))

ridge\_model.alpha = alpha

cv\_scores\_ridge = cross\_val\_score(ridge\_model, X\_train, y\_train, cv=10) # 10-fold cross-validation

scores\_ridge.append(np.mean(cv\_scores\_ridge))

# Finding the best alpha value

best\_alpha\_lasso = alphas[np.argmax(scores\_lasso)]

best\_alpha\_ridge = alphas[np.argmax(scores\_ridge)]

# Create subplots

fig, axs = plt.subplots(2, 1, figsize=(10, 12))

# Plotting the cost function for Lasso Regularization

axs[0].plot(alphas, scores\_lasso, '-o')

axs[0].set\_xlabel('Alpha')

axs[0].set\_ylabel('Cross-Validation Score')

axs[0].set\_title('Lasso Regularization Cost Function (log)')

axs[0].set\_xscale('log')

axs[0].grid(True)

# Highlighting the best alpha value for Lasso Regularization

axs[0].axvline(x=best\_alpha\_lasso, color='r', linestyle='--', label='Best Alpha: {:.2e}'.format(best\_alpha\_lasso))

axs[0].legend()

# Plotting the cost function for another model (assuming you have another set of data)

axs[1].plot(alphas, scores\_ridge, '-o') # Replace scores\_another\_model with your actual scores

axs[1].set\_xlabel('Alpha')

axs[1].set\_ylabel('Cross-Validation Score')

axs[1].set\_title('Ridge Regularization Cost Function (log)')

axs[1].set\_xscale('log')

axs[1].grid(True)

# Highlighting the best alpha value for the another model

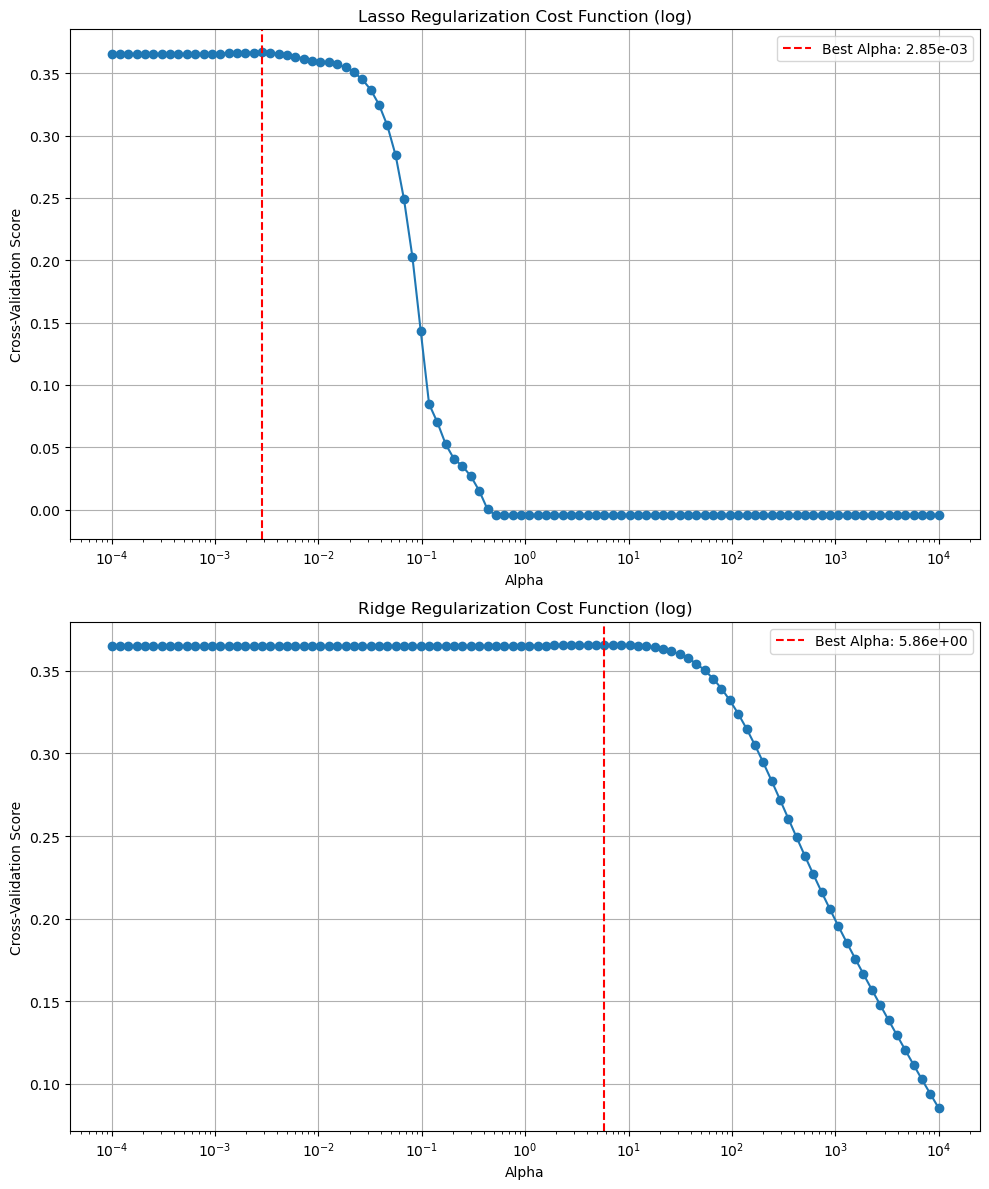
axs[1].axvline(x=best\_alpha\_ridge, color='r', linestyle='--', label='Best Alpha: {:.2e}'.format(best\_alpha\_ridge))

axs[1].legend()

# Adjust layout

plt.tight\_layout()

plt.show()



After tuning, we fit the hyperparameters into the model and fit the trained data to this model:

# Training the model with the best alpha

lasso\_model.alpha = best\_alpha\_lasso

lasso\_model.fit(X\_train, y\_train)

# Training the model with the best alpha

ridge\_model.alpha = best\_alpha\_ridge

ridge\_model.fit(X\_train, y\_train)

# Predictions on train and validation data

train\_predictions\_lasso = lasso\_model.predict(X\_train)

train\_predictions\_ridge = ridge\_model.predict(X\_train)

val\_predictions\_lasso = lasso\_model.predict(X\_val)

val\_predictions\_ridge = ridge\_model.predict(X\_val)

# Accuracy metrics

train\_accuracy\_lasso = accuracy\_score(y\_train, np.round(train\_predictions\_lasso))

train\_accuracy\_ridge = accuracy\_score(y\_train, np.round(train\_predictions\_ridge)) # Round predictions to 0 or 1 for binary classification

val\_accuracy\_lasso = accuracy\_score(y\_val, np.round(val\_predictions\_lasso))

val\_accuracy\_ridge = accuracy\_score(y\_val, np.round(val\_predictions\_ridge))

print("Train Accuracy: \nLasso - {:.4f}" .format(train\_accuracy\_lasso) ,"\nRidge - {:.4f} \n" .format(train\_accuracy\_ridge))

print("Validation Accuracy: \nLasso - {:.4f}" .format(val\_accuracy\_lasso) ,"\nRidge - {:.4f} " .format(val\_accuracy\_ridge))

Train Accuracy:

Lasso - 0.7978

Ridge - 0.8020

Validation Accuracy:

Lasso - 0.7989

Ridge - 0.7933

# Confusion matrix for Lasso model

conf\_matrix\_lasso = confusion\_matrix(y\_val, np.round(val\_predictions\_lasso))

# Confusion matrix for Ridge model

conf\_matrix\_ridge = confusion\_matrix(y\_val, np.round(val\_predictions\_ridge))

# Calculate precision, recall, and F1-score for Lasso Model

precision\_lasso = precision\_score(y\_val, np.round(val\_predictions\_lasso))

recall\_lasso = recall\_score(y\_val, np.round(val\_predictions\_lasso))

f1\_lasso = f1\_score(y\_val, np.round(val\_predictions\_lasso))

# Calculate precision, recall, and F1-score for Ridge Model

precision\_ridge = precision\_score(y\_val, np.round(val\_predictions\_ridge))

recall\_ridge = recall\_score(y\_val, np.round(val\_predictions\_ridge))

f1\_ridge = f1\_score(y\_val, np.round(val\_predictions\_ridge))

# Plot confusion matrix with additional metrics for Lasso Model

plt.figure(figsize=(12, 6))

plt.subplot(1, 2, 1)

sns.heatmap(conf\_matrix\_lasso, annot=True, fmt="d", cmap="Blues", cbar=False,

xticklabels=['Predicted Negative', 'Predicted Positive'],

yticklabels=['Actual Negative', 'Actual Positive'])

plt.title("Confusion Matrix - Lasso Model")

plt.xlabel("Predicted label")

plt.ylabel("True label")

plt.text(0.5, 1.1, f"Precision: {precision\_lasso:.3f}\nRecall: {recall\_lasso:.3f}\nF1-score: {f1\_lasso:.3f}",

horizontalalignment='center', verticalalignment='center', transform=plt.gca().transAxes)

# Plot confusion matrix with additional metrics for Ridge Model

plt.subplot(1, 2, 2)

sns.heatmap(conf\_matrix\_ridge, annot=True, fmt="d", cmap="Blues", cbar=False,

xticklabels=['Predicted Negative', 'Predicted Positive'],

yticklabels=['Actual Negative', 'Actual Positive'])

plt.title("Confusion Matrix - Ridge Model")

plt.xlabel("Predicted label")

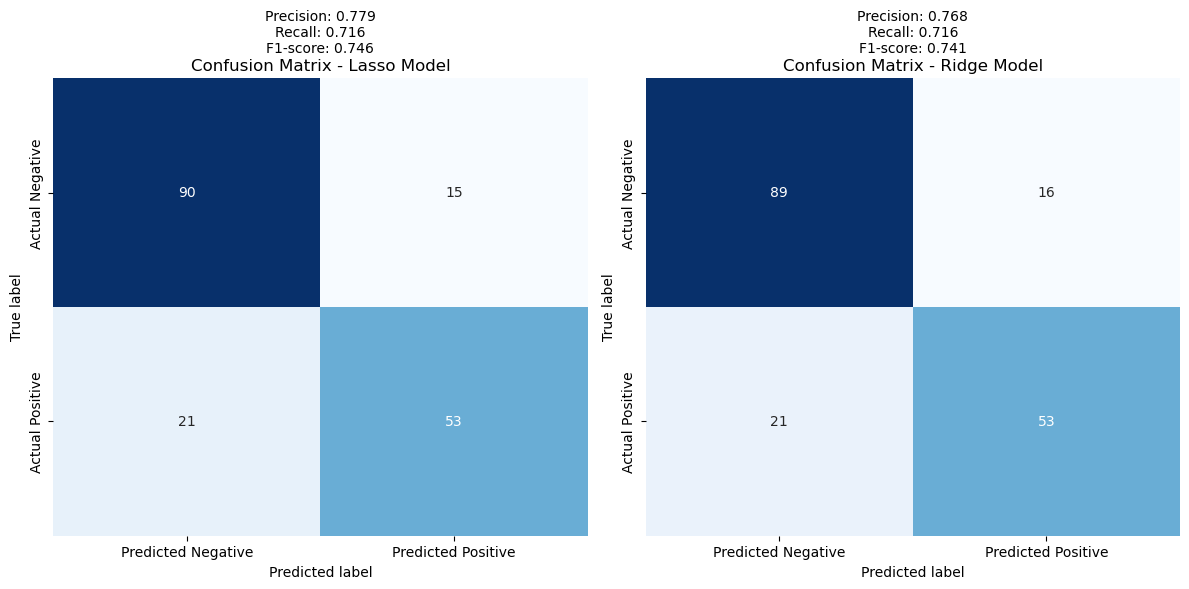
plt.ylabel("True label")

plt.text(0.5, 1.1, f"Precision: {precision\_ridge:.3f}\nRecall: {recall\_ridge:.3f}\nF1-score: {f1\_ridge:.3f}",

horizontalalignment='center', verticalalignment='center', transform=plt.gca().transAxes)

plt.tight\_layout()

plt.show()



### Gradient Boosting

Tuning Boosting Hyperparameters using Grid search 10-fold Cross Validation:

# Define hyperparameters grid

param\_grid = {

'n\_estimators': [50, 100, 150],

'learning\_rate': [0.01, 0.1, 0.2],

'max\_depth': [3, 5, 7]

}

# Create a Gradient Boosting Classifier

gb\_classifier = GradientBoostingClassifier(random\_state=42)

models = {'GB\_classifier': gb\_classifier}

param\_grids = {'GB\_classifier': param\_grid}

train\_and\_evaluate\_models(models, X\_train, y\_train, X\_val, y\_val, param\_grids, scoring='accuracy', cv=10)

# # Perform GridSearchCV to find the best hyperparameters

# grid\_search = model\_selection.RandomizedSearchCV( n\_iter= iterations,

# estimator=gb\_classifier, param\_distributions=param\_grid, cv=10, scoring='accuracy')

# grid\_search.fit(X\_train, y\_train)

# # Get the best hyperparameters

# best\_params = grid\_search.best\_params\_

# # Create a new Gradient Boosting Classifier with the best hyperparameters

# best\_gb\_classifier = GradientBoostingClassifier(\*\*best\_params, random\_state=42)

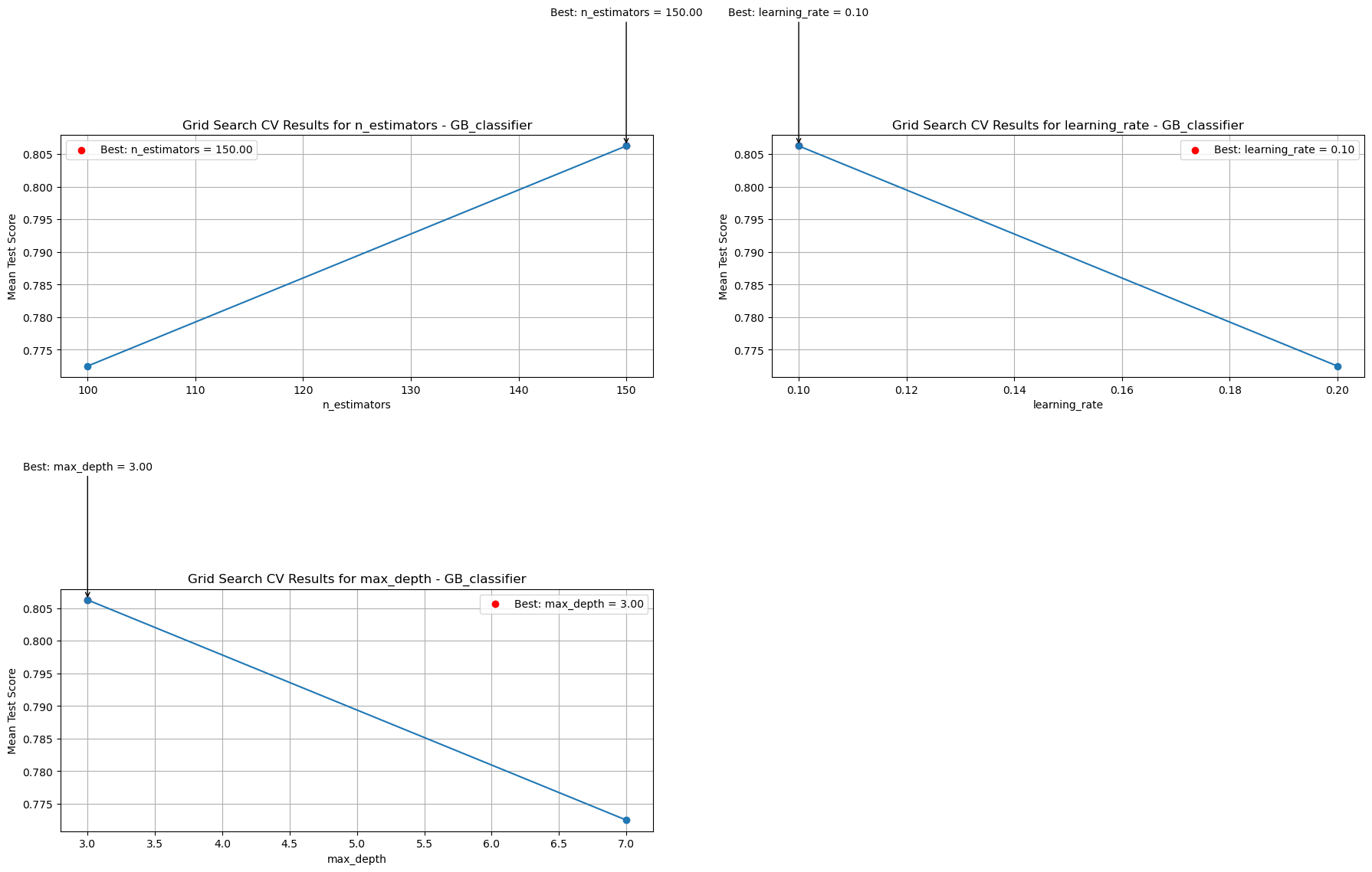
# best\_gb\_classifier.fit(X\_train, y\_train)

# # Plotting the cost function

# results = grid\_search.cv\_results\_

# scores = results['mean\_test\_score']

# params = results['params']



({'GB\_classifier': {'best\_params': {'n\_estimators': 150,

'max\_depth': 3,

'learning\_rate': 0.1},

'best\_score': 0.8062597809076681,

'validation\_score': 0.8156424581005587}},

Model Best Parameters \

0 GB\_classifier {'n\_estimators': 150, 'max\_depth': 3, 'learnin...

Best Score (CV) Validation Score

0 0.80626 0.815642 )

#### Results and Fitting model:

# plt.figure(figsize=(18, 12))

# for i, param\_name in enumerate(param\_grid.keys()):

# plt.subplot(2, 2, i + 1)

# param\_values = [param[param\_name] for param in params]

# plt.plot(param\_values, scores, marker='o')

# plt.xlabel(param\_name)

# plt.ylabel('Mean Test Score')

# plt.title('Grid Search CV Results for {}'.format(param\_name))

# plt.grid(True)

# # Marking the best parameter value

# best\_value = best\_params[param\_name]

# best\_score = grid\_search.best\_score\_

# plt.scatter(best\_value, best\_score, color='red', label='Best: {} = {:.2f}'.format(param\_name, best\_value))

# plt.annotate('Best: {} = {:.2f}'.format(param\_name, best\_value), xy=(best\_value, best\_score), xytext=(best\_value, best\_score + 0.02),

# arrowprops=dict(facecolor='black', arrowstyle='->'), horizontalalignment='center')

# plt.legend()

# plt.tight\_layout()

# plt.show()

visualize\_grid\_search\_results(param\_grid, params, scores, best\_params, best\_score, title='')

# Print the best hyperparameters

print("Best Hyperparameters:", best\_params)

# Predictions on validation data

train\_predictions = best\_gb\_classifier.predict(X\_train)

# Predictions on validation data

val\_predictions = best\_gb\_classifier.predict(X\_val)

# Accuracy metrics

train\_accuracy = accuracy\_score(y\_train, np.round(train\_predictions))

val\_accuracy = accuracy\_score(y\_val, np.round(val\_predictions))

print("Train Accuracy: {:.4f}" .format(train\_accuracy))

print("Validation Accuracy: {:.4f}" .format(val\_accuracy))

---------------------------------------------------------------------------

NameError Traceback (most recent call last)

Cell In[166], line 24

1 # plt.figure(figsize=(18, 12))

2

3 # for i, param\_name in enumerate(param\_grid.keys()):

(...)

20 # plt.tight\_layout()

21 # plt.show()

---> 24 visualize\_grid\_search\_results(param\_grid, params, scores, best\_params, best\_score,title='')

27 # Print the best hyperparameters

28 print("Best Hyperparameters:", best\_params)

NameError: name 'params' is not defined

evaluate\_best\_model(best\_model, X\_train, y\_train, X\_val, y\_val)

# # Confusion matrix for Gradient Boosting Model

# conf\_matrix = confusion\_matrix(y\_val, np.round(val\_predictions))

# # Calculate precision, recall, and F1-score for Gradient Boosting Model

# precision\_gb = precision\_score(y\_val, np.round(val\_predictions))

# recall\_gb = recall\_score(y\_val, np.round(val\_predictions))

# f1\_gb = f1\_score(y\_val, np.round(val\_predictions))

# # Plot confusion matrix with additional metrics for Gradient Boosting Model

# plt.figure(figsize=(12, 6))

# plt.subplot(1, 2, 1)

# sns.heatmap(conf\_matrix, annot=True, fmt="d", cmap="Greens", cbar=False,

# xticklabels=['Predicted Negative', 'Predicted Positive'],

# yticklabels=['Actual Negative', 'Actual Positive'])

# plt.title("Confusion Matrix - Gradient Boosting Model")

# plt.xlabel("Predicted label")

# plt.ylabel("True label")

# plt.text(0.5, 1.15, f"Precision: {precision\_gb:.2f}\nRecall: {recall\_gb:.2f}\nF1-score: {f1\_gb:.2f}",

# horizontalalignment='center', verticalalignment='center', transform=plt.gca().transAxes)

# plt.tight\_layout()

# plt.show()

### SVM

plt.show()

And the best hyperparameters are:

print("Best Hyperparameters:", best\_params)

print("Train Accuracy: {:.4f}" .format(train\_accuracy))

print("Validation Accuracy: {:.4f}" .format(val\_accuracy))

\*we added more variety of values in the parameters, but it took longer with no impact to the accuracy, so we stayed with these values.

plt.show()

## Test input data for submission

passenger\_df\_test = passenger\_df[passenger\_df.Survived == -1].drop("Survived", axis=1)

passenger\_df\_test.head(10)

predictions = best\_model.predict(passenger\_df\_test)

#predictions = best\_svm\_classifier.predict(passenger\_df\_test)

#predictions = best\_gb\_classifier.predict(passenger\_df\_test)

#predictions = lasso\_model.predict(passenger\_df\_test)

#predictions = ridge\_model.predict(passenger\_df\_test)

predictions = predictions.astype(int)

# Convert predictions into binary output

#binary\_predictions = (predictions >= 0.5).astype(int)

output = pd.DataFrame({'PassengerId': passenger\_df\_test.index, 'Survived': predictions})

#output = pd.DataFrame({'PassengerId': passenger\_df\_test.index, 'Survived': binary\_predictions})

output.to\_csv('submission.csv', index=False)

print("Your submission was successfully saved!")

output.sample(10)