Chapter 3 - Regression Models

Segment 3 - Logistic regression

In [5]:
```python
import numpy as np
import pandas as pd
import seaborn as sb
import matplotlib.pyplot as plt
import sklearn

from pandas import Series, DataFrame
from pylab import rcParams
from sklearn import preprocessing
```

In [6]:
```python
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
from sklearn.model_selection import cross_val_predict

from sklearn import metrics
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
from sklearn.metrics import precision_score, recall_score
```

In [7]:
```python
%matplotlib inline
rcParams['figure.figsize'] = 5, 4
sb.set_style('whitegrid')
```

Logistic regression on the titanic dataset

In [8]:
```python
titanic_training = pd.read_csv('titanic-training-data.csv')
titanic_training.columns = ['PassengerId', 'Survived', 'Pclass', 'Name', 'Sex', 'Age', 'SibSp', 'Parch', 'Ticke
print(titanic_training.head())
```

```
   PassengerId  Survived  Pclass  \
0            1         0       3
1            2         1       1
2            3         1       3
3            4         1       1
4            5         0       3

                                                Name     Sex   Age  SibSp  \
0                            Braund, Mr. Owen Harris    male  22.0      1
1  Cumings, Mrs. John Bradley (Florence Briggs Th...  female  38.0      1
2                             Heikkinen, Miss. Laina  female  26.0      0
3       Futrelle, Mrs. Jacques Heath (Lily May Peel)  female  35.0      1
4                           Allen, Mr. William Henry    male  35.0      0

   Parch            Ticket     Fare Cabin Embarked
0      0         A/5 21171   7.2500   NaN        S
1      0          PC 17599  71.2833   C85        C
2      0  STON/O2. 3101282   7.9250   NaN        S
3      0            113803  53.1000  C123        S
4      0            373450   8.0500   NaN        S
```

In [9]:
```python
titanic_training.head()
```

Out[9]:

	PassengerId	Survived	Pclass	Name	Sex	Age	SibSp	Parch	Ticket	Fare	Cabin	Embarked
0	1	0	3	Braund, Mr. Owen Harris	male	22.0	1	0	A/5 21171	7.2500	NaN	S
1	2	1	1	Cumings, Mrs. John Bradley (Florence Briggs Th...	female	38.0	1	0	PC 17599	71.2833	C85	C
2	3	1	3	Heikkinen, Miss. Laina	female	26.0	0	0	STON/O2. 3101282	7.9250	NaN	S
3	4	1	1	Futrelle, Mrs. Jacques Heath (Lily May Peel)	female	35.0	1	0	113803	53.1000	C123	S
4	5	0	3	Allen, Mr. William Henry	male	35.0	0	0	373450	8.0500	NaN	S

In [10]:
```python
print(titanic_training.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 891 entries, 0 to 890
Data columns (total 12 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   PassengerId  891 non-null    int64
 1   Survived     891 non-null    int64
 2   Pclass       891 non-null    int64
 3   Name         891 non-null    object
 4   Sex          891 non-null    object
 5   Age          714 non-null    float64
 6   SibSp        891 non-null    int64
 7   Parch        891 non-null    int64
 8   Ticket       891 non-null    object
 9   Fare         891 non-null    float64
 10  Cabin        204 non-null    object
 11  Embarked     889 non-null    object
dtypes: float64(2), int64(5), object(5)
memory usage: 83.7+ KB
None
```

VARIABLE DESCRIPTIONS

Survived - Survival (0 = No; 1 = Yes)

Pclass - Passenger Class (1 = 1st; 2 = 2nd; 3 = 3rd)

Name - Name

Sex - Sex

Age - Age

SibSp - Number of Siblings/Spouses Aboard

Parch - Number of Parents/Children Aboard

Ticket - Ticket Number

Fare - Passenger Fare (British pound)

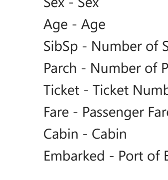
Cabin - Cabin

Embarked - Port of Embarkation (C = Cherbourg, France; Q = Queenstown, UK; S = Southampton - Cobh, Ireland)

Checking that your target variable is binary

In [11]:
```python
sb.countplot(x='Survived', data=titanic_training, palette='hls')
```

Out[11]: <AxesSubplot:xlabel='Survived', ylabel='count'>



Checking for missing values

In [12]:
```python
titanic_training.isnull().sum()
```

Out[12]:
```
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
```

In [13]:
```python
titanic_training.describe()
```

Out[13]:

	PassengerId	Survived	Pclass	Age	SibSp	Parch	Fare
count	891.000000	891.000000	891.000000	714.000000	891.000000	891.000000	891.000000
mean	446.000000	0.383838	2.308642	29.699118	0.523008	0.381594	32.204208
std	257.353842	0.486592	0.836071	14.526497	1.102743	0.806057	49.693429
min	1.000000	0.000000	1.000000	0.420000	0.000000	0.000000	0.000000
25%	223.500000	0.000000	2.000000	20.125000	0.000000	0.000000	7.910400
50%	446.000000	0.000000	3.000000	28.000000	0.000000	0.000000	14.454200
75%	668.500000	1.000000	3.000000	38.000000	1.000000	0.000000	31.000000
max	891.000000	1.000000	3.000000	80.000000	8.000000	6.000000	512.329200

Taking care of missing values

Dropping missing values

So let's just go ahead and drop all the variables that aren't relevant for predicting survival. We should at least keep the following:

- Survived - This variable is obviously relevant.
- Pclass - Does a passenger's class on the boat affect their survivability?
- Sex - Could a passenger's gender impact their survival rate?
- Age - Does a person's age impact their survival rate?
- SibSp - Does the number of relatives on the boat (that are siblings or a spouse) affect a person survivability? Probability
- Parch - Does the number of relatives on the boat (that are children or parents) affect a person survivability? Probability
- Fare - Does the fare a person paid effect his survivability? Maybe - let's keep it.
- Embarked - Does a person's point of embarkation matter? It depends on how the boat was filled... Let's keep it.

What about a person's name, ticket number, and passenger ID number? They're irrelavant for predicting survivability. And as you recall, the cabin variable is almost all missing values, so we can just drop all of these.

In [14]:
```python
titanic_data = titanic_training.drop(['Name', 'Ticket', 'Cabin'], axis=1)
titanic_data.head()
```

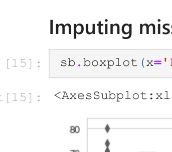
Out[14]:

	PassengerId	Survived	Pclass	Sex	Age	SibSp	Parch	Fare	Embarked
0	1	0	3	male	22.0	1	0	7.2500	S
1	2	1	1	female	38.0	1	0	71.2833	C
2	3	1	3	female	26.0	0	0	7.9250	S
3	4	1	1	female	35.0	1	0	53.1000	S
4	5	0	3	male	35.0	0	0	8.0500	S

Imputing missing values

In [15]:
```python
sb.boxplot(x='Parch', y='Age', data=titanic_data, palette='hls')
```

Out[15]: <AxesSubplot:xlabel='Parch', ylabel='Age'>



In [16]:
```python
Parch_groups = titanic_data.groupby(titanic_data['Parch'])
Parch_groups.mean()
```

Out[16]:

	PassengerId	Survived	Pclass	Age	SibSp	Fare
Parch						
0	445.255162	0.343658	2.321534	32.178503	0.237463	25.586774
1	465.110169	0.550847	2.203390	24.422000	1.084746	46.778180
2	416.662500	0.500000	2.275000	17.216912	2.062500	64.337604
3	579.200000	0.600000	2.600000	33.200000	1.000000	25.951660
4	384.000000	0.000000	2.500000	44.500000	0.750000	84.968750
5	435.200000	0.200000	3.000000	39.200000	0.600000	32.550000
6	679.000000	0.000000	3.000000	43.000000	1.000000	46.900000

In [17]:
```python
def age_approx(cols):
    Age = cols[0]
    Parch = cols[1]

    if pd.isnull(Age):
        if Parch == 0:
            return 32
        elif Parch == 1:
            return 24
        elif Parch == 2:
            return 17
        elif Parch == 3:
            return 33
        elif Parch == 4:
            return 45
        else:
            return 30

    else:
        return Age
```

In [18]:
```python
titanic_data['Age']= titanic_data[['Age', 'Parch']].apply(age_approx, axis=1)
titanic_data.isnull().sum()
```

Out[18]:
```
PassengerId    0
Survived       0
Pclass         0
Sex            0
Age            0
SibSp          0
Parch          0
Fare           0
Embarked       2
dtype: int64
```

In [19]:
```python
# DROPPING Two missing row with missing values and reset index
```

In [20]:
```python
titanic_data.dropna(inplace=True)
titanic_data.reset_index(inplace=True, drop=True)

print(titanic_data.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 889 entries, 0 to 888
Data columns (total 9 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   PassengerId  889 non-null    int64
 1   Survived     889 non-null    int64
 2   Pclass       889 non-null    int64
 3   Sex          889 non-null    object
 4   Age          889 non-null    float64
 5   SibSp        889 non-null    int64
 6   Parch        889 non-null    int64
 7   Fare         889 non-null    float64
 8   Embarked     889 non-null    object
dtypes: float64(2), int64(5), object(2)
memory usage: 62.6+ KB
None
```

Converting categorical variables to a dummy indicators

In [21]:
```python
from sklearn.preprocessing import LabelEncoder
label_encoder = LabelEncoder()
gender_cat = titanic_data['Sex']
gender_encoded = label_encoder.fit_transform(gender_cat)
gender_encoded[0:5]
```

Out[21]: `array([1, 0, 0, 0, 1])`

In [22]:
```python
titanic_data.head()
```

Out[22]:

	PassengerId	Survived	Pclass	Sex	Age	SibSp	Parch	Fare	Embarked
0	1	0	3	male	22.0	1	0	7.2500	S
1	2	1	1	female	38.0	1	0	71.2833	C
2	3	1	3	female	26.0	0	0	7.9250	S
3	4	1	1	female	35.0	1	0	53.1000	S
4	5	0	3	male	35.0	0	0	8.0500	S

In [23]:
```python
# 1 = male / 0 = female
```

In [24]:
```python
gender_Df = pd.DataFrame(gender_encoded,columns = ['Male gender'])
gender_Df.head()
```

Out[24]:

	Male gender
0	1
1	0
2	0
3	0
4	1

In [25]:
```python
embarked_cat = titanic_data['Embarked']
embarked_encoded = label_encoder.fit_transform(embarked_cat)
embarked_encoded[0:100]
```

Out[25]:
```
array([2, 0, 2, 2, 2, 1, 2, 2, 2, 0, 2, 2, 2, 2, 2, 2, 1, 2, 2, 0, 2, 2,
       1, 2, 2, 2, 0, 2, 1, 2, 0, 0, 1, 2, 0, 2, 0, 2, 2, 0, 2, 2, 0, 0,
       1, 2, 1, 1, 0, 2, 2, 2, 0, 2, 0, 2, 2, 0, 2, 2, 0, 2, 2, 0, 0, 2,
       2, 2, 2, 2, 2, 2, 0, 2, 2, 2, 2, 2, 2, 2, 2, 1, 2, 2, 2, 2, 2, 2,
       2, 2, 2, 2, 2, 2, 2, 0, 0, 2, 2, 2])
```

In [28]:
```python
from sklearn.preprocessing import OneHotEncoder
binary_encoder = OneHotEncoder(categories='auto')
embarked_1hot = binary_encoder.fit_transform(embarked_encoded.reshape(-1,1))
embarked_1hot_mat = embarked_1hot.toarray()
embarked_DF = pd.DataFrame(embarked_1hot_mat, columns = ['C','Q','S'])
embarked_DF.head()
```

Out[28]:

	C	Q	S
0	0.0	0.0	1.0
1	1.0	0.0	0.0
2	0.0	0.0	1.0
3	0.0	0.0	1.0
4	0.0	0.0	1.0

In [32]:
```python
titanic_data.drop(['Sex', 'Embarked'], axis=1, inplace=True)
titanic_data.head()
```

Out[32]:

	PassengerId	Survived	Pclass	Age	SibSp	Parch	Fare
0	1	0	3	22.0	1	0	7.2500
1	2	1	1	38.0	1	0	71.2833
2	3	1	3	26.0	0	0	7.9250
3	4	1	1	35.0	1	0	53.1000
4	5	0	3	35.0	0	0	8.0500

In [37]:
```python
titanic_dmy = pd.concat([titanic_data,gender_Df,embarked_DF],axis=1, verify_integrity = True). astype(float)
titanic_dmy[0:5]
```

Out[37]:

	PassengerId	Survived	Pclass	Age	SibSp	Parch	Fare	Male gender	C	Q	S
0	1.0	0.0	3.0	22.0	1.0	0.0	7.2500	1.0	0.0	0.0	1.0
1	2.0	1.0	1.0	38.0	1.0	0.0	71.2833	0.0	1.0	0.0	0.0
2	3.0	1.0	3.0	26.0	0.0	0.0	7.9250	0.0	0.0	0.0	1.0
3	4.0	1.0	1.0	35.0	1.0	0.0	53.1000	0.0	0.0	0.0	1.0
4	5.0	0.0	3.0	35.0	0.0	0.0	8.0500	1.0	0.0	0.0	1.0

Checking for independence between features

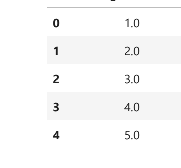
In [40]:
```python
(titanic_dmy.corr())
```

Out[40]:

	PassengerId	Survived	Pclass	Age	SibSp	Parch	Fare	Male gender	C	Q	S
PassengerId	1.000000	-0.005028	-0.035330	0.026945	-0.057686	-0.001657	0.012703	0.043136	-0.001208	-0.033694	0.022269
Survived	-0.005028	1.000000	-0.335549	-0.072126	-0.034040	0.083151	0.255290	-0.541585	0.169966	0.004536	-0.151777
Pclass	-0.035330	-0.335549	1.000000	-0.328299	0.081656	0.016824	-0.548193	0.127741	-0.245733	0.220558	0.076466
Age	0.026945	-0.072126	-0.328299	1.000000	-0.295432	-0.220454	0.076341	0.103011	0.034083	0.012844	-0.037949
SibSp	-0.057686	-0.034040	0.081656	-0.295432	1.000000	0.414542	0.160887	-0.116348	-0.060074	-0.026692	0.069438
Parch	-0.001657	0.083151	0.016824	-0.220454	0.414542	1.000000	0.217532	-0.247508	-0.011588	-0.081585	0.061512
Fare	0.012703	0.255290	-0.548193	0.076341	0.160887	0.217532	1.000000	-0.179958	0.270731	-0.116684	-0.163758
Male gender	0.043136	-0.541585	0.127741	0.103011	-0.116348	-0.247508	-0.179958	1.000000	-0.084520	-0.075217	0.121405
C	-0.001208	0.169966	-0.245733	0.034083	-0.060074	-0.011588	0.270731	-0.084520	1.000000	-0.148646	-0.782613
Q	-0.033694	0.004536	0.220558	0.012844	-0.026692	-0.081585	-0.116684	-0.075217	-0.148646	1.000000	-0.499261
S	0.022269	-0.151777	0.076466	-0.037949	0.069438	0.061512	-0.163758	0.121405	-0.782613	-0.499261	1.000000

In [39]:
```python
sb.heatmap(titanic_dmy.corr())
```

Out[39]: <AxesSubplot:>



In [44]:
```python
# dropping variables that are not independent
titanic_dmy.drop(['Fare', 'Pclass'], axis = 1, inplace = True)
titanic_dmy.head()
```

Out[44]:

	PassengerId	Survived	Age	SibSp	Parch	Male gender	C	Q	S
0	1.0	0.0	22.0	1.0	0.0	1.0	0.0	0.0	1.0
1	2.0	1.0	38.0	1.0	0.0	0.0	1.0	0.0	0.0
2	3.0	1.0	26.0	0.0	0.0	0.0	0.0	0.0	1.0
3	4.0	1.0	35.0	1.0	0.0	0.0	0.0	0.0	1.0
4	5.0	0.0	35.0	0.0	0.0	1.0	0.0	0.0	1.0

Checking that your dataset size is sufficient

In [ ]:
```python
# rule of thumb 50 records per predictive feature
```

In [46]:
```python
(titanic_dmy.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 889 entries, 0 to 888
Data columns (total 9 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   PassengerId  889 non-null    float64
 1   Survived     889 non-null    float64
 2   Age          889 non-null    float64
 3   SibSp        889 non-null    float64
 4   Parch        889 non-null    float64
 5   Male gender  889 non-null    float64
 6   C            889 non-null    float64
 7   Q            889 non-null    float64
 8   S            889 non-null    float64
dtypes: float64(9)
memory usage: 62.6 KB
```

In [56]:
```python
x_train, x_test, y_train, y_test = train_test_split(titanic_dmy.drop('Survived',axis=1),
                                                    titanic_dmy['Survived'],
                                                    test_size=0.2, random_state=200)
```

In [57]:
```python
print(x_train.shape)
print(y_train.shape)
```

```
(711, 8)
(711,)
```

In [58]:
```python
x_train[0:5]
```

Out[58]:

	PassengerId	Age	SibSp	Parch	Male gender	C	Q	S
719	721.0	6.0	0.0	1.0	0.0	0.0	0.0	1.0
165	167.0	24.0	0.0	1.0	0.0	0.0	0.0	1.0
879	882.0	33.0	0.0	0.0	1.0	0.0	0.0	1.0
451	453.0	30.0	0.0	0.0	1.0	1.0	0.0	0.0
181	183.0	9.0	4.0	2.0	1.0	0.0	0.0	1.0

Deploying and evaluating the model

In [61]:
```python
LogReg = LogisticRegression(solver = 'liblinear')
LogReg.fit(x_train, y_train)
```

Out[61]: `LogisticRegression(solver='liblinear')`

In [62]:
```python
y_pred = LogReg.predict(x_test)
```

Model Evaluation

Classification report without cross-validation

In [63]:
```python
print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

         0.0       0.83      0.88      0.85       109
         1.0       0.79      0.71      0.75        69

    accuracy                           0.81       178
   macro avg       0.81      0.80      0.80       178
weighted avg       0.81      0.81      0.81       178
```

K-fold cross-validation & confusion matrices

In [64]:
```python
y_train_pred = cross_val_predict(LogReg, x_train, y_train, cv=5)
confusion_matrix(y_train, y_train_pred)
```

Out[64]:
```
array([[377,  63],
       [ 91, 180]], dtype=int64)
```

In [66]:
```python
precision_score(y_train, y_train_pred)
```

Out[66]: `0.7407407407407407`

Make a test prediction

In [67]:
```python
titanic_dmy[863:864]
```

Out[67]:

	PassengerId	Survived	Age	SibSp	Parch	Male gender	C	Q	S
863	866.0	1.0	42.0	0.0	0.0	0.0	0.0	0.0	1.0

In [69]:
```python
test_passenger = np.array([866, 40, 0, 0, 0, 0, 0, 1]).reshape(1,-1)
print(LogReg.predict(test_passenger))
print(LogReg.predict_proba(test_passenger))
```

```
[1.]
[[0.26351831 0.73648169]]
```

In [ ]:

In [ ]: