

## 02\_logistic\_regression

December 21, 2019

### 1 Kaggle Titanic survival - logistic regression model

Can we predict which passengers would survive the sinking of the Titanic?

See:

<https://www.kaggle.com/c/titanic/overview/evaluation>

[https://gitlab.com/michaelallen1966/1908\\_coding\\_club\\_kaggle\\_titanic](https://gitlab.com/michaelallen1966/1908_coding_club_kaggle_titanic)

The original data comes from:

<https://www.kaggle.com/c/titanic/data>

Though we will download and use a data set that has been pre-processed ready for machine learning.

The data includes:

Variable	Definition
survival	Survival (0 = No, 1 = Yes)
pclass	Ticket class
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)

#### 1.1 Logistic regression

In this example we will use logistic regression (see [https://en.wikipedia.org/wiki/Logistic\\_regression](https://en.wikipedia.org/wiki/Logistic_regression)).

For an introductory video on logistic regression see: <https://www.youtube.com/watch?v=yIYKR4sgzI8>

Logistic regression takes a range of features (which we will normalise/standardise to put on the same scale) and returns a probability that a certain classification (survival in this case) is true.

We will go through the following steps:

- Download and save pre-processed data
- Split data into features (X) and label (y)
- Split data into training and test sets (we will test on data that has not been used to fit the model)
- Standardise data
- Fit a logistic regression model (from sklearn learn)
- Predict survival of the test set, and assess accuracy
- Review model coefficients (weights) to see importance of features
- Show probability of survival for passengers

## 1.2 Load modules

A standard Anaconda install of Python (<https://www.anaconda.com/distribution/>) contains all the necessary modules.

```
[1]: import numpy as np
import pandas as pd
# Import machine learning methods
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
```

## 1.3 Load data

The section below downloads pre-processed data, and saves it to a subfolder (from where this code is run). If data has already been downloaded that cell may be skipped.

Code that was used to pre-process the data ready for machine learning may be found at: [https://github.com/MichaelAllen1966/1804\\_python\\_healthcare/blob/master/titanic/01\\_preprocessing.ipynb](https://github.com/MichaelAllen1966/1804_python_healthcare/blob/master/titanic/01_preprocessing.ipynb)

```
[2]: download_required = True

if download_required:

    # Download processed data:
    address = 'https://raw.githubusercontent.com/MichaelAllen1966/' + \
              '1804_python_healthcare/master/titanic/data/processed_data.csv'

    data = pd.read_csv(address)

    # Create a data subfolder if one does not already exist
    import os
    data_directory = './data/'
    if not os.path.exists(data_directory):
        os.makedirs(data_directory)
```

```
# Save data
data.to_csv(data_directory+'processed_data.csv')
```

```
[3]: data = pd.read_csv('data/processed_data.csv')
```

## 1.4 Examine loaded data

The data is in the form of a Pandas DataFrame, so we have column headers providing information of what is contained in each column.

We will use the DataFrame `.head()` method to show the first few rows of the imported DataFrame. By default this shows the first 5 rows. Here we will look at the first 10.

```
[4]: data.head(10)
```

```
[4]:
```

	Unnamed: 0	Unnamed: 0.1	PassengerId	Survived	Pclass	Age	SibSp	\
0	0	0	1	0	3	22.0	1	
1	1	1	2	1	1	38.0	1	
2	2	2	3	1	3	26.0	0	
3	3	3	4	1	1	35.0	1	
4	4	4	5	0	3	35.0	0	
5	5	5	6	0	3	28.0	0	
6	6	6	7	0	1	54.0	0	
7	7	7	8	0	3	2.0	3	
8	8	8	9	1	3	27.0	0	
9	9	9	10	1	2	14.0	1	

  

	Parch	Fare	AgeImputed	...	Embarked_missing	CabinLetter_A	\
0	0	7.2500	False	...	0	0	
1	0	71.2833	False	...	0	0	
2	0	7.9250	False	...	0	0	
3	0	53.1000	False	...	0	0	
4	0	8.0500	False	...	0	0	
5	0	8.4583	True	...	0	0	
6	0	51.8625	False	...	0	0	
7	1	21.0750	False	...	0	0	
8	2	11.1333	False	...	0	0	
9	0	30.0708	False	...	0	0	

  

	CabinLetter_B	CabinLetter_C	CabinLetter_D	CabinLetter_E	CabinLetter_F	\
0	0	0	0	0	0	
1	0	1	0	0	0	
2	0	0	0	0	0	
3	0	1	0	0	0	
4	0	0	0	0	0	
5	0	0	0	0	0	
6	0	0	0	1	0	

7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0

	CabinLetter_G	CabinLetter_T	CabinLetter_missing
0	0	0	1
1	0	0	0
2	0	0	1
3	0	0	0
4	0	0	1
5	0	0	1
6	0	0	0
7	0	0	1
8	0	0	1
9	0	0	1

[10 rows x 28 columns]

We can also show a summary of the data with the `.describe()` method

```
[5]: data.describe()
```

```
[5]:
```

	Unnamed: 0	Unnamed: 0.1	PassengerId	Survived	Pclass	\
count	891.000000	891.000000	891.000000	891.000000	891.000000	
mean	445.000000	445.000000	446.000000	0.383838	2.308642	
std	257.353842	257.353842	257.353842	0.486592	0.836071	
min	0.000000	0.000000	1.000000	0.000000	1.000000	
25%	222.500000	222.500000	223.500000	0.000000	2.000000	
50%	445.000000	445.000000	446.000000	0.000000	3.000000	
75%	667.500000	667.500000	668.500000	1.000000	3.000000	
max	890.000000	890.000000	891.000000	1.000000	3.000000	

  

	Age	SibSp	Parch	Fare	CabinNumber	...	\
count	891.000000	891.000000	891.000000	891.000000	891.000000	...	
mean	29.361582	0.523008	0.381594	32.204208	11.021324	...	
std	13.019697	1.102743	0.806057	49.693429	26.638204	...	
min	0.420000	0.000000	0.000000	0.000000	0.000000	...	
25%	22.000000	0.000000	0.000000	7.910400	0.000000	...	
50%	28.000000	0.000000	0.000000	14.454200	0.000000	...	
75%	35.000000	1.000000	0.000000	31.000000	0.000000	...	
max	80.000000	8.000000	6.000000	512.329200	148.000000	...	

  

	Embarked_missing	CabinLetter_A	CabinLetter_B	CabinLetter_C	\
count	891.000000	891.000000	891.000000	891.000000	
mean	0.002245	0.016835	0.052750	0.066218	
std	0.047351	0.128725	0.223659	0.248802	
min	0.000000	0.000000	0.000000	0.000000	

25%	0.000000	0.000000	0.000000	0.000000
50%	0.000000	0.000000	0.000000	0.000000
75%	0.000000	0.000000	0.000000	0.000000
max	1.000000	1.000000	1.000000	1.000000

	CabinLetter_D	CabinLetter_E	CabinLetter_F	CabinLetter_G \
count	891.000000	891.000000	891.000000	891.000000
mean	0.037037	0.035915	0.014590	0.004489
std	0.188959	0.186182	0.119973	0.066890
min	0.000000	0.000000	0.000000	0.000000
25%	0.000000	0.000000	0.000000	0.000000
50%	0.000000	0.000000	0.000000	0.000000
75%	0.000000	0.000000	0.000000	0.000000
max	1.000000	1.000000	1.000000	1.000000

	CabinLetter_T	CabinLetter_missing
count	891.000000	891.000000
mean	0.001122	0.771044
std	0.033501	0.420397
min	0.000000	0.000000
25%	0.000000	1.000000
50%	0.000000	1.000000
75%	0.000000	1.000000
max	1.000000	1.000000

[8 rows x 23 columns]

The first column is a passenger index number. We will remove this, as this is not part of the original Titanic passenger data.

## 2 Drop Passengerid (axis=1 indicates we are removing a column rather than a row)

```
data.drop('PassengerId', inplace=True, axis=1)
```

### 2.1 Looking at a summary of passengers who survived or did not survive

Before running machine learning models, it is always good to have a look at your data. Here we will separate passengers who survived from those who died, and we will have a look at differences in features.

We will use a *mask* to select and filter passengers

```
[6]: mask = data['Survived'] == 1 # Mask for passengers who survive
      survived = data[mask] # filter using mask
```

```
mask = data['Survived'] == 0 # Mask for passengers who died
died = data[mask] # filter using mask
```

Now let's look at average (mean) values for survived and died

```
[7]: survived.mean()
```

```
[7]: Unnamed: 0          443.368421
     Unnamed: 0.1      443.368421
     PassengerId      444.368421
     Survived          1.000000
     Pclass            1.950292
     Age              28.291433
     SibSp             0.473684
     Parch             0.464912
     Fare             48.395408
     AgeImputed        0.152047
     EmbarkedImputed   0.005848
     CabinLetterImputed 0.602339
     CabinNumber       18.961988
     CabinNumberImputed 0.611111
     male              0.318713
     Embarked_C        0.271930
     Embarked_Q        0.087719
     Embarked_S        0.634503
     Embarked_missing  0.005848
     CabinLetter_A      0.020468
     CabinLetter_B      0.102339
     CabinLetter_C      0.102339
     CabinLetter_D      0.073099
     CabinLetter_E      0.070175
     CabinLetter_F      0.023392
     CabinLetter_G      0.005848
     CabinLetter_T      0.000000
     CabinLetter_missing 0.602339
     dtype: float64
```

```
died.mean()
```

We can make looking at them side by side more easy by putting these values in a new DataFrame.

```
[8]: summary = pd.DataFrame() # New empty DataFrame
     summary['survived'] = survived.mean()
     summary['died'] = died.mean()
```

Now let's look at them side by side. See if you can spot what features you think might have influenced survival.

```
[9]: summary
```

```
[9]:
```

	survived	died
Unnamed: 0	443.368421	446.016393
Unnamed: 0.1	443.368421	446.016393
PassengerId	444.368421	447.016393
Survived	1.000000	0.000000
Pclass	1.950292	2.531876
Age	28.291433	30.028233
SibSp	0.473684	0.553734
Parch	0.464912	0.329690
Fare	48.395408	22.117887
AgeImputed	0.152047	0.227687
EmbarkedImputed	0.005848	0.000000
CabinLetterImputed	0.602339	0.876138
CabinNumber	18.961988	6.074681
CabinNumberImputed	0.611111	0.885246
male	0.318713	0.852459
Embarked_C	0.271930	0.136612
Embarked_Q	0.087719	0.085610
Embarked_S	0.634503	0.777778
Embarked_missing	0.005848	0.000000
CabinLetter_A	0.020468	0.014572
CabinLetter_B	0.102339	0.021858
CabinLetter_C	0.102339	0.043716
CabinLetter_D	0.073099	0.014572
CabinLetter_E	0.070175	0.014572
CabinLetter_F	0.023392	0.009107
CabinLetter_G	0.005848	0.003643
CabinLetter_T	0.000000	0.001821
CabinLetter_missing	0.602339	0.876138

## 2.2 Divide into X (features) and y (lables)

We will separate out our features (the data we use to make a prediction) from our label (what we are truing to predict). By convention our features are called X (usually upper case to denote multiple features), and the label (survvive or not) y.

```
[10]: X = data.drop('Survived',axis=1) # X = all 'data' except the 'survived' column
      y = data['Survived'] # y = 'survived' column from 'data'
```

## 2.3 Divide into training and tets sets

When we test a machine learning model we should always test it on data that has not been used to train the model. We will use sklearn's `train_test_split` method to randomly split the data: 75% for training, and 25% for testing.

```
[11]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.25)
```

## 2.4 Standardise data

We want all of our features to be on roughly the same scale. This generally leads to a better model, and also allows us to more easily compare the importance of different features.

One simple method is to scale all features 0-1 (by subtracting the minimum value for each value, and dividing by the new remaining maximum value).

But a more common method used in many machine learning methods is standardisation, where we use the mean and standard deviation of the training set of data to normalise the data. We subtract the mean of the test set values, and divide by the standard deviation of the training data. Note that the mean and standard deviation of the training data are used to standardise the test set data as well.

Here we will use sklearn's `StandardScaler` method. This method also copes with problems we might otherwise have (such as if one feature has zero standard deviation in the training set).

```
[12]: def standardise_data(X_train, X_test):  
  
    # Initialise a new scaling object for normalising input data  
    sc = StandardScaler()  
  
    # Set up the scaler just on the training set  
    sc.fit(X_train)  
  
    # Apply the scaler to the training and test sets  
    train_std=sc.transform(X_train)  
    test_std=sc.transform(X_test)  
  
    return train_std, test_std
```

```
[13]: X_train_std, X_test_std = standardise_data(X_train, X_test)
```

## 2.5 Fit logistic regression model

Now we will fit a logistic regression model, using sklearn's `LogisticRegression` method. Our machine learning model fitting is only two lines of code! By using the name `model` for our logistic regression model we will make our model more interchangeable later on.

```
[14]: model = LogisticRegression()  
model.fit(X_train_std,y_train)
```

```
/home/michael/anaconda3/lib/python3.7/site-  
packages/sklearn/linear_model/logistic.py:432: FutureWarning: Default solver
```



will be changed to 'lbfgs' in 0.22. Specify a solver to silence this warning.  
FutureWarning)

```
[14]: LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                        intercept_scaling=1, l1_ratio=None, max_iter=100,
                        multi_class='warn', n_jobs=None, penalty='l2',
                        random_state=None, solver='warn', tol=0.0001, verbose=0,
                        warm_start=False)
```

## 2.6 Predict values

Now we can use the trained model to predict survival. We will test the accuracy of both the training and test data sets.

```
[15]: # Predict training and test set labels
y_pred_train = model.predict(X_train_std)
y_pred_test = model.predict(X_test_std)
```

## 2.7 Calculate accuracy

In this example we will measure accuracy simply as the proportion of passengers where we make the correct prediction. In a later notebook we will look at other measures of accuracy which explore false positives and false negatives in more detail.

```
[16]: accuracy_train = np.mean(y_pred_train == y_train)
accuracy_test = np.mean(y_pred_test == y_test)

print ('Accuracy of predicting training data =', accuracy_train)
print ('Accuracy of predicting test data =', accuracy_test)
```

Accuracy of predicting training data = 0.8143712574850299

Accuracy of predicting test data = 0.7802690582959642

Not bad - about 80% accuracy. You will probably see that accuracy of predicting the training set is usually higher than the test set. Because we are only testing one random sample, you may occasionally see otherwise. In later note books we will look at the best way to repeat multiple tests, and look at what to do if the accuracy of the training set is significantly higher than the test set (a problem called 'over-fitting').

## 2.8 Examining the model coefficients (weights)

Not all features are equally important. And some may be of little or no use at all, unnecessarily increasing the complexity of the model. In a later notebook we will look at selecting features which add value to the model (or removing features that don't).

Here we will look at the importance of features – how they affect our estimation of survival. These are known as the model *coefficients* (if you come from a traditional statistics background), or model *weights* (if you come from a machine learning background).

Because we have standardised our input data the magnitude of the weights may be compared as an indicator of their influence in the model. Weights with higher negative numbers mean that that feature correlates with reduced chance of survival. Weights with higher positive numbers mean that that feature correlates with increased chance of survival. Those weights with values closer to zero (either positive or negative) have less influence in the model.

We access the model weights by examining the model `coef_` attribute. The model may predict more than one outcome label, in which case we have weights for each label. Because we are predicting a single label (survive or not), the weights are found in the first element (`[0]`) of the `coef_` attribute.

```
[17]: co_eff = model.coef_[0]
      co_eff
```

```
[17]: array([-0.00248957, -0.00248957, -0.00248957, -0.95624158, -0.6785179 ,
        -0.38883306, -0.13929632,  0.19672427, -0.0599065 ,  0.07967199,
         0.05939782,  0.08163159, -0.41901589, -1.37158941,  0.04645157,
         0.06496513, -0.0886454 ,  0.07967199, -0.08496594, -0.04711795,
        -0.25400325,  0.04995434,  0.19512391,  0.15447834, -0.02618731,
        -0.14696925,  0.05939782])
```

So we have an array of model weights.

Not very readable for us mere humans is it?!

We will transfer the weights array to a Pandas DataFrame. The array order is in the same order of the list of features of `X`, so we will put that those into the DataFrame as well. And we will sort by influence in the model. Because both large negative and positive values are more influential in the model we will take the *absolute* value of the weight (that is remove any negative sign), and then sort by that absolute value. That will give us a more readable table of most influential features in the model.

```
[18]: co_eff_df = pd.DataFrame() # create empty DataFrame
      co_eff_df['feature'] = list(X) # Get feature names from X
      co_eff_df['co_eff'] = co_eff
      co_eff_df['abs_co_eff'] = np.abs(co_eff)
      co_eff_df.sort_values(by='abs_co_eff', ascending=False, inplace=True)
```

```
[19]: co_eff_df
```

```
[19]:
```

	feature	co_eff	abs_co_eff
13	male	-1.371589	1.371589
3	Pclass	-0.956242	0.956242
4	Age	-0.678518	0.678518
12	CabinNumberImputed	-0.419016	0.419016
5	SibSp	-0.388833	0.388833

20	CabinLetter_C	-0.254003	0.254003
7	Fare	0.196724	0.196724
22	CabinLetter_E	0.195124	0.195124
23	CabinLetter_F	0.154478	0.154478
25	CabinLetter_T	-0.146969	0.146969
6	Parch	-0.139296	0.139296
16	Embarked_S	-0.088645	0.088645
18	CabinLetter_A	-0.084966	0.084966
11	CabinNumber	0.081632	0.081632
9	EmbarkedImputed	0.079672	0.079672
17	Embarked_missing	0.079672	0.079672
15	Embarked_Q	0.064965	0.064965
8	AgeImputed	-0.059906	0.059906
26	CabinLetter_missing	0.059398	0.059398
10	CabinLetterImputed	0.059398	0.059398
21	CabinLetter_D	0.049954	0.049954
19	CabinLetter_B	-0.047118	0.047118
14	Embarked_C	0.046452	0.046452
24	CabinLetter_G	-0.026187	0.026187
1	Unnamed: 0.1	-0.002490	0.002490
2	PassengerId	-0.002490	0.002490
0	Unnamed: 0	-0.002490	0.002490

So are three most influential features are:

- male (being male reduces probability of survival)
- Pclass (lower class passengers, who have a higher class number, reduces probability of survival)
- age (being older reduces probability of survival)

## 2.9 Show predicted probabilities

The predicted probabilities are for the two alternative classes 0 (does not survive) or 1 (survive).

Ordinarily we do not see these probabilities - the `predict` method used above applies a cut-off of 0.5 to classify passengers into survived or not, but we can see the individual probabilities for each passenger.

Later we will use these to adjust sensitivity of our model to detecting survivors or non-survivors.

Each passenger has two values. These are the probability of not surviving (first value) or surviving (second value). Because we only have two possible classes we only need to look at one. Multiple values are important when there are more than one class being predicted.

```
[20]: # Show first ten predicted classes
      classes = model.predict(X_test_std)
      classes[0:10]
```

```
[20]: array([1, 1, 0, 1, 1, 0, 0, 1, 1, 0])
```

```
[21]: # Show first ten predicted probabilities
      # (note how the values relate to the classes predicted above)
      probabilities = model.predict_proba(X_test_std)
      probabilities[0:10]
```

```
[21]: array([[0.22510433, 0.77489567],
             [0.09303391, 0.90696609],
             [0.54761577, 0.45238423],
             [0.18461523, 0.81538477],
             [0.01074761, 0.98925239],
             [0.93272569, 0.06727431],
             [0.56405583, 0.43594417],
             [0.0854364 , 0.9145636 ],
             [0.30866528, 0.69133472],
             [0.91474666, 0.08525334]])
```