

### Logistic Regression

Let's learn something!





- Not all labels are continuous, sometimes you need to predict categories, this is known as classification.
- Logistic Regression is one of the basic ways to perform classification (don't be confused by the word "regression")





# Sections 4-4.3 of Introduction to Statistical Learning By Gareth James, et al.





 If you want to fully understand some of the concepts behind the evaluation methods and metrics behind classification, the reading is highly recommended!



- We want to learn about Logistic Regression as a method for Classification.
- Some examples of classification problems:
  - Spam versus "Ham" emails
  - Loan Default (yes/no)
  - Disease Diagnosis
- Above were all examples of Binary Classification





- So far we've only seen regression problems where we try to predict a continuous value.
- Although the name may be confusing at first, logistic regression allows us to solve classification problems, where we are trying to predict discrete categories.



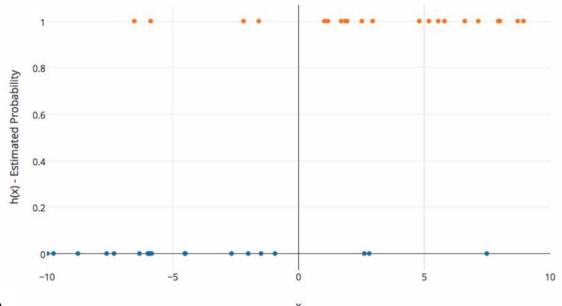


- The convention for binary classification is to have two classes 0 and 1.
- Let's walk through the basic idea for logistic regression.
- We'll also explain why it has the term regression in it, even though it's used for classification!



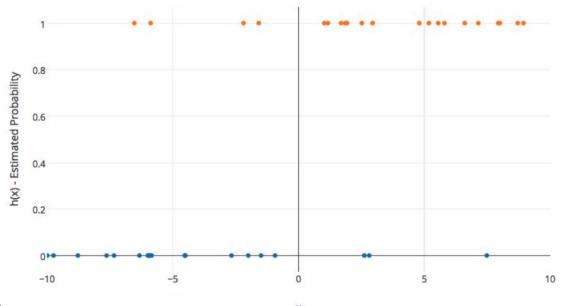


• Imagine we plotted out some categorical data against one feature.



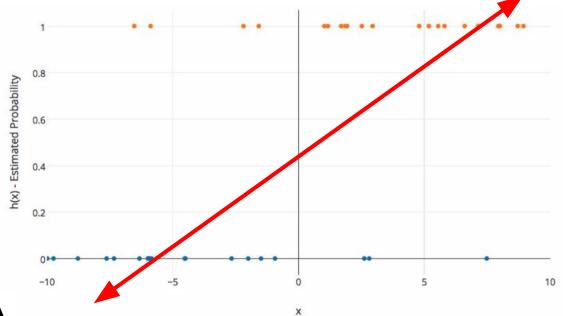


 The X axis represents a feature value and the Y axis represents the probability of belonging to class 1.





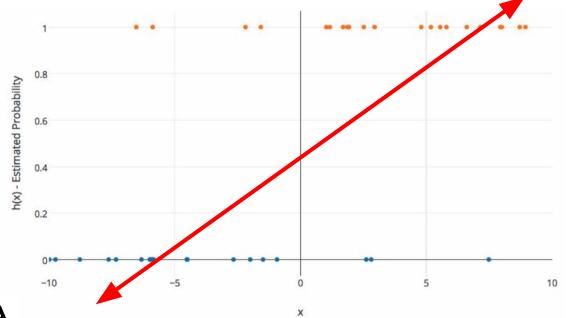
 We can't use a normal linear regression model on binary groups. It won't lead to a good fit:







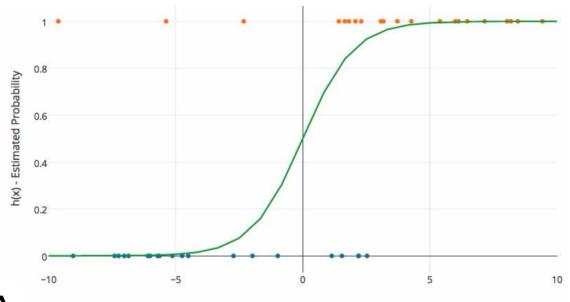
 We need a function that will fit binary categorical data!





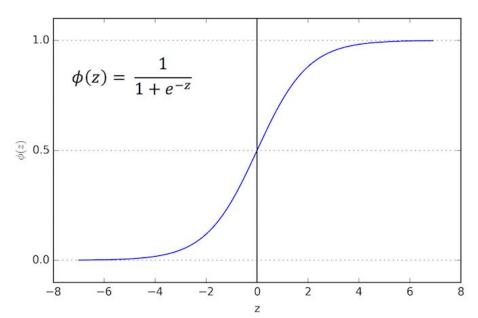


 It would be great if we could find a function with this sort of behavior:



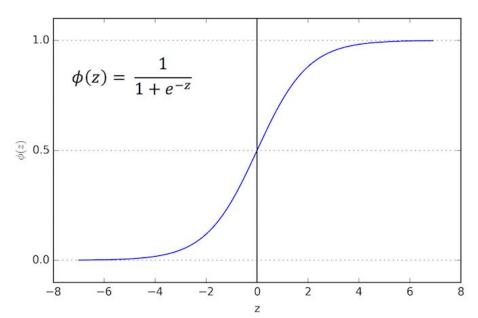


 The Sigmoid (aka Logistic) Function takes in any value and outputs it to be between 0 and 1.



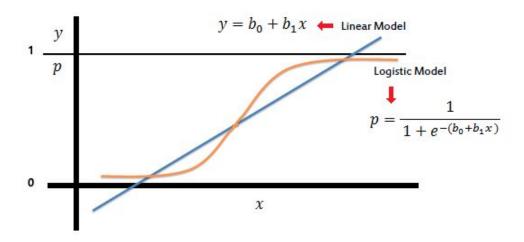


This means we can take our Linear Regression
 Solution and place it into the Sigmoid Function.



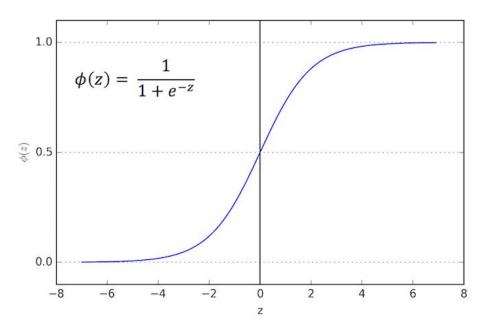


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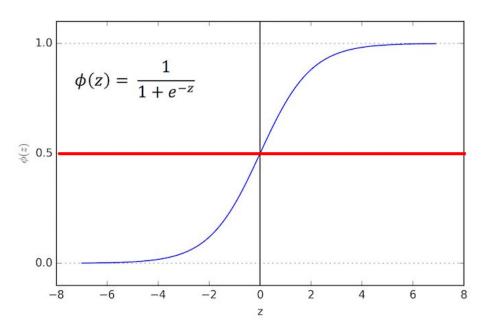


 This results in a probability from 0 to 1 of belonging in the 1 class.





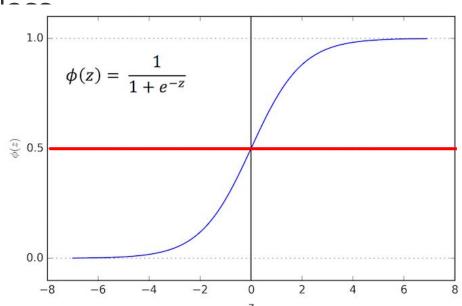
 We can set a cutoff point at 0.5, anything below it results in class 0, anything above is class 1.







 We use the logistic function to output a value ranging from 0 to 1. Based off of this probability we assign a c'---







- After you train a logistic regression model on some training data, you will evaluate your model's performance on some test data.
- You can use a confusion matrix to evaluate classification models.





		predicted condition	
	total population	prediction positive	prediction negative
true	condition positive	True Positive (TP)	False Negative (FN) (type II error)
condition	condition negative	False Positive (FP) (Type I error)	True Negative (TN)



			predicted condition		
		total population	prediction positive	prediction negative	$= \frac{\Sigma \text{ condition positive}}{\Sigma \text{ total population}}$
true	true	condition positive	True Positive (TP)	False Negative (FN) (type II error)	True Positive Rate (TPR), Sensitivity, Recall, Probability of Detection $= \frac{\Sigma \text{ TP}}{\Sigma \text{ condition positive}}$
	condition	condition I negative	False Positive (FP) (Type I error)	True Negative (TN)	False Positive Rate (FPR), Fall-out, Probability of False Alarm $= \frac{\sum FP}{\sum \text{ condition negative}}$
		Accuracy $\Sigma TP + \Sigma TN$	Positive Predictive Value (PPV), $= \frac{\Sigma \text{ TP}}{\Sigma \text{ prediction positive}}$	False Omission Rate (FOR) $= \frac{\Sigma \text{ FN}}{\Sigma \text{ prediction negative}}$	Positive Likelihood Ratio (LR+) $= \frac{TPR}{FPR}$
		$\Sigma$ total population	False Discovery Rate (FDR) $= \frac{\sum FP}{\sum prediction positive}$	Negative Predictive Value (NPV) $= \frac{\Sigma \text{ TN}}{\Sigma \text{ prediction negative}}$	Negative Likelihood Ratio (LR–) $= \frac{FNR}{TNR}$



- The main point to remember with the confusion matrix and the various calculated metrics is that they are all fundamentally ways of comparing the predicted values versus the true values.
- What constitutes "good" metrics, will really depend on the specific situation!



- We can use a confusion matrix to evaluate our model.
- For example, imagine testing for disease.

n=165	Predicted: NO	Predicted: YES
Actual: NO	50	10
Actual: YES	5	100

Example: Test for presence of disease NO = negative test = False = 0 YES = positive test = True = 1



n=165	Predicted: NO	Predicted: YES	
Actual: NO	TN = 50	FP = <b>1</b> 0	60
Actual: YES	FN = 5	TP = 100	105
	55	110	

#### **Basic Terminology:**

- True Positives (TP)
- True Negatives (TN)
- False Positives (FP)
- False Negatives (FN)





n=165	Predicted: NO	Predicted: YES	
Actual: NO	TN = 50	FP = <b>1</b> 0	60
Actual: YES	FN = 5	TP = 100	105
	55	110	

#### Accuracy:

- Overall, how often is it correct?
- (TP + TN) / total = 150/165 = 0.91





n=165	Predicted: NO	Predicted: YES	
Actual: NO	TN = 50	FP = <b>1</b> 0	60
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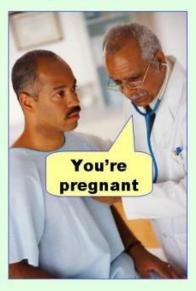
### Misclassification Rate (Error Rate):

- Overall, how often is it wrong?
- (FP + FN) / total = 15/165 = 0.09





**Type I error** (false positive)



**Type II error** (false negative)







- Still confused on the confusion matrix?
- No problem! Check out the Wikipedia page for it, it has a really good diagram with all the formulas for all the metrics.
- Throughout the course, we'll usually just print out metrics (e.g. accuracy).



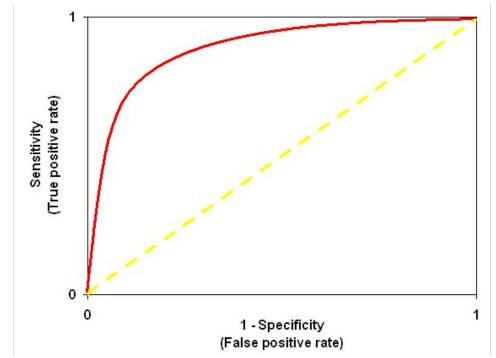


- Binary classification has some of its own special classification metrics.
- These include visualizations of metrics from the confusion matrix.
- The Receiver Operator Curve (ROC) curve was developed during World War II to help analyze radar data.





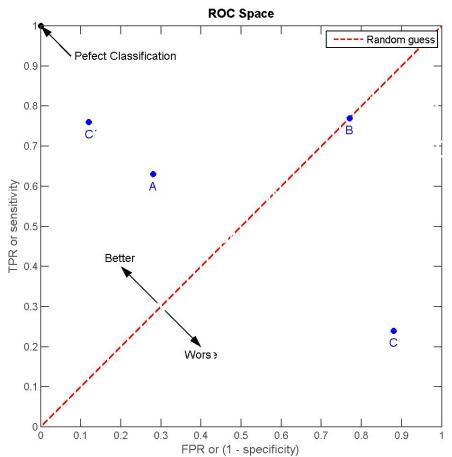
• The ROC curve:







#### **Model Evaluation**







- A full discussion of the ROC curve is beyond the scope of this course, but the reading assignment goes into much more detail.
- For now, you just need to know that the area under the curve is a metric for how well a model fit the data.





- Let's continue on exploring these concepts with a walk through of the documentation example
- We'll also add some more stuff on evaluation to the example!



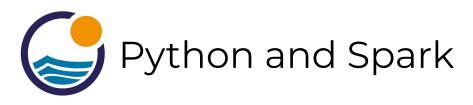


### Logistic Regression Documentation Example





- Let's quickly walk through the documentation Logistic Regression example.
- After viewing this, you should begin to pick up on Spark's pattern for machine learning syntax.



- We will also introduce the concept of "Evaluators".
- Evaluators behave similar to Machine Learning Algorithm objects, but are designed to take in evaluation DataFrames ~

#### model.evaluate(test\_data)



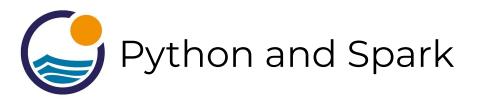


- Evaluators are technically still "experimental" according to the documentation, so use caution when using them for production code.
- But they have been a part of Spark since version 1.4, so they have some stability.



- The files for this lecture are
  - Logistic\_Regression\_Example.ipynb
  - sample\_libsvm\_data.txt
- Look under the Logistic Regression folder under the Machine Learning folder.
- All links we show can be found in the





Let's get started in a new notebook!





## Logistic Regression Code Along





- Let's work through a "classic" classification example!
- The titanic dataset is a common exercise for classification in machine learning, there are lots of examples of it online for other machine learning libraries!

- We'll use it to attempt to predict what passengers survived the titanic crash based solely on passenger's features (age, cabin, children, etc...)
- We will also explore a few more things!



- We'll see some better ways to deal with categorical data through a two-step process.
- We will also show how to use pipelines to set stages and build models that can be easily used again!



- Our data will also have a lot of missing information, so we will need to deal with that as well.
- Let's get started!

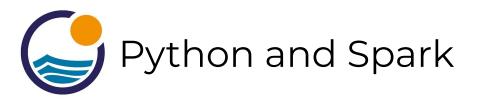


## Logistic Regression Consulting Project





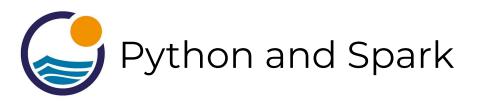
- You did such a great job on the previous consulting project that word is starting to spread about your abilities!
- You've been contacted by a top marketing agency to help them out with customer churn!



You just landed in New York City!







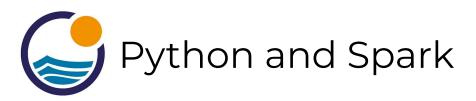
 You need to help out a marketing agency predict customer churn!







- A marketing agency has many customers that use their service to produce ads for the client/customer websites.
- They've noticed that they have quite a bit of churn in clients.



 They currently randomly assign account managers, but want you to create a machine learning model that will help predict which customers will churn (stop buying their service) so that they can correctly assign the customers most at risk to churn an account manager.

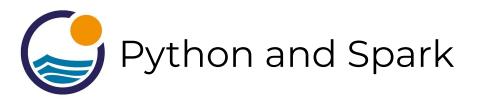




- Luckily they have some historical data, can you help them out?
- Create a classification algorithm that will help classify whether or not a customer churned.



 Then the company can test this against incoming data for future customers to predict which customers will churn and assign them an account manager.



- The data is under customer\_churn.csv
- Let's quickly go over the data and what your main task is.



Name : Name of the latest contact at Company

Age: Customer Age

Total\_Purchase: Total Ads Purchased

Account\_Manager: Binary 0=No manager, 1= Account manager assigned

Years: Total Years as a customer

Num\_sites: Number of websites that use the service.

Onboard\_date: Date that the name of the latest contact was onboarded

Location: Client HQ Address

Company: Name of Client Company

Churn: 0 or 1 indicating whether customer has churned.





- Your goal is to create a model that can predict whether a customer will churn (0 or 1) based off the features.
- Remember that the account manager is currently randomly assigned!



- As always, treat this consulting project as a loosely guided exercise, or skip ahead and treat it as a code along project!
- Best of luck!



## Logistic Regression Consulting Project Solutions

