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valuation Error Metrics

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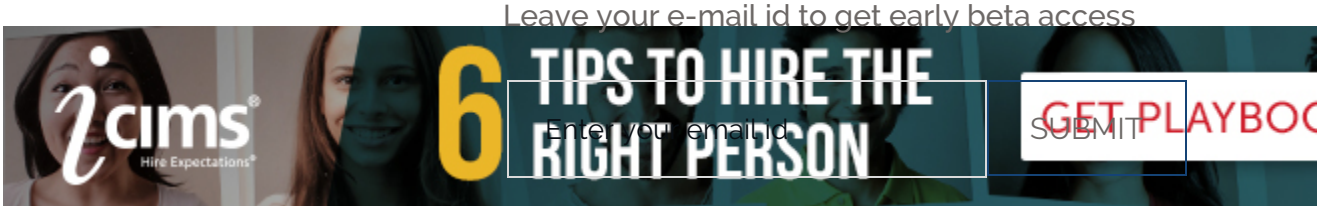

Introduction

Predictive Modeling works on constructive feedback principle. You build a model. Get feedback from metrics, make improvements and continue until you achieve a

trics explain the performance of a model. An etrics is their capability to discriminate among

even check model accuracy. Once they are edly map predicted values on unseen data. This is

is not your motive. But, creating and selecting a model which gives high accuracy on out of sample data. Hence, it is crucial to check accuracy of the model prior to computing predicted values.

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nt kinds of metrics to evaluate our models. The ds on the type of model and the implementation ned building your model, these 7 metrics will help racy. Considering the rising popularity of cross – nciples in this article.

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Table of Contents

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edictive models

els, we are talking either about a regression model
n model (nominal or binary output). The evaluation
s are different.

vo types of algorithms (dependent on the kind of

1. **Class output** : Algorithms like SVM and KNN create a class output. For instance, in a binary classification problem, the outputs will be either 0 or 1. However, today we have algorithms which can convert these class outputs to probability. But these algorithms are not well accepted by the statistics community.
2. **Probability output** : Algorithms like Logistic Regression, Random Forest, Gradient Boosting, Adaboost etc. give probability outputs. Converting probability outputs to class output is just a matter of creating a threshold probability.

In regression problems, we do not have such inconsistencies in output. The output is always continuous in nature and requires no further treatment.

Illustrative Example

For classification model evaluation metric discussion, I have used my predictions for the problem BCI challenge on Kaggle (link (https://www.kaggle.com/c/inria-bci-challenge)) . The solution of the problem is irrelevant for the discussion, however the final predictions on the training set has been used for this article. The predictions made puts which have been converted to class outputs

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atrix, where N is the number of classes being we have N=2, and hence we get a 2 X 2 matrix. Here are a few definitions you need to remember for a confusion matrix :

- **Accuracy** : the proportion of the total number of predictions that were correct.
- **ision** : the proportion of positive cases that were
- roportion of negative cases that were correctly
- on of actual positive cases which are correctly
- ual negative cases which are correctly identified.

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Model	Target			
	Positive	Negative		
Positive	a	b	*Positive Predictive Value*	a/(a+b)
Negative	c	d	*Negative Predictive Value*	d/(c+d)
	Sensitivity	*Specificity*	**Accuracy** = (a+d)/(a+b+c+d)	
	a/(a+c)	d/(b+d)		

(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/Confusion_matrix.png)

Count of ID	Target		
Model	1	0	Grand Total	
1	3,834	639	4,473	85.7%
0	16	951	967	1.7%
Grand Total	3,850	1,590	5,440	
	99.6%	40.19%		88.0%

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Step 1 : Calculate probability for each observation

Step 2 : Rank these probabilities in decreasing order.

Step 3 : Build deciles with each group having almost 10% of the observations.

Step 4 : Calculate the response rate at each deciles for Good (Responders) ,Bad (Non-responders) and total.

You will get following table from which you need to plot Gain/Lift charts:

Lift/Gain	Column Labels		%Rights	%Wrongs	%Population	Cum %Right	Cum %Pop	Lift @decile	Total Lift
Row Labels	0	1 Grand Total	0%	0%	0%	0%	0%		
1	543	543	14%	0%	10%	14%	10%	141%	141%
			14%	0%	10%	28%	20%	141%	141%
			14%	0%	10%	42%	30%	139%	141%
			14%	1%	10%	56%	40%	137%	140%
			14%	1%	10%	69%	50%	136%	139%
			13%	3%	10%	83%	60%	130%	138%
			11%	7%	10%	94%	70%	114%	134%
			5%	22%	10%	99%	80%	52%	124%
			1%	32%	10%	100%	90%	8%	111%
			0%	34%	10%	100%	100%	1%	100%

blog/wp-
.png)
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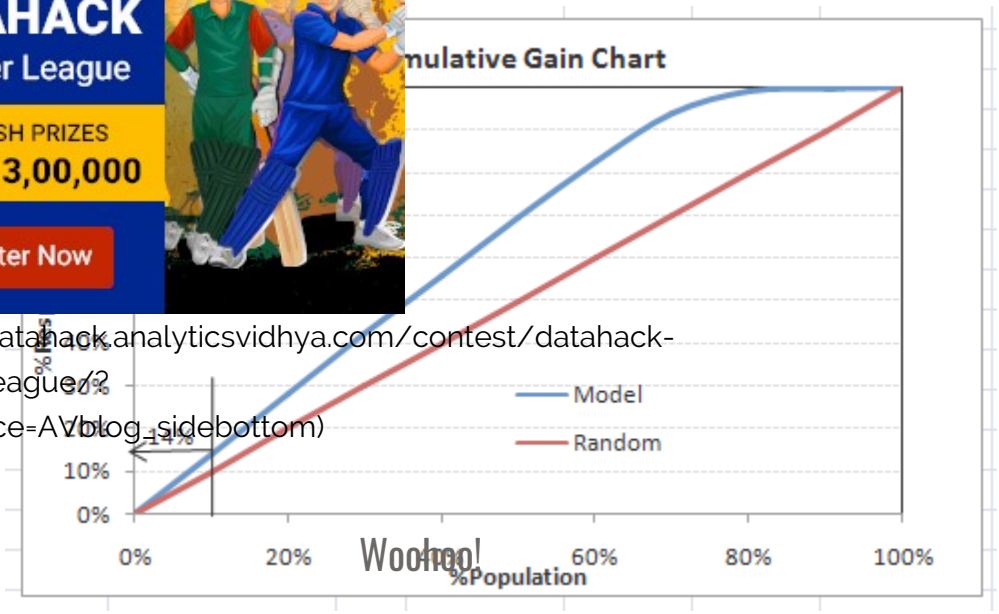
This is a very informative table. Cumulative Gain chart is the graph between e %Population. For the case in hand here is the

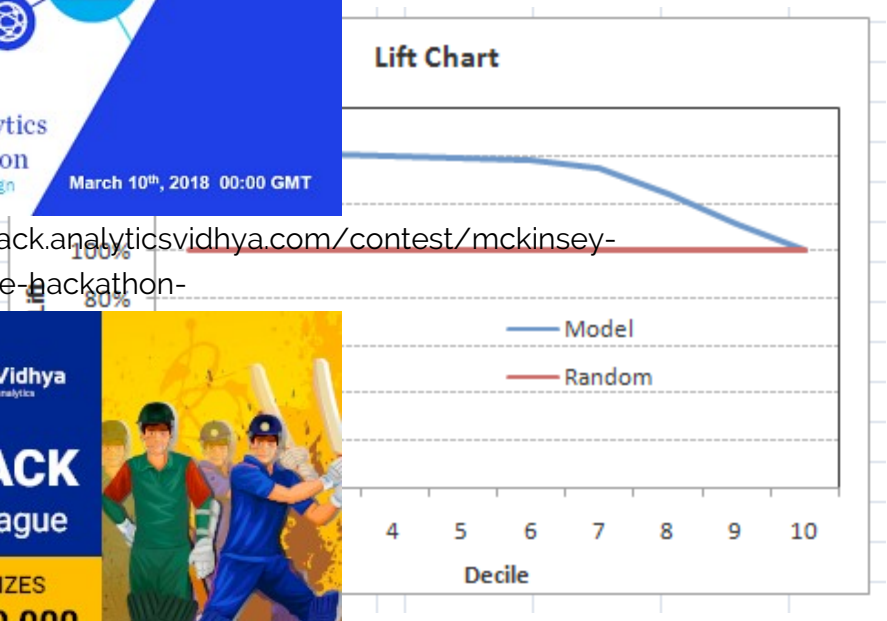


(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/CumGain.png)

This graph tells you how well is your model segregating responders from non-responders. For example, the first decile however has 10% of the population, has 14% of responders. This means we have a 140% lift at first decile.

What is the maximum lift we could have reached in first decile? From the first table of this article, we know that the total number of responders are 3850. Also the first decile will contains 543 observations. Hence, the maximum lift at first decile could have been 543/3850 ~ 14.1%. Hence, we are quite close to perfection with this model.

ve is the plot between total lift and %population. always stays flat at 100%. Here is the plot for the



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blog/wp-content/uploads/2015/01/Lift.png)

decile number :

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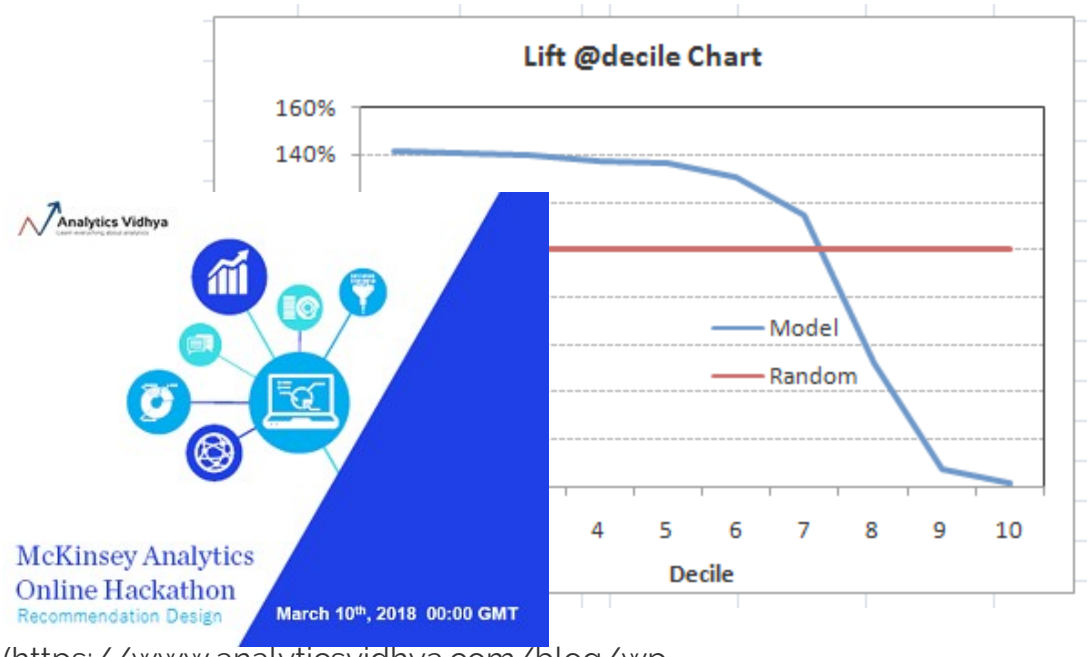

(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/Liftdecile.png)

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s you that our model does well till the 7th decile.
ed towards non-responders. Any model with lift @
decile and maximum 7th decile is a good model.
ng first.

n campaign targeting problems. This tells us till
rs for an specific campaign. Also, it tells you how
he new target base.

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3. Kolomogorov Smirnov chart

K-S or Kolmogorov-Smirnov chart measures performance of classification models. More accurately, K-S is a measure of the degree of separation between the positive and negative distributions. The K-S is 100, if the scores partition the population into two separate groups in which one group contains all the positives and the other all the negatives.

On the other hand, If the model cannot differentiate between positives and negatives, then it is as if the model selects cases randomly from the population. The K-S would be 0. In most classification models the K-S will fall between 0 and 100, and that the higher the value the better the model is at separating the positive from negative cases.

table :

			Cummulative		
ghts	%Wrongs	Cum %Rig	Cum %Wrong	K-S	
0%	0%	0%	0%	0%	
14%	0%	14%	0%	14%	
14%	0%	28%	0%	28%	
14%	0%	42%	1%	42%	
14%	1%	56%	2%	54%	
14%	1%	69%	3%	67%	
		83%	5%	77%	
11%	7%	94%	12%	82%	K-S
5%	22%	99%	34%	65%	
1%	32%	100%	66%	34%	
0%	34%	100%	100%	0%	

log/wp-content/uploads/2015/01/KS.png)

od and Bad to see the maximum separation.

(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/KS_plot.png)

The metrics covered till here are mostly used in classification problems. Till here, we learnt about confusion matrix, lift and gain chart and kolmogorov-smirnov chart. Let's

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nt metrics.

urve (AUC – ROC)

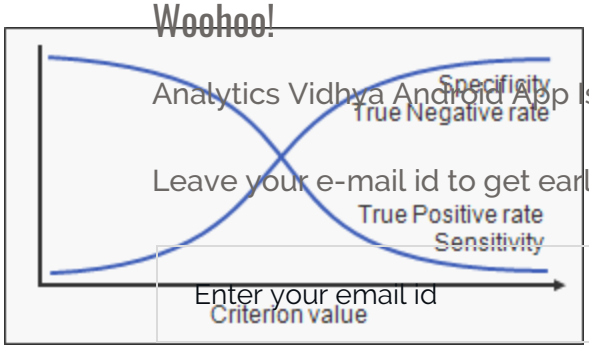
cs used in the industry. The biggest advantage of ndent of the change in proportion of responders. following sections.

Let's first try to understand what is ROC (Receiver operating characteristic) curve. If we look at the confusion matrix below, we observe that for a probabilistic model, we get

	arget		
	Negative		
	b	*Positive Predictive Value*	a/(a+b)
	d	*Negative Predictive Value*	d/(c+d)
	Specificity	**Accuracy** = (a+d)/(a+b+c+d)	
	d/(b+d)		

(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/Confusion_matrix.png)

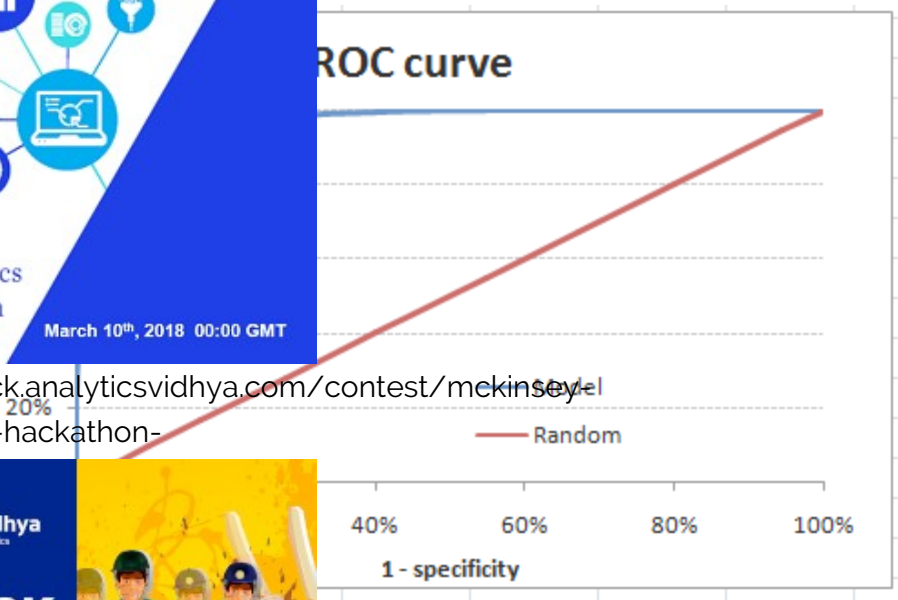
Hence, for each sensitivity, we get a different specificity.The two vary as follows:



(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/curves.png)

The ROC curve is the plot between sensitivity and (1- specificity). (1- specificity) is also known as false positive rate and sensitivity is also known as True Positive rate.

se in hand.



(https://datahack.analyticsvidhya.com/contest/mckinsey-analytics-online-hackathon-

log/wp-content/uploads/2015/01/ROC.png)

0.5 (refer to confusion matrix). Here is the

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et

Model	1	0	Grand Total	
1	3,834	639	4,473	85.7%
0	16	951	967	1.7%
Grand Total	3,850	1,590	5,440	
	99.6%	40.19%		88.0%

(https://www.analyticsvidhya.com/blog/wp-content/uploads/2015/01/Confusion_matrix2.png)

As you can see, the sensitivity at this threshold is 99.6% and the (1-specificity) is ~60%. This coordinate becomes on point in our ROC curve. To bring this curve down to a single number, we find the area under this curve (AUC).

Note that the area of entire square is 1*1 = 1. Hence AUC itself is the ratio under the curve and the total area. For the case in hand, we get AUC ROC as 96.4%. Following are a few thumb rules:

ellent band for the current model. But this might it becomes very important to to in-time and out-

Points to Remember:
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1. For a model which gives class as output, will be represented as a single point in ROC

with each other as the judgement needs to be g multiple metrics. For instance, model with arameter (0.8,0.2) can be coming out of the same ot be directly compared.

e were fortunate enough to get a single number ed to look at the entire curve to make conclusive decisions. It is also possible that one model performs better in some region and other performs better in other.

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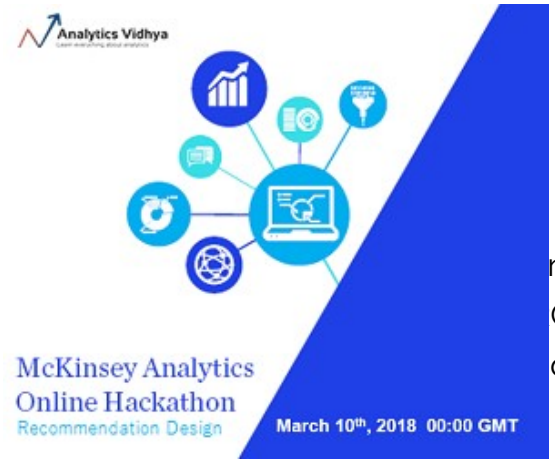
Advantages of using ROC

Why should you use ROC and not metrics like lift curve?

Lift is dependent on total response rate of the population. Hence, if the response rate of the population changes, the same model will give a different lift chart. A solution to this concern can be true lift chart (finding the ratio of lift and perfect model lift at each decile). But such ratio rarely makes sense for the business.

ROC curve on the other hand is almost independent of the response rate. This is because it has the two axis coming out from columnar calculations of confusion matrix. The numerator and denominator of both x and y axis will change on similar scale in case of response rate shift.



n classification problems. Gini coefficient can be
OC number. Gini is nothing but ratio between area
diagnol line & the area of the above triangle.

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Gini = 2*AUC – 1

the case in hand we get Gini as 92.7%.

nt ratio

portant metric for any classification predictions
assume we have 3 students who have some
are our predictions :

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A – 0.9

B – 0.5

C – 0.3

Now picture this. if we were to fetch pairs of two from these three student, how many pairs will we have? We will have 3 pairs : AB, BC, CA. Now, after the year ends we saw that A and C passed this year while B failed. No, we choose all the pairs where we will find one responder and other non-responder. How many such pairs do we have?

We have two pairs AB and BC. Now for each of the 2 pairs, the concordant pair is where the probability of responder was higher than non-responder. Whereas discordant pair is where the vice-versa holds true. In case both the probabilities were equal, we say its a tie. Let's see what happens in our case :

– Concordant

C – Discordant

cases in this example. Concordant ratio of more
d model. This metric generally is not used when
get etc. It is primarily used to access the model's
how many to target are again taken by KS / Lift
charts.

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or (RMSE)

metric used in regression problems. It follows an
nd follow a normal distribution. Here are the key

wers this metric to show large number deviations.
helps to deliver more robust results which
prevents cancelling the positive and negative error values. In other words, this metric aptly displays the plausible magnitude of error term.

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3. It avoids the use of absolute error values which is highly undesirable in mathematical calculations.
4. When we have more samples, reconstructing the error distribution using RMSE is considered to be more reliable.
5. RMSE is highly affected by outlier values. Hence, make sure you've removed outliers from your data set prior to using this metric.
6. As compared to mean absolute error, RMSE gives higher weightage and punishes large errors.

RMSE metric is given by:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (Predicted_i - Actual_i)^2}{N}}$$

tions.

other method to check the model performance. prominent in data science. But, with arrival of ed with more robut methods of model selection. **ion**.

ally a evaluation metric which is used openly to communicate model accuracy. But, the result of cross validation provides good analytic intuitive result to generalize the performance of a model.

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n in detail.

of cross validation. Due to busy schedules, these pate in data science competitions. Long time back, I participated in TFI Competition on Kaggle. Without delving into my competition performance, I would like to show you the dissimilarity between my public and private leaderboard score.

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Here is an example of scoring on Kaggle!

For TFI competition, following were three of my solution and scores (Lesser the better) :

Submission	Files	Public Score	Private Score	Selected?
Mon, 04 May 2015 12:59:31	submissio _all_wit _sai3.csv	1649776.86428	1809956.02878	☑
	ubmissio _all_wit	1651071.47287	1802503.24607	☐
	ubmissio _all.csv	1677138.71291	1795007.23155	☑

(https://www.analyticsvidhya.com/wp-content/uploads/2015/05/kagglescores.png)

(https://datahack.analyticsvidhya.com/contest/mckinsey-analytics-online-hackathon-

(https://datahack.analyticsvidhya.com/contest/datahack-premier-league/?utm_source=AVblog_sidebottom)

vhich has the worst Public score turned to be the here were more than 20 models above the "submission_all.csv" as my final entry (which really phenomenon ? The dissimilarity in my public and r-fitting.

ou model become highly complex that it starts s no value to model, but only inaccuracy.

s how you can know if a solution is an over-fit or not before we actually know the test results.

The concept : Cross Validation

Cross Validation is one of the most important concepts in any type of data modelling. It simply says, try to leave a sample on which you do not train the model and test the model on this sample before finalizing the model.

wp-content/uploads/2015/05/validation.png)

Above diagram shows how to validate model with in-time sample. We simply divide the population into 2 samples, and build model on one sample. Rest of the population is used for in-time validation.

Could there be a negative side of the above approach?

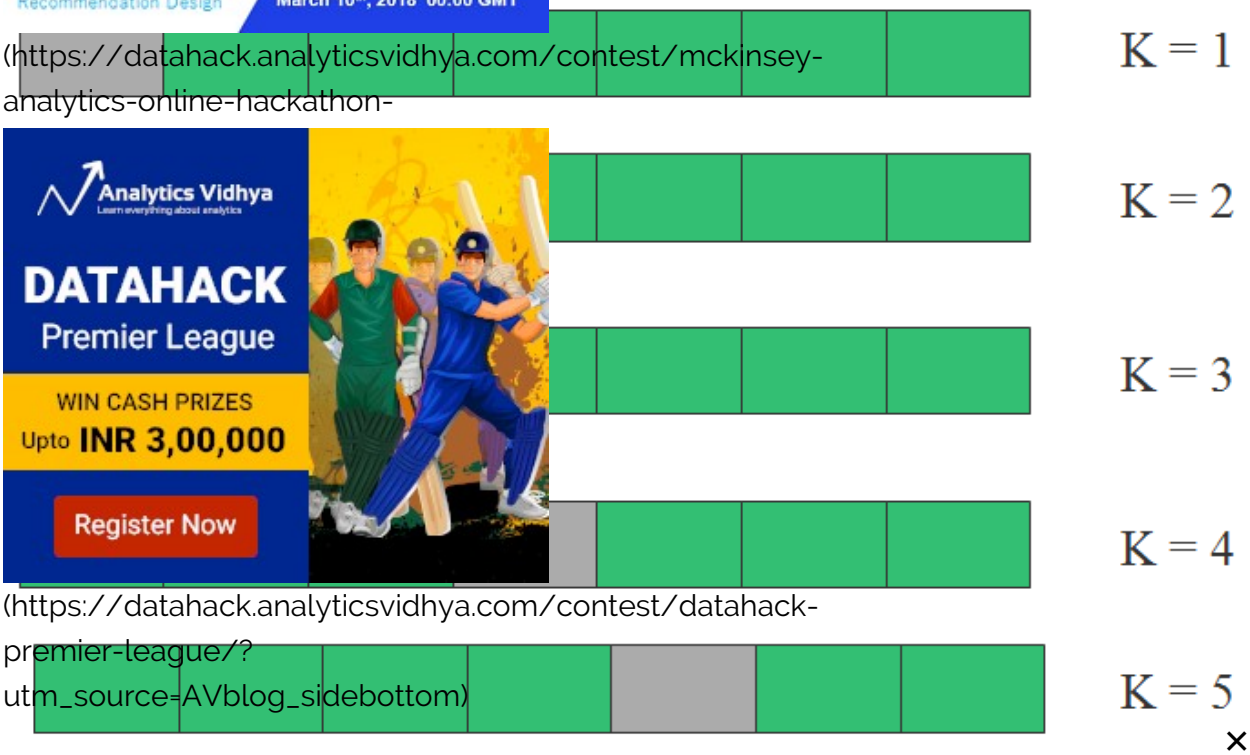
I believe, a negative side of this approach is that we loose a good amount of data from training the model. Hence, the model is very high bias. And this won't give best estimate for the coefficients. So what's the next best option?

What if, we make a 50:50 split of training population and the train on first 50 and validate on rest 50. Then, we train on the other 50, test on first 50. This way we train the model on the entire population, however on 50% in one go. This reduces bias because of sample selection to some extent but gives a smaller sample to train the model on.

ss validation.

k-fold from 2-fold cross validation. Now, we will

dation work.



(https://www.analyticsvidhya.com/wp-content/uploads/2015/05/kfolds.png)

This is a 7-fold cross validation.

Here's what goes on behind the scene : we divide the entire population into 7 equal samples. Now we train models on 6 samples (Green boxes) and validate on 1 sample (grey box). Then, at the second iteration we train the model with a different sample held as validation. In 7 iterations, we have basically built model on each sample and is a way to reduce the selection bias and reduce ce we have all the 7 models, we take average of odels is best.

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(non over-fit) model?

d to check whether a model is an overfit or not. If he k times modelling are close to each other and the mean of metric is highest. In a Kaggle competition, you might rely more on the cross validation score and not on the Kaggle public score. This way you will be sure ance.

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th any model?

ry similar. Here is how you code a k-fold in

```
from sklearn import cross_validation model = RandomForestClassifier (n_estimators=100)
#Simple K-Fold cross validation. 5 folds.

#(Note: in older scikit-learn versions the "n_folds" argument is named "k".)

cv = cross_validation.KFold(len(train), n_folds=5, indices=False)

results = []

# "model" can be replaced by your model object #"Error_function" can be replaced by the error function of your analysis
```

```
for traincv, testcv in cv:

            probas = model.fit(train[traincv], target[traincv]).predict_proba
(train[testcv])
```


```
function )

lidated results

results).mean() )
```

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This is the tricky part. We have a trade off to choose k.

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tion bias but low variance in the performances.

on bias but high variance in the performances.

milar to our 50-50 example. Here we build model
ach time. But as the validation is a significant
performance is minimal.

k = number of observations (n) : This is also known as "Leave one out". We have n samples and modelling repeated n number of times leaving only one observation out for cross validation. Hence, the selection bias is minimal but the variance of validation performance is very large.

Generally a value of k = 10 is recommended for most purpose.

End Notes

Measuring the performance on training sample is point less. And leaving a in-time validation batch aside is a waste of data. K-Fold gives us a way to use every singe lection bias to a good extent. Also, K-fold cross elling technique.

his article are some of the most used metrics of ession problems.

lassification and regression problem ? Have you r any kind of analysis? Did you see any significant dation? Do let us know your thoughts about this guide in the comments section below.

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al skills and test your potential?
athons
idhya.com/contest/all) and compete
ll over the world.

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(https://www.analyticsvidhya.com/blog/2016/02/7-important-model-evaluation-error-metrics/?share=reddit&nb=1)

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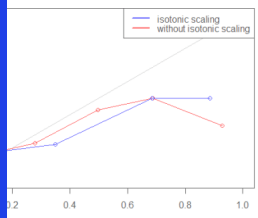

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on to Minimize LogLoss

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December 29, 2015

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Author

Tavish Srivastava (https://www.analyticsvidhya.com/blog/author/tavish1/)

I am Tavish Srivastava, a post graduate from IIT Madras in Mechanical Engineering. I have more than two years of work experience in Analytics. My experience ranges from hands on analytics in a developing country like India to convince banking partners with analytical solution in matured market like US. For last two and a half years I have contributed to various sales strategies, marketing strategies and Recruitment strategies in both Insurance and Banking industry.

This is article is quiet old now and you might not get a prompt response from the author. We would request you to post this comment on Analytics Vidhya **Discussion portal** (https://discuss.analyticsvidhya.com/) to get your queries resolved.

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this would be useful. It is a good matrix to identify better model in case of multi class classification.
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/WWW.ANALYTICSVIDHYA.COM/BLOG/2016/02/7-IMPORTANT-MODEL--105911)

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Hi,
Great post thanks. Just in number one confusion matrix you miscalculated the negative predicted value.
It is not 1.7% but 98.3%. Same for specificity (59.81% instead of 40.19%). Since you reuse this example for ROC, your curve is actually better. But anyways your argument still holds. Nicely presented.

venkata ramana reddy kanduia says:
FEBRUARY 21, 2016 AT 10:20 AM (HTTPS://WWW.ANALYTICSVIDHYA.COM/BLOG/2016/02/7-IMPORTANT-MODEL-EVALUATION-ERROR-METRICS/#COMMENT-105996)

Its a good information

Saniav.S says:

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rticle.Thank you..

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on matrix, negative predicrive value is 951/967 or not? Is there an error in confusion matrix example or in formulas?
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idhya) says:

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egative predictive value should be 98.3454%. Can

MARCH 2, 2016 AT 8:03 AM (HTTPS://WWW.ANALYTICSVIDHYA.COM/BLOG/2016/02/7-IMPORTANT-MODEL-EVALUATION-ERROR-METRICS/#COMMENT-106471)

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Hi Tavish,
Thanks again , for this valuable article.
It would be great , if along with this very informative explanation , you can also provide how to code it , preferably in R.
Thanks.

Mac Lover says:

MARCH 12, 2016 AT 8:54 AM (HTTPS://WWW.ANALYTICSVIDHYA.COM/BLOG/2016/02/7-IMPORTANT-MODEL-EVALUATION-ERROR-METRICS/#COMMENT-107161)

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build a model. Get feedback from metrics, make improvements and …

Sudhindra says:

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-114691)

al Models and the application scenarios please for a

/WWW.ANALYTICSVIDHYA.COM/BLOG/2016/02/7-IMPORTANT-MODEL-
-118493)

Hi, can you further explain this "Lift is dependent on total response rate of the population"? Is this only applicable when you are able to correctly predict 100% of the 1st (or more) deciles?

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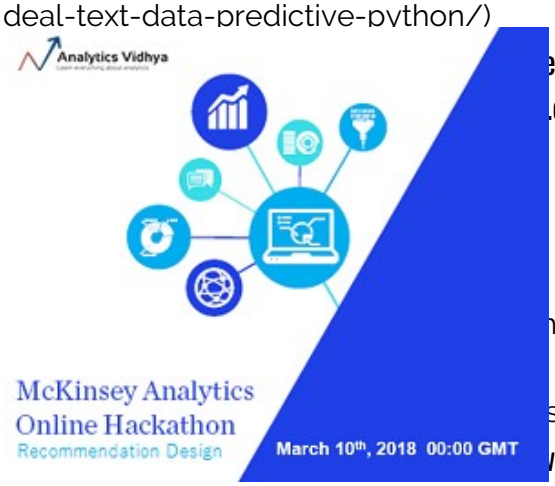

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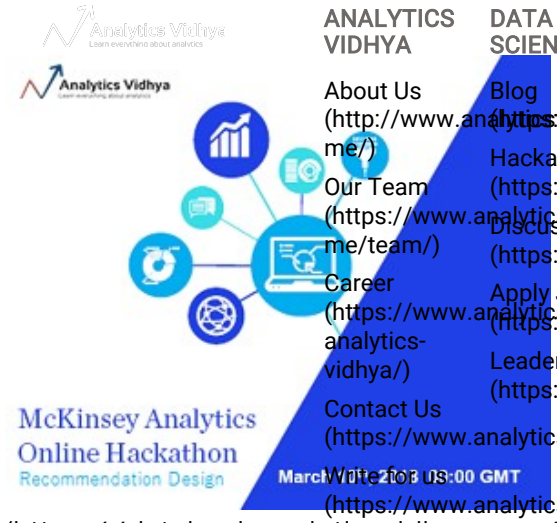

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