Credit Card Fraud Detection Capstone Project - Report

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Abstract

This is the final assignment for the Harvard Data Science Professional Program taught by the famous Prof. of Biostatistics Rafael Irizarry from Harvard University. In this capstone project, we have to choose a dataset and we have to analyze it and perform our machine learning tasks in complete autonomy without external help.

Contents

1 Executive Summary

It is important that credit card companies are able to recognize fraudulent credit card transactions so that customers are not charged for items that they did not purchase. The datasets contains transactions made by credit cards in September 2013 by european cardholders.

Due to imbalancing nature of the data, many observations could be predicted as False Negative, in this case Legal Transactions instead of Fraudolent Transaction. For example, a model that predict always **0** (Legal) can archieve an Accuracy of **99.8**. For that reason, the metric used for measuring the score is the **Area Under The Precision-Recall Curve (AUCPR)** instead of the traditional AUC curve. A desiderable result is an AUCPR at least greater than **0.85**.

For archieving the task of classifying credit card fraud detection, they are trained several algorithms such as Naive Bayes Classifier, KNN, SVM, Random Forest, GBM, XGBoost and LightGBM.

In this analysis, a XGBoost Model is capable of an AUCPR of **0.8623** and this is great!

2 Exploratory Data Analysis

2.1 The Dataset

This dataset presents transactions that occurred in two days, where we have **492 frauds** out of **284,807 transactions**. The dataset is highly unbalanced, the positive class (frauds) account for 0.172% of all transactions.

The dataset contains only numerical input variables which are the result of a PCA transformation. Unfortu- nately, due to confidentiality issues, we cannot provide the original features and more background information about the data. Features V1, V2, . . . V28 are the principal components obtained with PCA, the only features which have not been transformed with PCA are 'Time' and 'Amount'.

Source

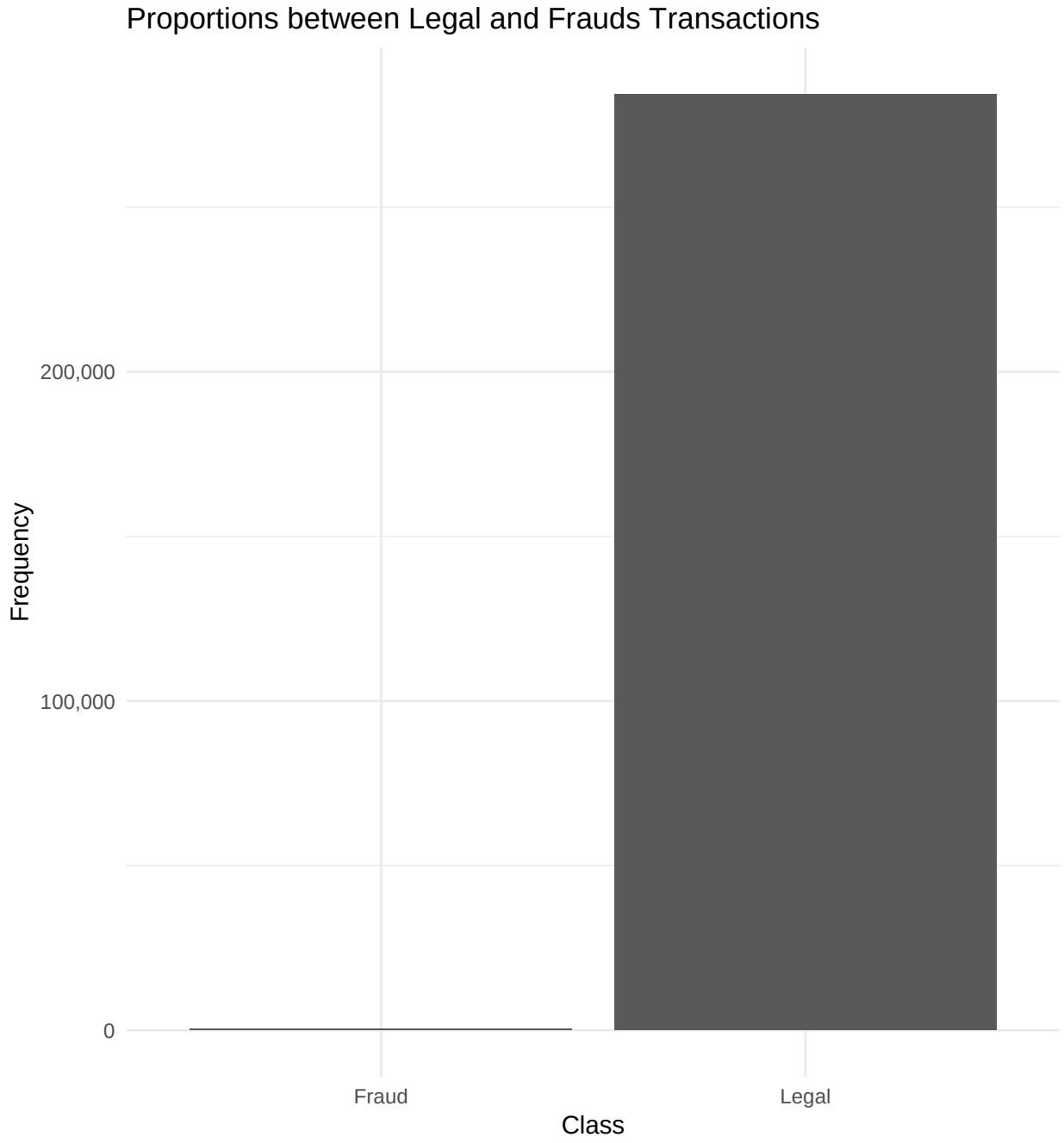
https://www.kaggle.com/mlg-ulb/creditcardfraud

Dimensions

Length	Columns
284807	31

Imbalanced Dataset

This is a very imbalanced dataset. It means that there are few rows that represent a class. In this case, only **492** transactions are frauds, represented by **1** and **284315**are not, represented by **0**.



Class	Count
0	284315
1	492

Missing Values

As the table below suggests, there aren't missing values in this dataframe.

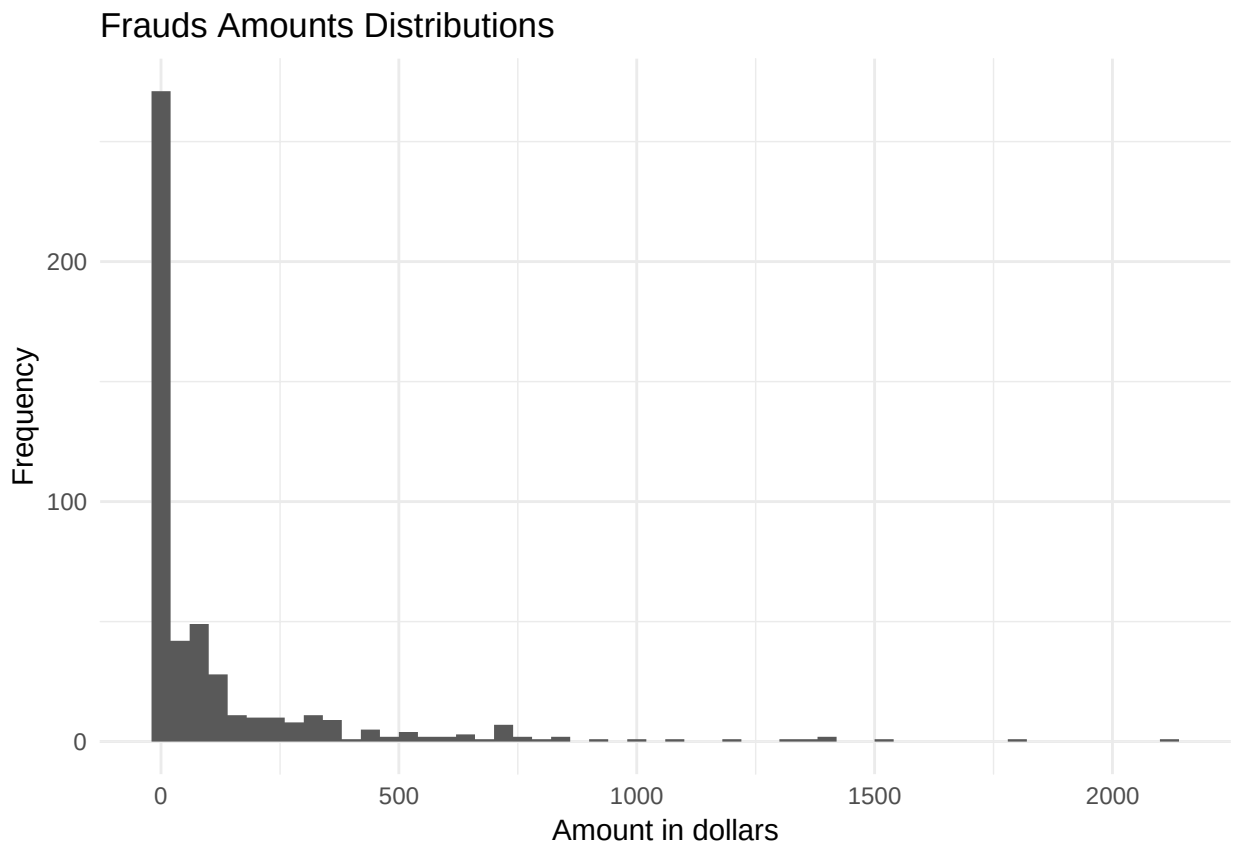
	Missing Values
Time	0
V1	0
V2	0
V3	0
V4	0
V5	0
V6	0
V7	0
V8	0
V9	0
V10	0
V11	0
V12	0
V13	0
V14	0
V15	0
V16	0
V17	0
V18	0
V19	0
V20	0
V21	0
V22	0
V23	0
V24	0
V25	0
V26	0
V27	0
V28	0
Amount	0
Class	0

First 10 Rows of `creditcard` dataset

Time	V1	V2	V3	V4	V5	V28	Amount	Class
0	-1.3598071	-0.0727812	2.5363467	1.3781552	-0.3383208	-0.0210531	149.62	0
0	1.1918571	0.2661507	0.1664801	0.4481541	0.0600176	0.0147242	2.69	0
1	-1.3583541	-1.3401631	1.7732093	0.3797796	-0.5031981	-0.0597518	378.66	0
1	-0.9662717	-0.1852260	1.7929933	-0.8632913	-0.0103089	0.0614576	123.50	0
2	-1.1582331	0.8777368	1.5487178	0.4030339	-0.4071934	0.2151531	69.99	0
2	-0.4259659	0.9605230	1.1411093	-0.1682521	0.4209869	0.0810803	3.67	0
4	1.2296576	0.1410035	0.0453708	1.2026127	0.1918810	0.0051678	4.99	0
7	-0.6442694	1.4179635	1.0743804	-0.4921990	0.9489341	-1.0853392	40.80	0
7	-0.8942861	0.2861572	-0.1131922	-0.2715261	2.6695987	0.1424043	93.20	0
9	-0.3382618	1.1195934	1.0443666	-0.2221873	0.4993608	0.0830756	3.68	0

Frauds Amount Distributions

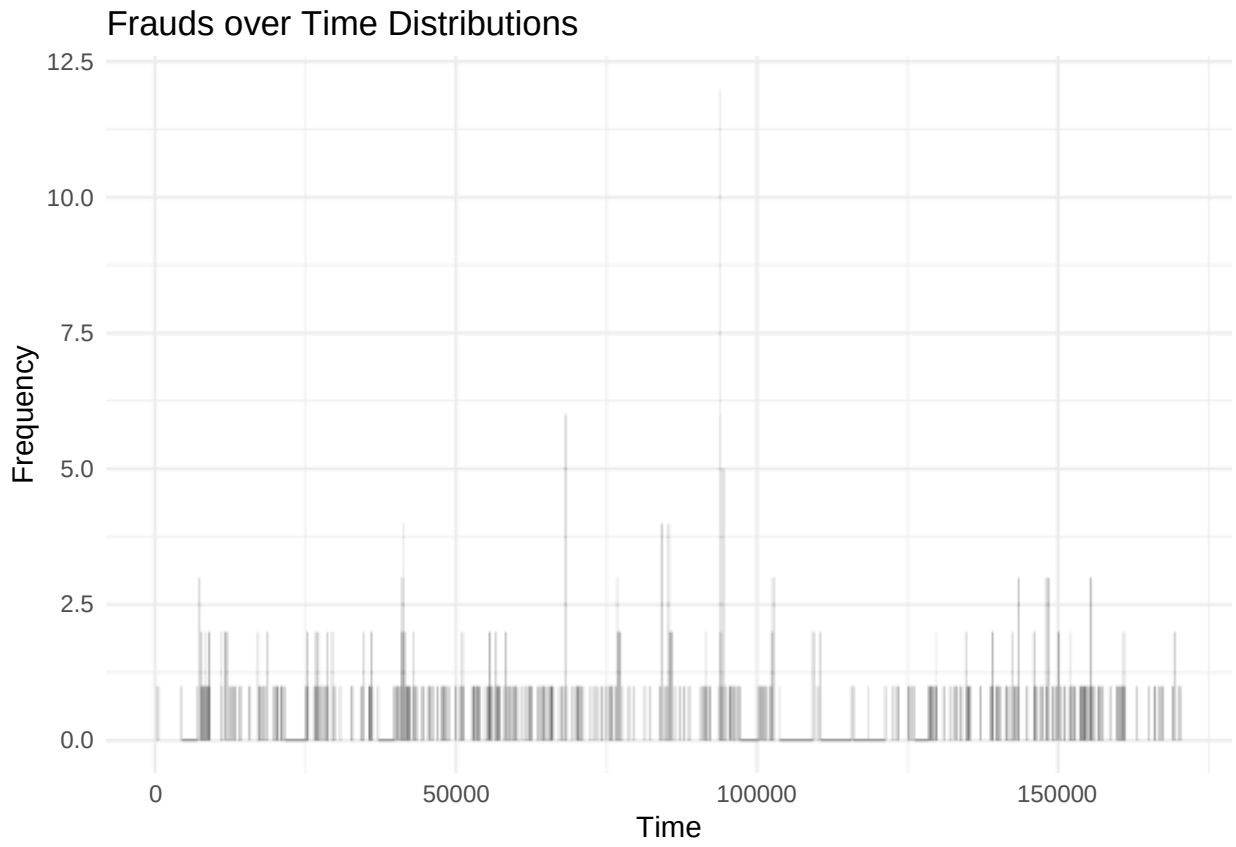
Small amount of money, less or equal of one dollar are scammed more frequently.



Amount	count
1.00	113
0.00	27
99.99	27
0.76	17
0.77	10
0.01	5
2.00	4
3.79	4
0.68	3
1.10	3

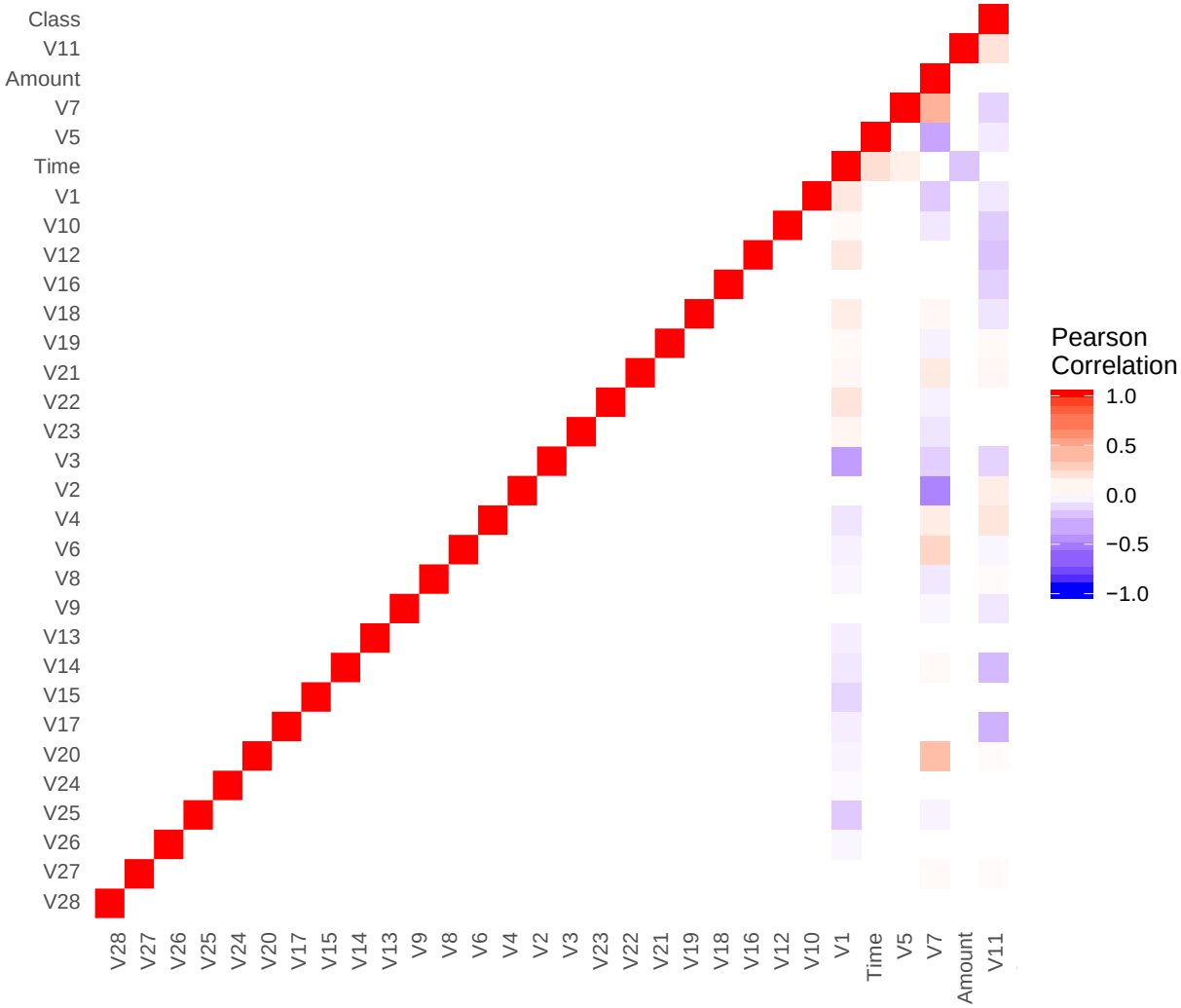
Frauds over Time Distribution

There aren't correlation between `time` and frauds. A fraud can happen anytime. It seems not particularly useful for the modelling phase. The correlation matrix below, confirms this assumpion.



Time	count
68207	6
84204	4
85285	4
93853	4
93860	4
93879	4
94362	4
148053	2
406	1
472	1

Correlations between each variables



3 Data Pre-Processing

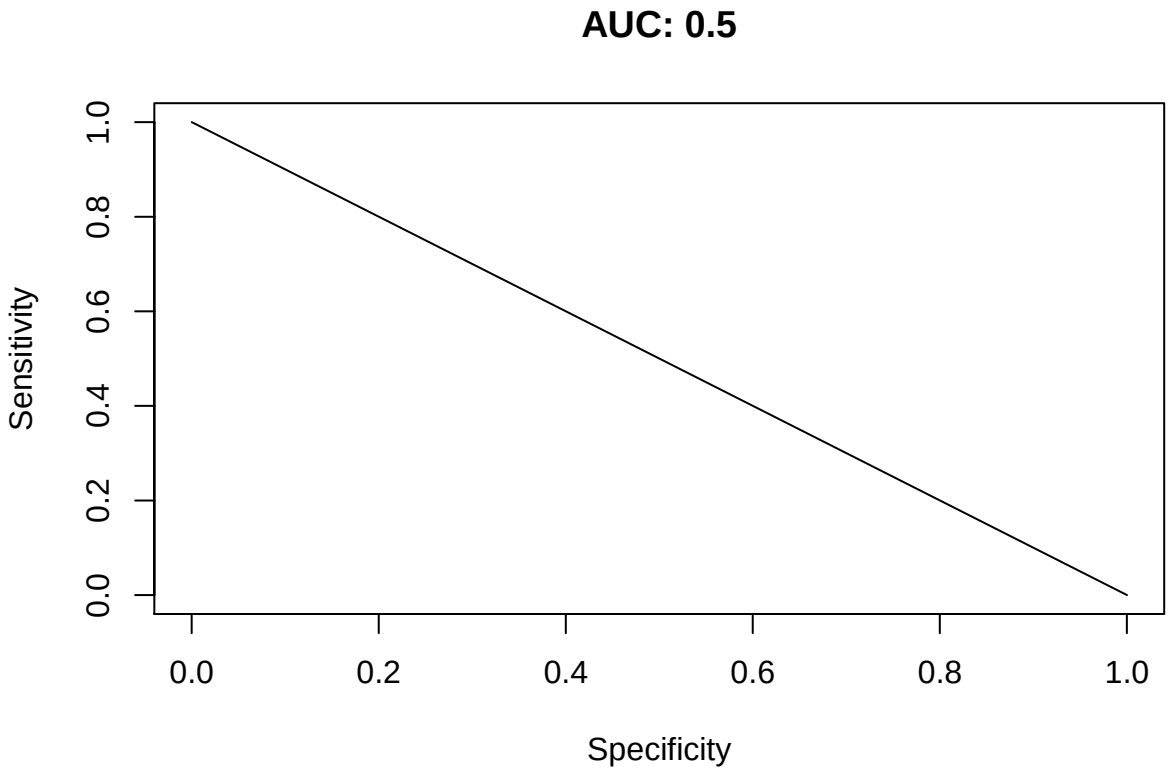
Before continuing to build models, It have to do a little data pre-processing: 1.Remove the

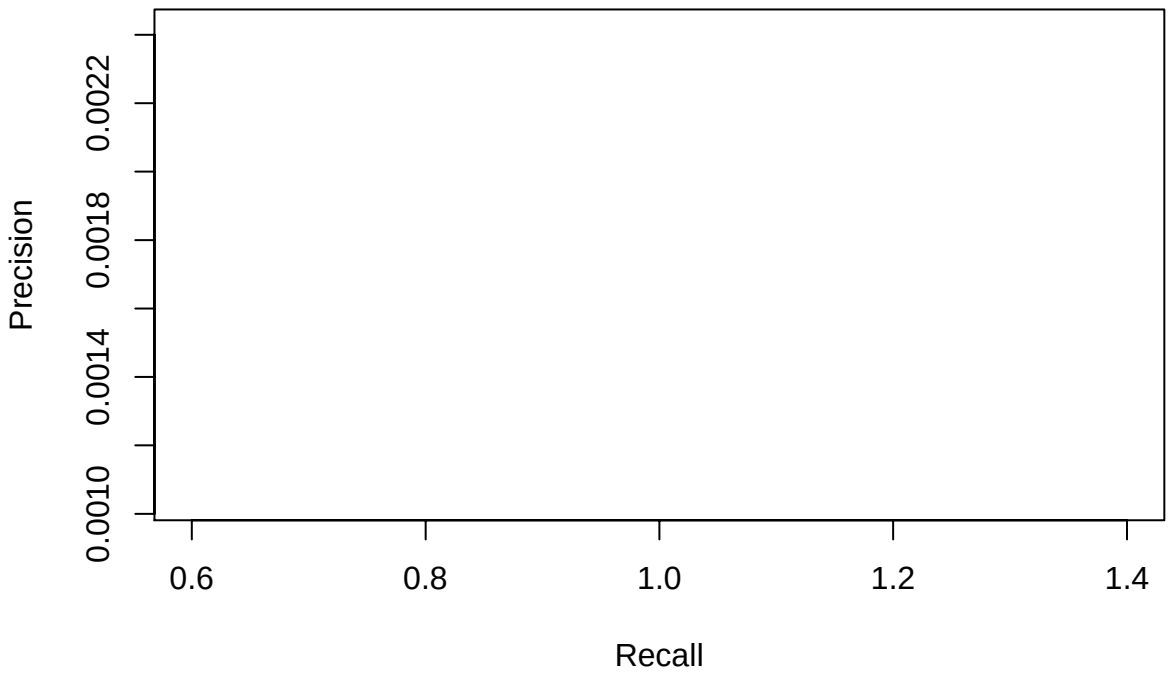
"Time" column from the dataset. It isn't useful.
2.Split the dataset into train, test, cv dataset.

4 Analysis - Models Building and Comparison

4.1 Naive Baseline Algorithm - Predict Always "Legal" Transaction

Predicting always "Legal" transaction can archieve an impressive accuracy of **99.8** and an AUC of **0.92**. Because the recall and precision are **0**, it is impossible to compute the AUCPR, so that is **0**.

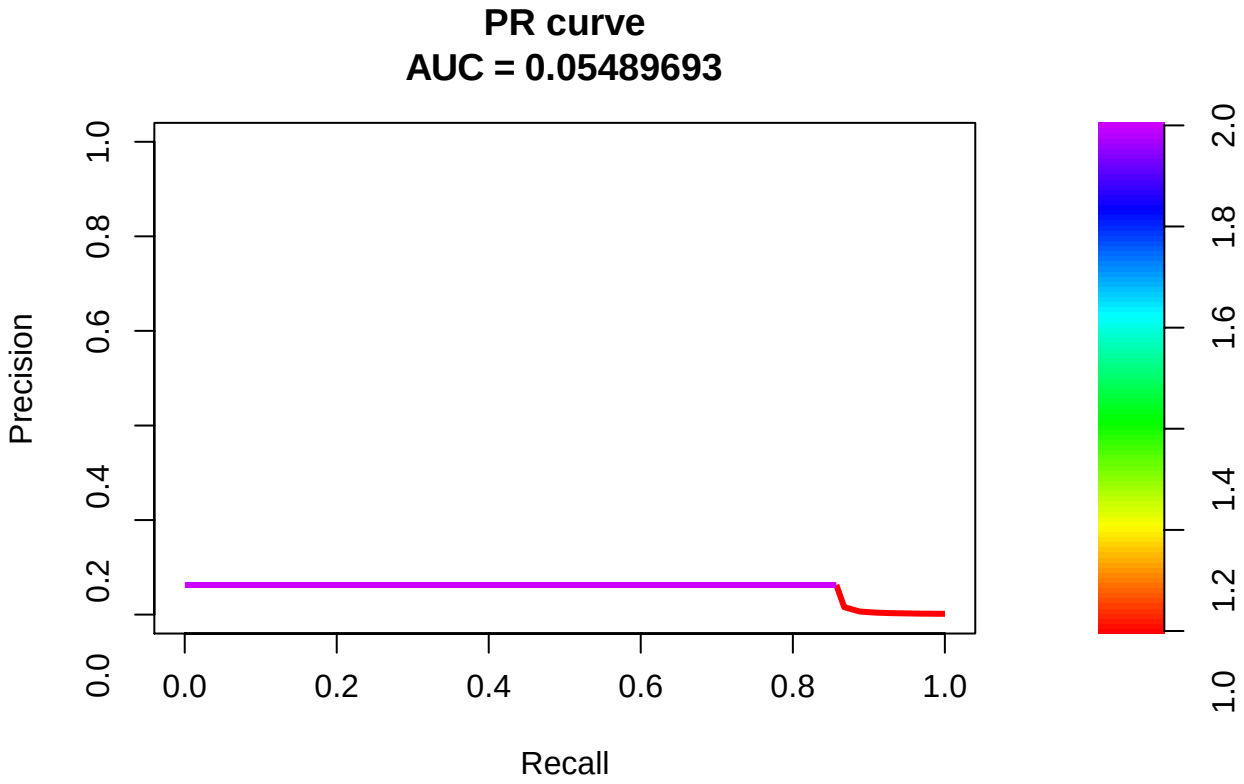


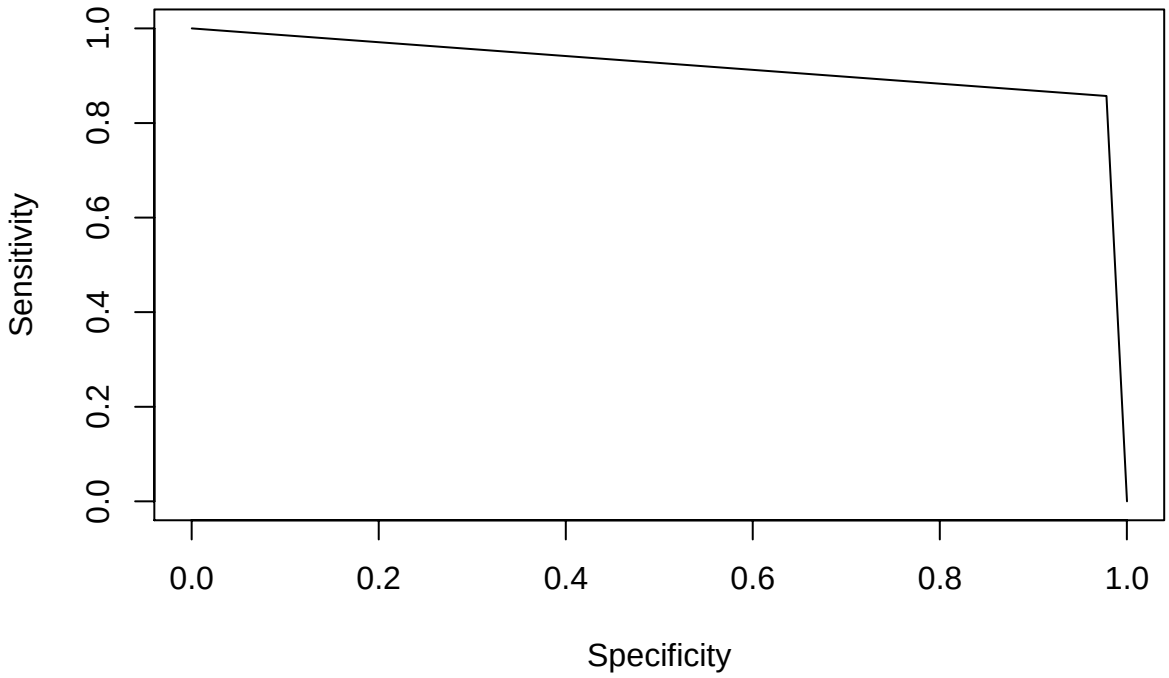


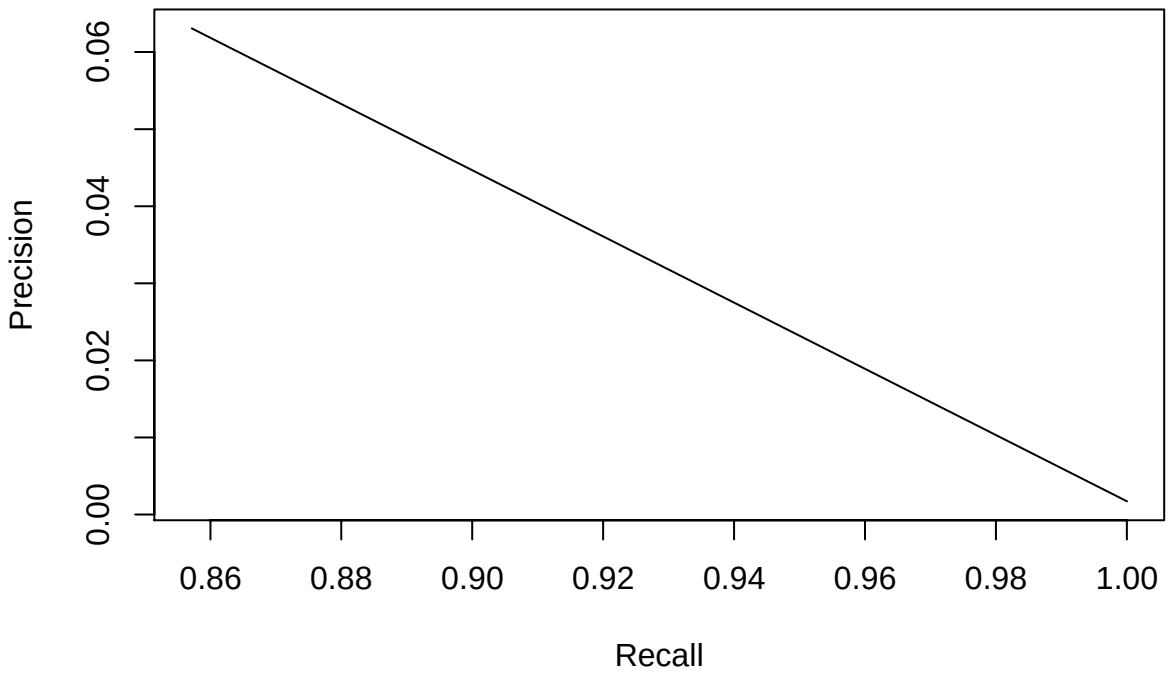
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5	0

4.2 Naive Bayes

A step forward is building a Naive Bayes Classifier. The performance improve a little bit: AUC is **0.92** and finally the there is an AUCPR of **0.05**. It is a poor result according to the metric of interest and it is easy to improve.



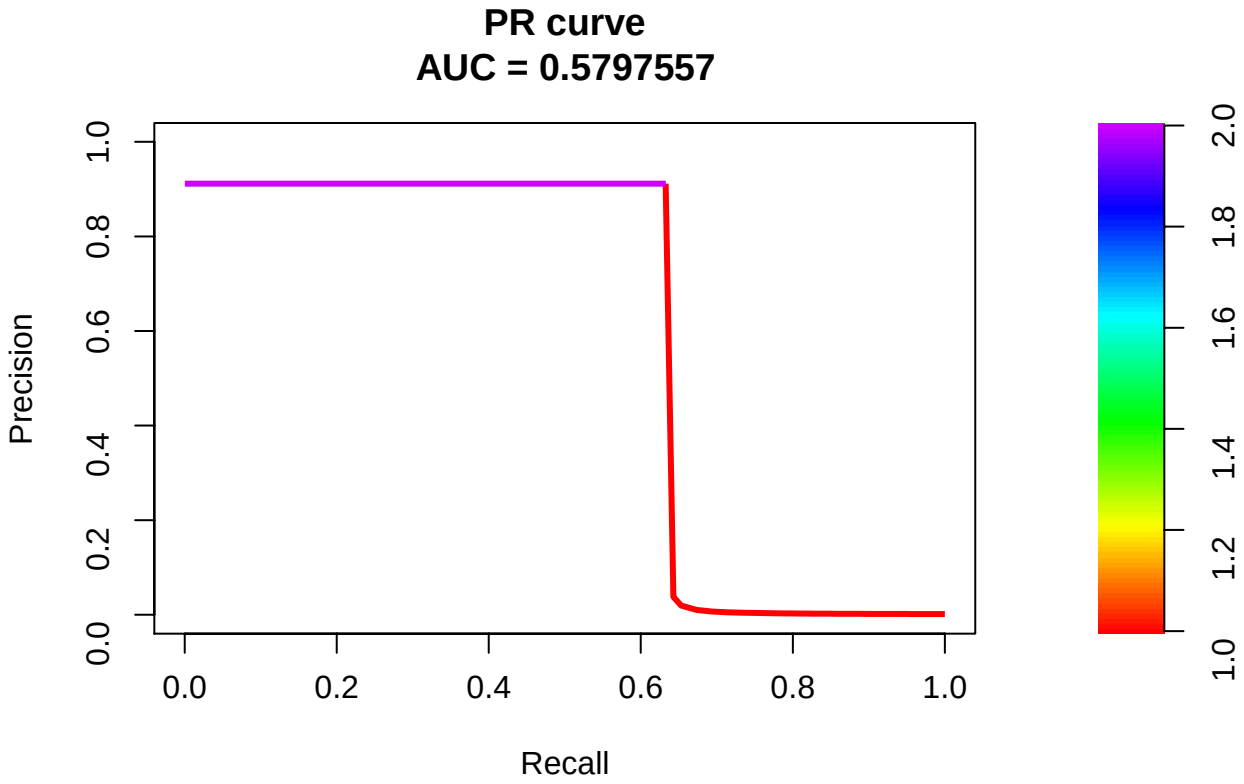

AUC: 0.917597684660626
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity

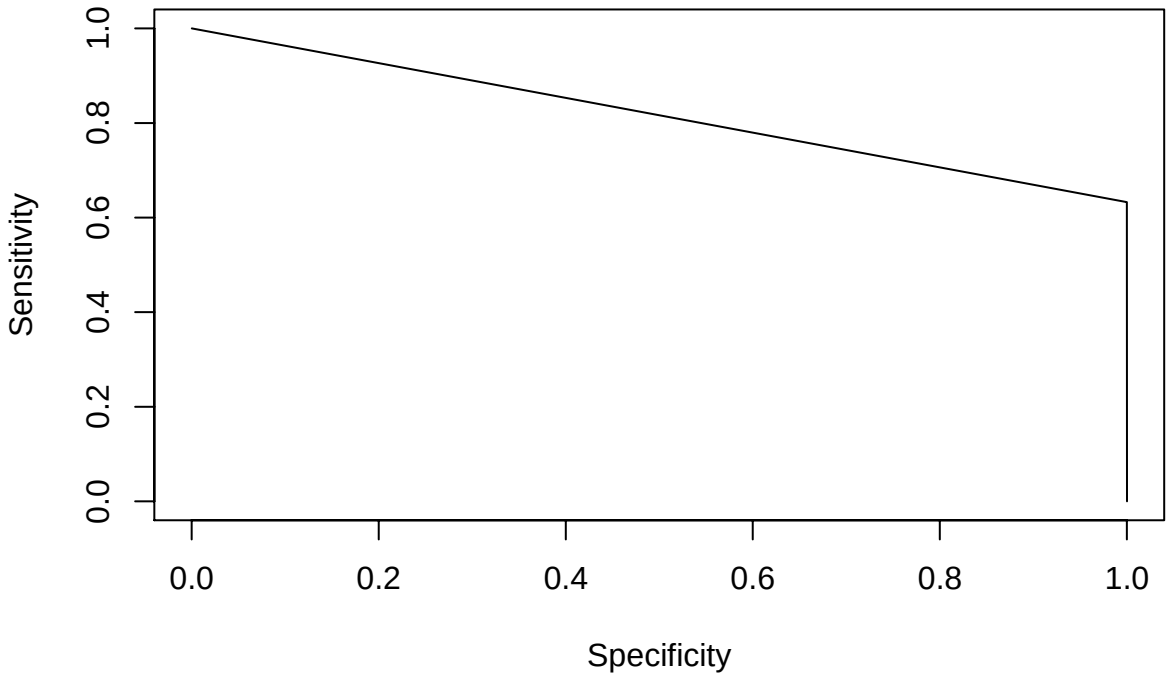


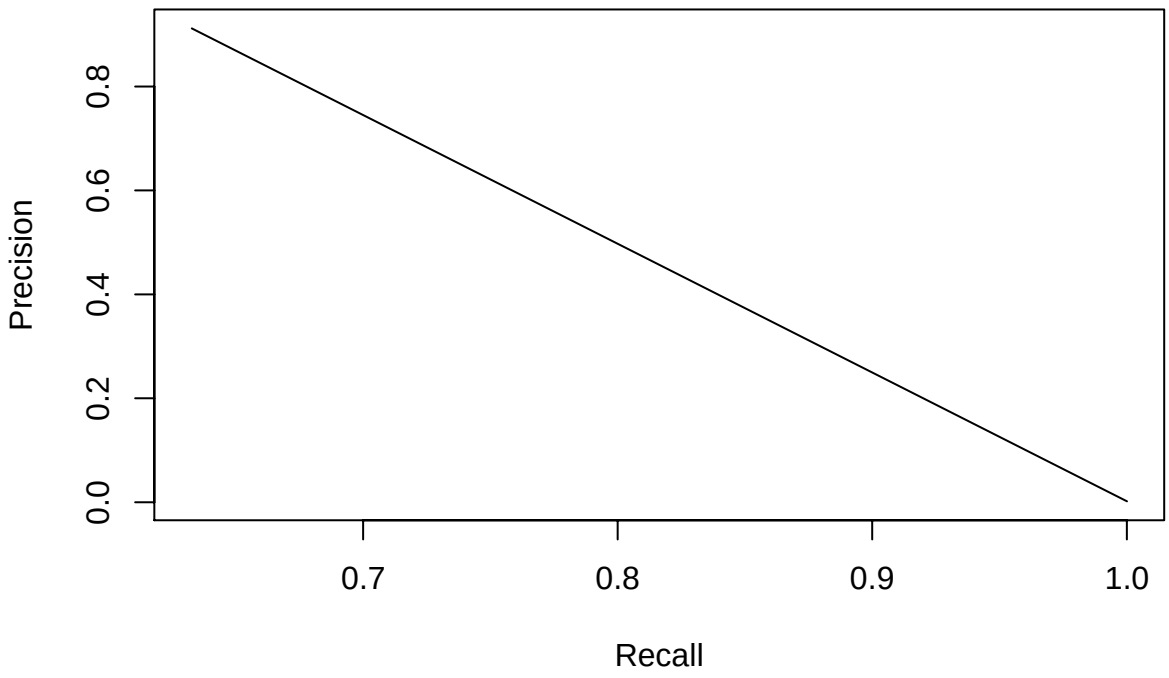
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969

4.3 KNN - K-Nearest Neighbors

A KNN Model with k=5 can achieve a significant improvement in respect to the previous models, as regard AUCPR of **0.58** at the expense of a little drop off AUC, that is **0.81**.



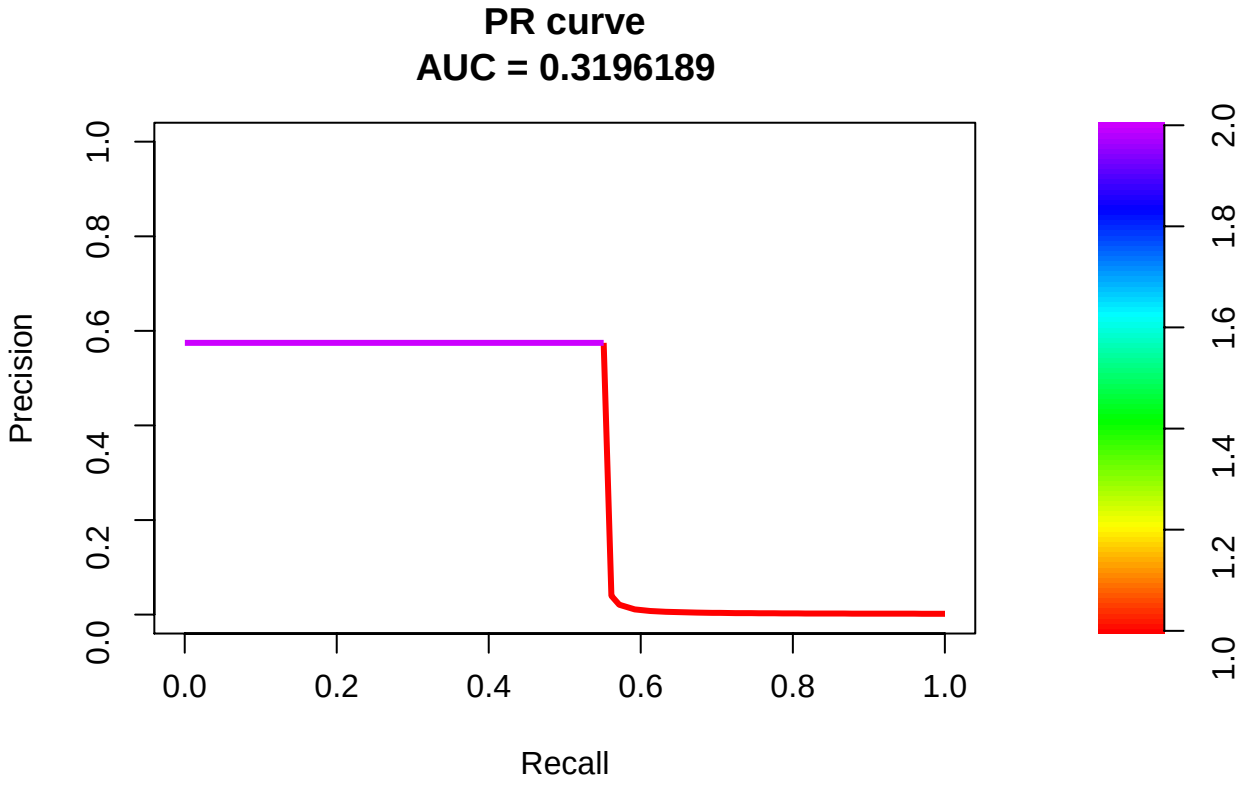

AUC: 0.816273772228058
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0

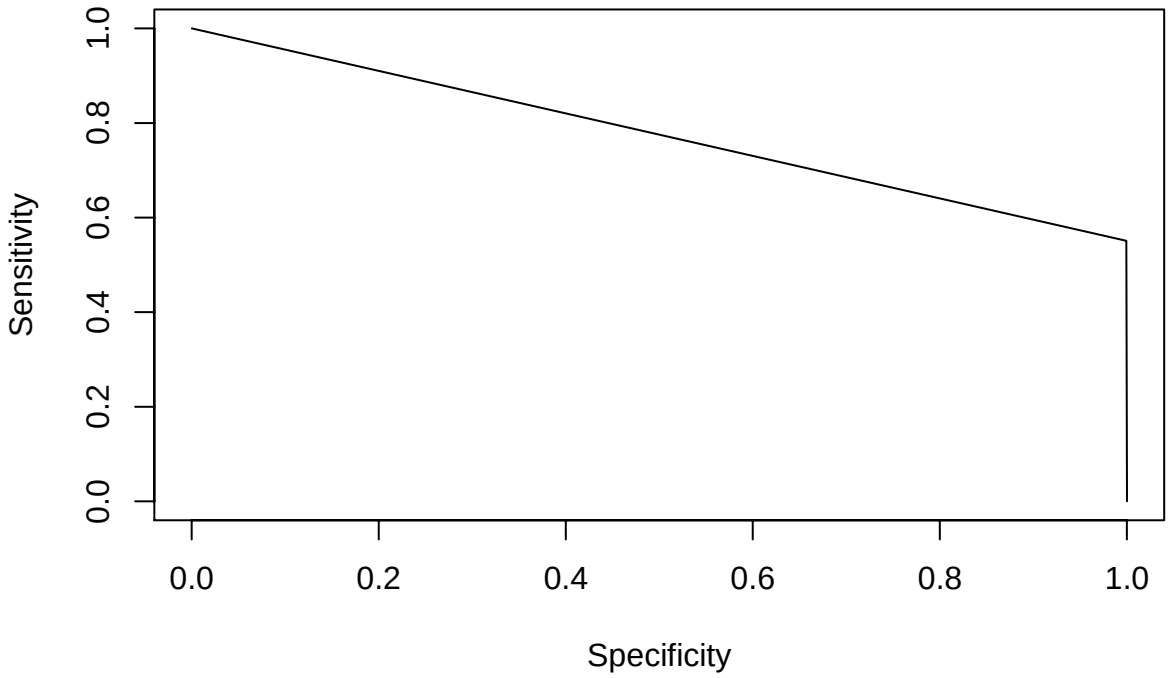


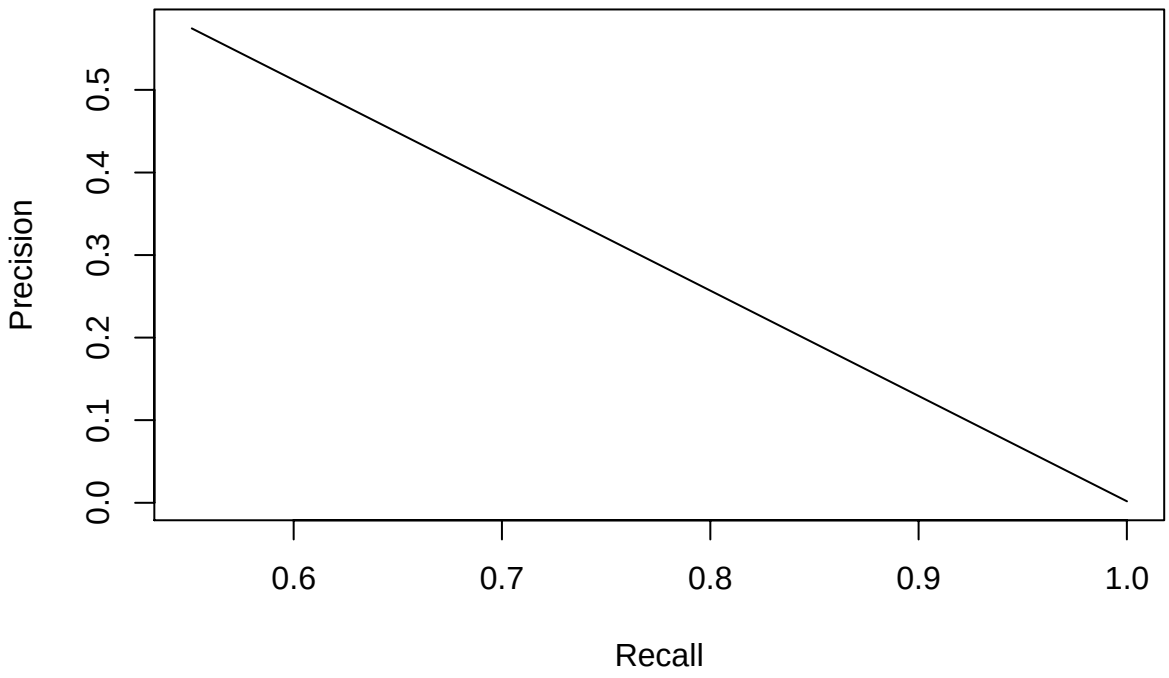
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557

4.4 SVM - Support Vector Machine

The SVM Model with a Sigmoid Kernel represent a step back on all fronts because the AUCPR is **0.32** and AUC is **0.77**.



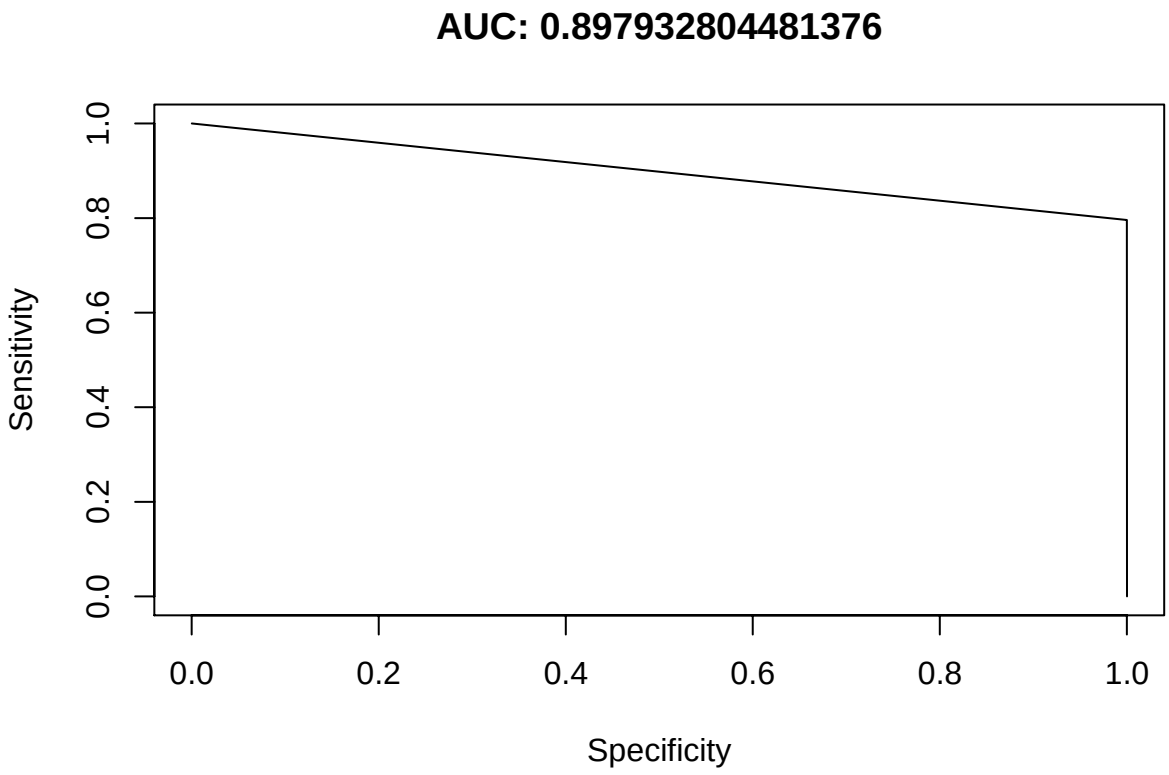

AUC: 0.775158481520389
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0

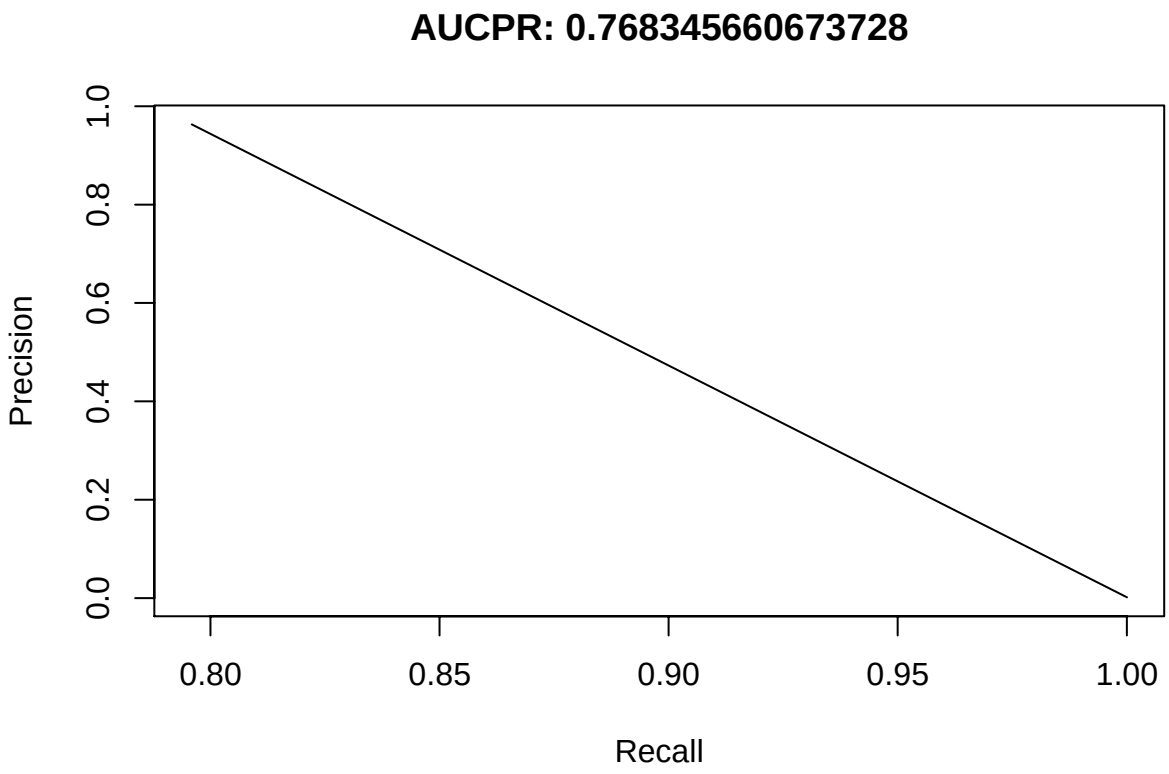


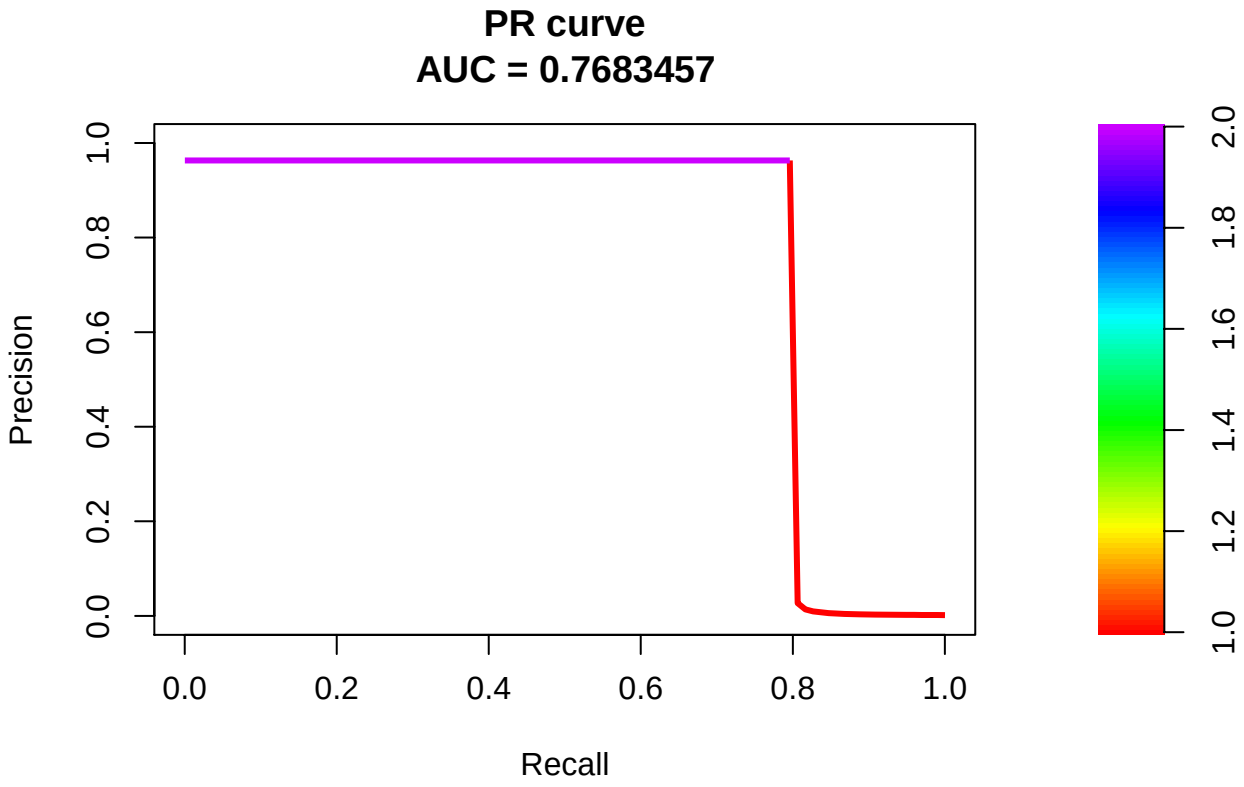
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557
SVM - Support Vector Machine	0.7751585	0.3196189

4.5 Random Forest

The ensemble methods are capable of a significant increase in performance. At the expense of another little drop off in terms of AUC (**0.9**) respect to the Naive Bayes model, there is a huge step forward in terms of AUCPR, that is **0.77**. This model doesn't reach the desidered performance (AUCPR > 0.85), but it's close to it. As the plot and the table below suggest, there are few predictors like **V17**, **V12** and **V14** that are particularly useful for classifying a fraud.




AUCPR: 0.768345660673728
Precision
0.0
0.2
0.4
0.6
0.8
1.0
0.80
0.85
0.90
0.95
1.00
Recall

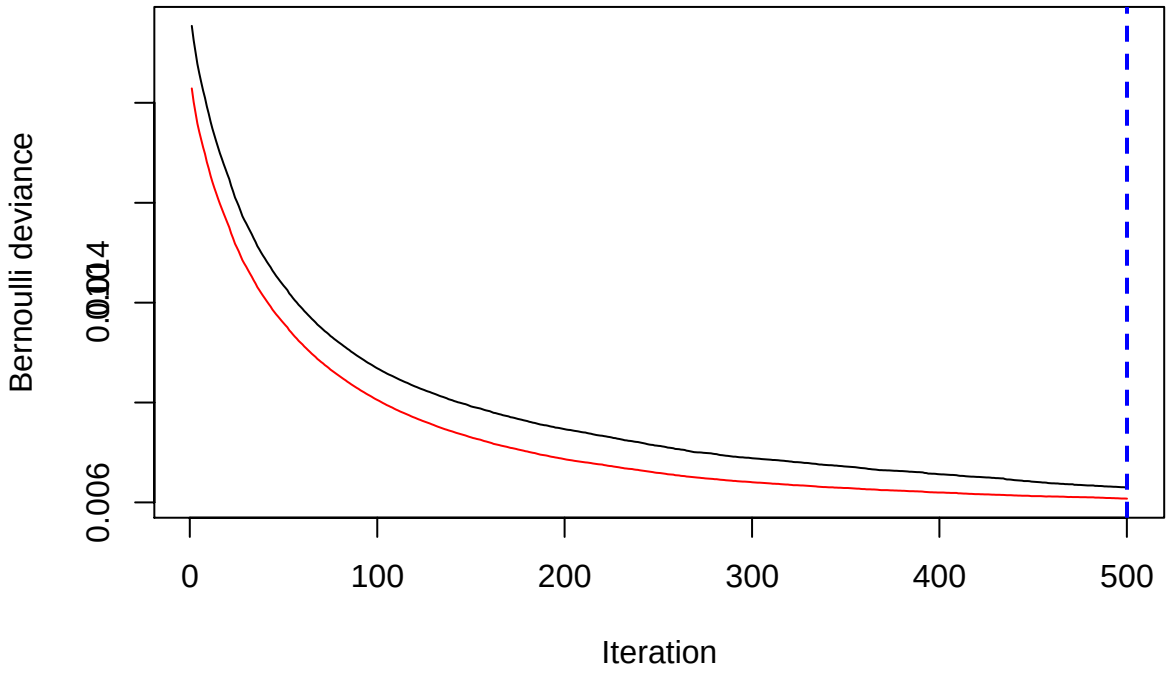


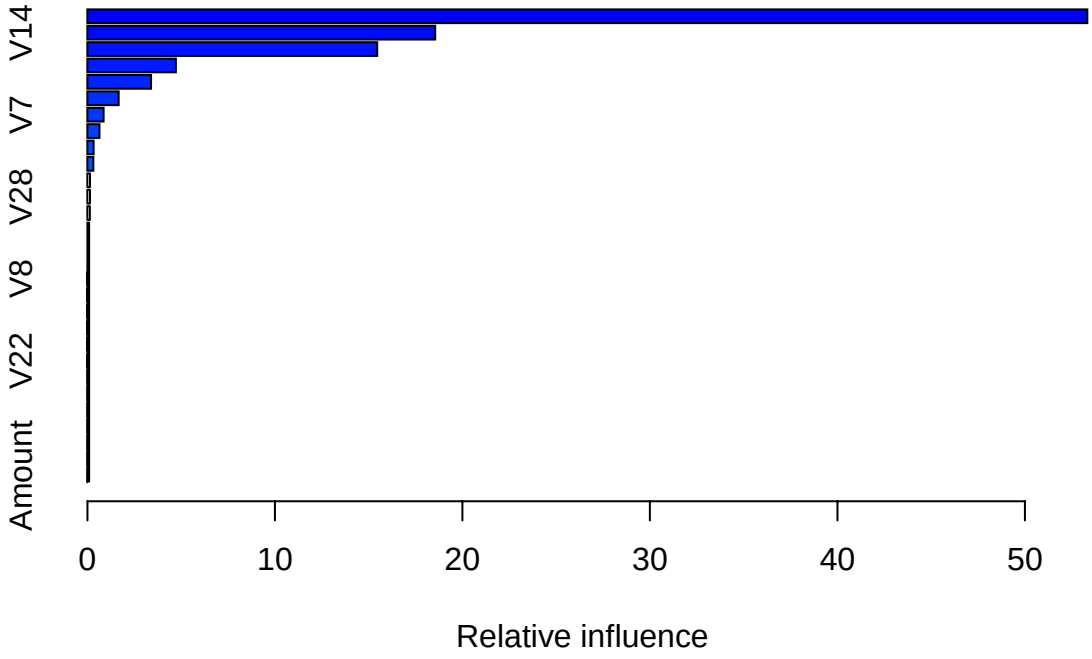
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557
SVM - Support Vector Machine	0.7751585	0.3196189
Random Forest	0.8979328	0.7683457

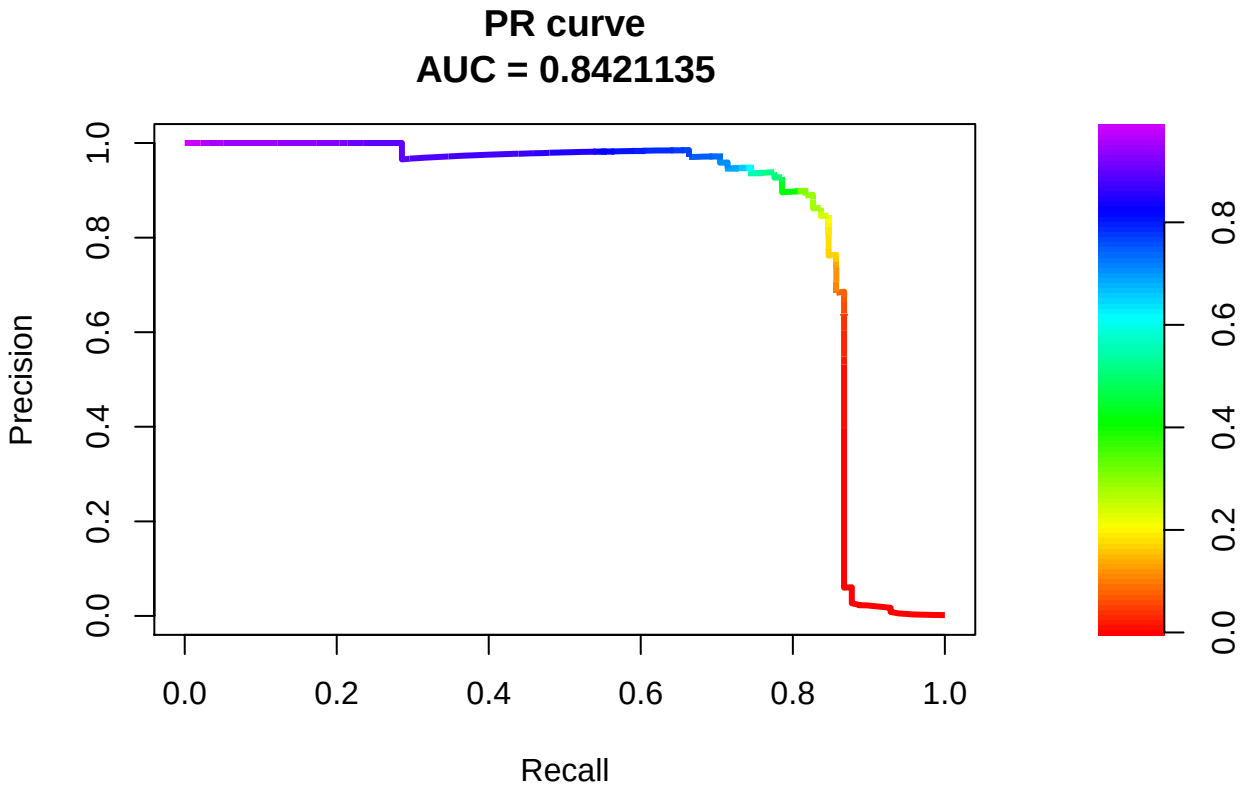
	MeanDecreaseGini
V1	8.708982
V2	7.784292
V3	8.985490
V4	17.257080
V5	7.772203
V6	8.821890
V7	19.072039
V8	7.013489
V9	23.520504
V10	43.772484
V11	44.997607
V12	73.056009
V13	6.829304
V14	63.479173
V15	6.388524
V16	40.124086
V17	105.084852
V18	16.236771
V19	8.041600
V20	8.359602
V21	10.723973
V22	5.886333
V23	4.705090
V24	6.127916
V25	5.290926
V26	10.888757
V27	9.216603
V28	6.266699
Amount	7.974071

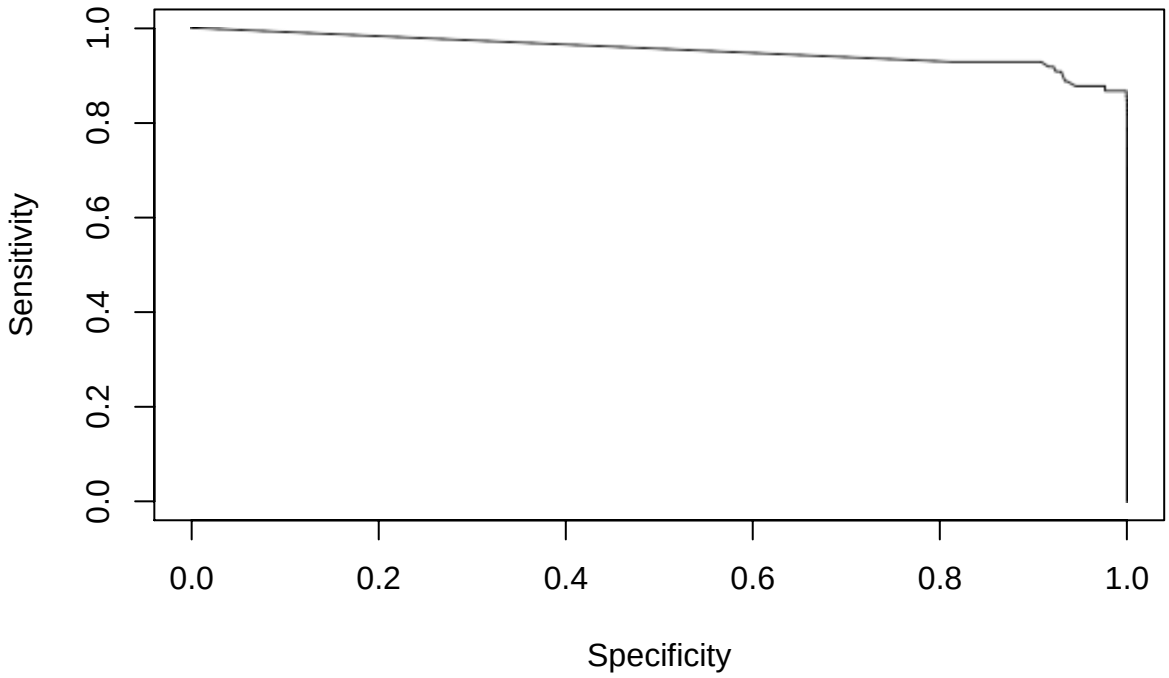
4.6 GBM - Generalized Boosted Regression

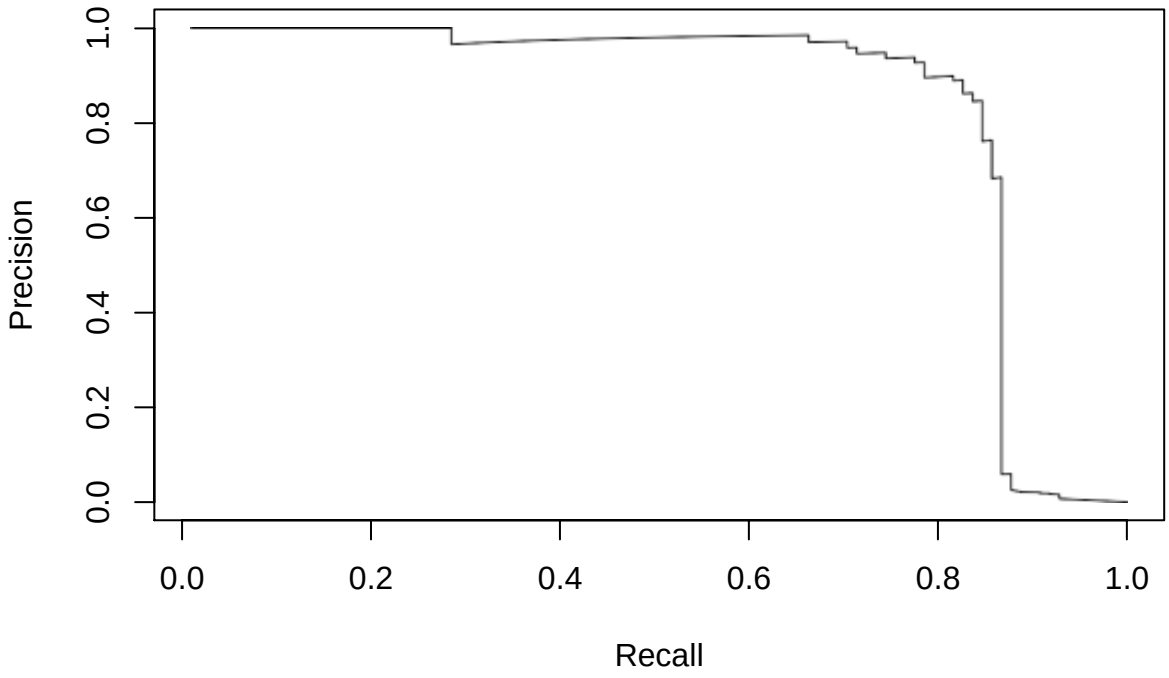
The GBM performance are really good: with an AUC of **0.95** and AUCPR of **0.94**, It doesn't achieve the target for a breath. As the Random Forest model shows, the **V17** and **V14** are still relevant to predict a fraud.




V14
V7
V28
V8
V22
Amount
0
10
20
30
40
50
Relative influence


PR curve
AUC = 0.8421135
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8


AUC: 0.953857319795125
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity



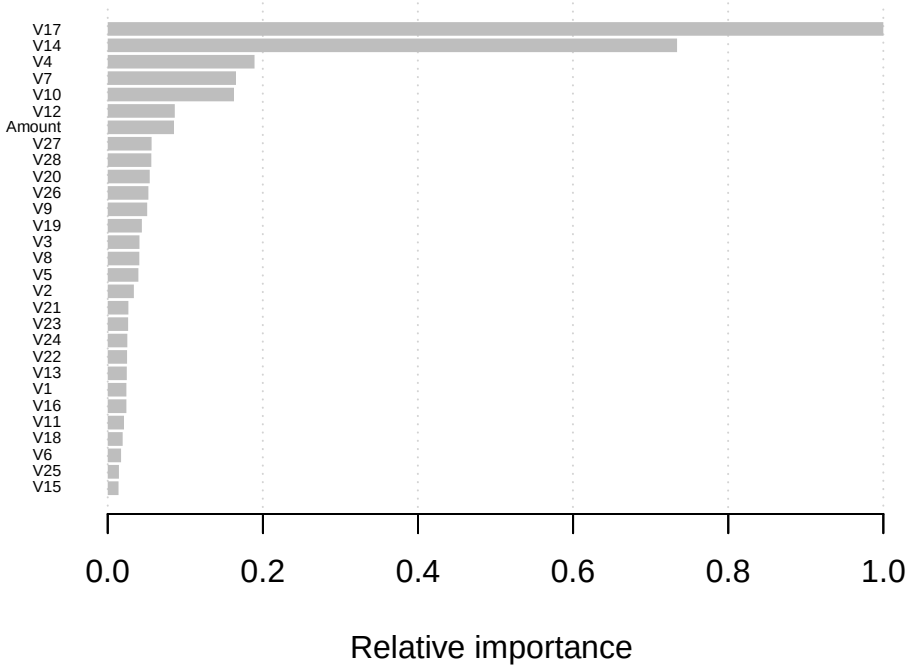
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557
SVM - Support Vector Machine	0.7751585	0.3196189
Random Forest	0.8979328	0.7683457
GBM - Generalized Boosted Regression	0.9538573	0.8421135

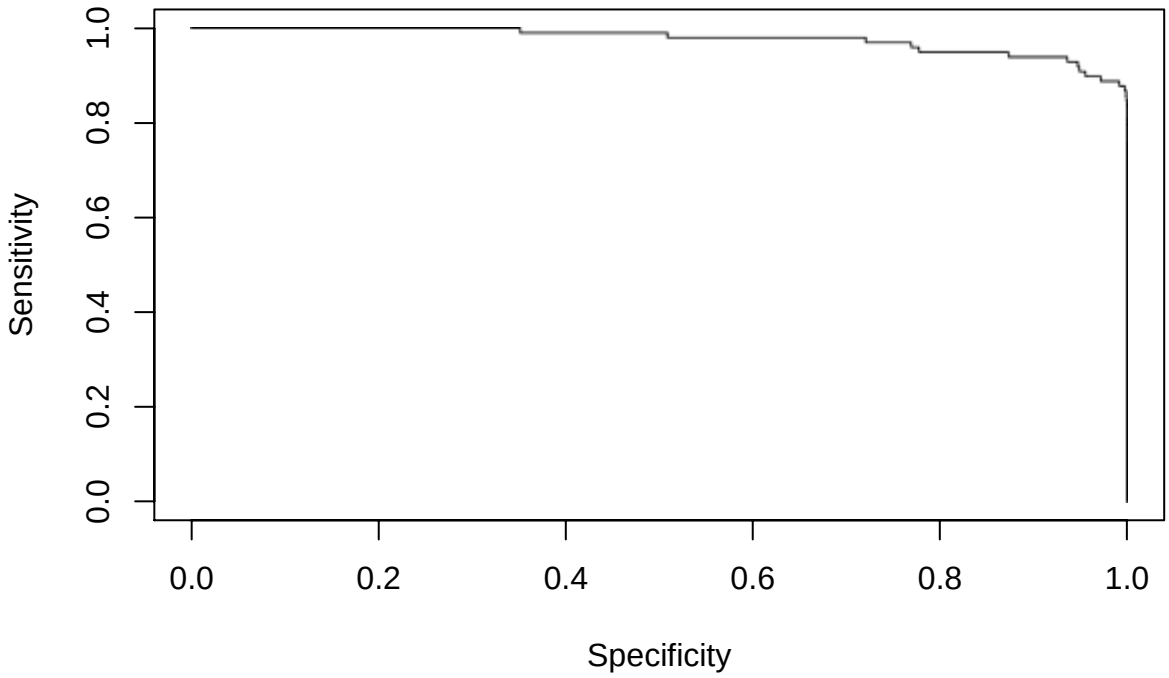
	var	rel.inf
V17	V17	53.3300209
V14	V14	18.5530357
V12	V12	15.4550412
V10	V10	4.7219307
V20	V20	3.3949817
V11	V11	1.6650329
V7	V7	0.8612551
V9	V9	0.6445507
V4	V4	0.3346926
V26	V26	0.3156347
V3	V3	0.1467431
V28	V28	0.1435442
V18	V18	0.1392624
V16	V16	0.0918682
V27	V27	0.0711635
V25	V25	0.0489084
V8	V8	0.0172958
V5	V5	0.0155866
V6	V6	0.0147381
V15	V15	0.0134430
V21	V21	0.0114564
V22	V22	0.0074806
V19	V19	0.0019186
V1	V1	0.0004148
V2	V2	0.0000000
V13	V13	0.0000000
V23	V23	0.0000000
V24	V24	0.0000000
Amount	Amount	0.0000000

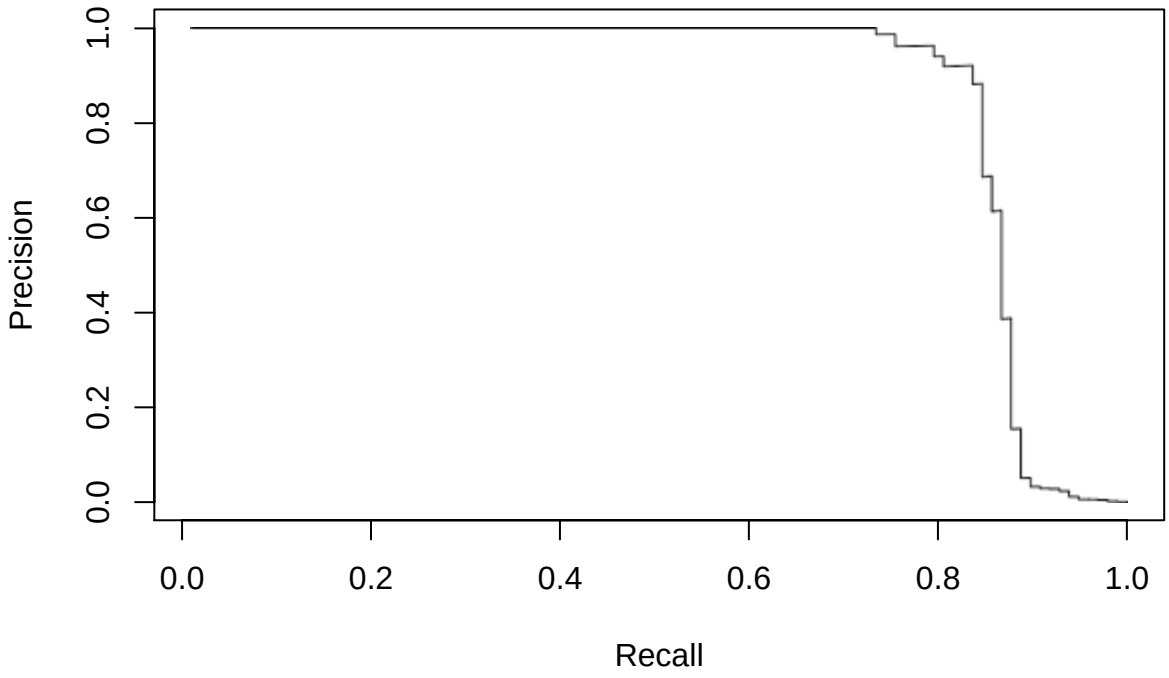
4.7 XGBoost

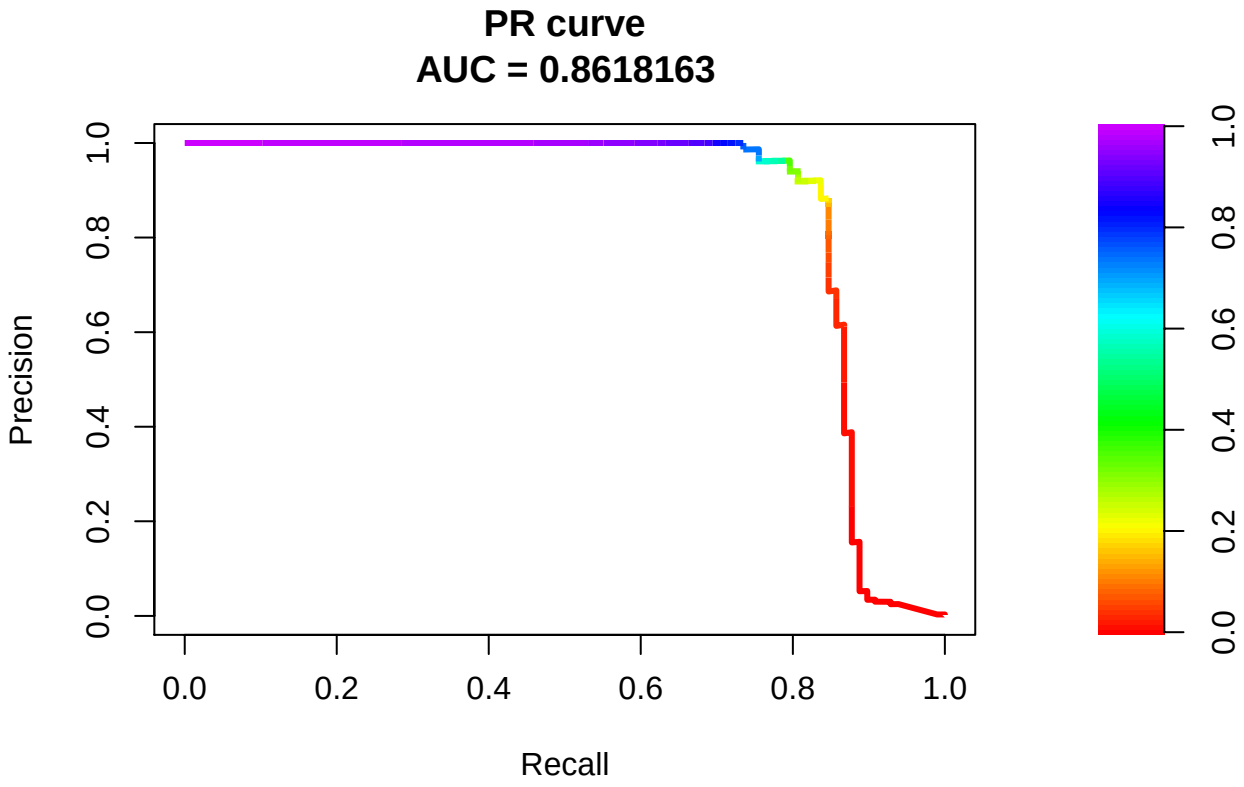
XGBoost are a top class model. It always stays on TOP5 (or wins them) in every competitions on Kaggle and in this case, its' very fast to train and its performance are awesome. With an AUC of **0.98** and an AUCPR of **0.86** it reach and overtake the desidered performance. As the previous model shown, **V17** and **V14** are still relevant to predict a fraud.

```
## [1]  test-aucpr:0.658215 cv-aucpr:0.651097
## Multiple eval metrics are present. Will use cv_aucpr for early stopping. ##
Will train until cv_aucpr hasn't improved in 40 rounds.
##
## [101] test-aucpr:0.857385 cv-aucpr:0.877270 ##
[201]  test-aucpr:0.862116  cv-aucpr:0.886406  ##
Stopping. Best iteration:
## [190] test-aucpr:0.861816 cv-aucpr:0.887686
```




AUC: 0.977038976961337
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity


AUCPR: 0.86181626247754
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0



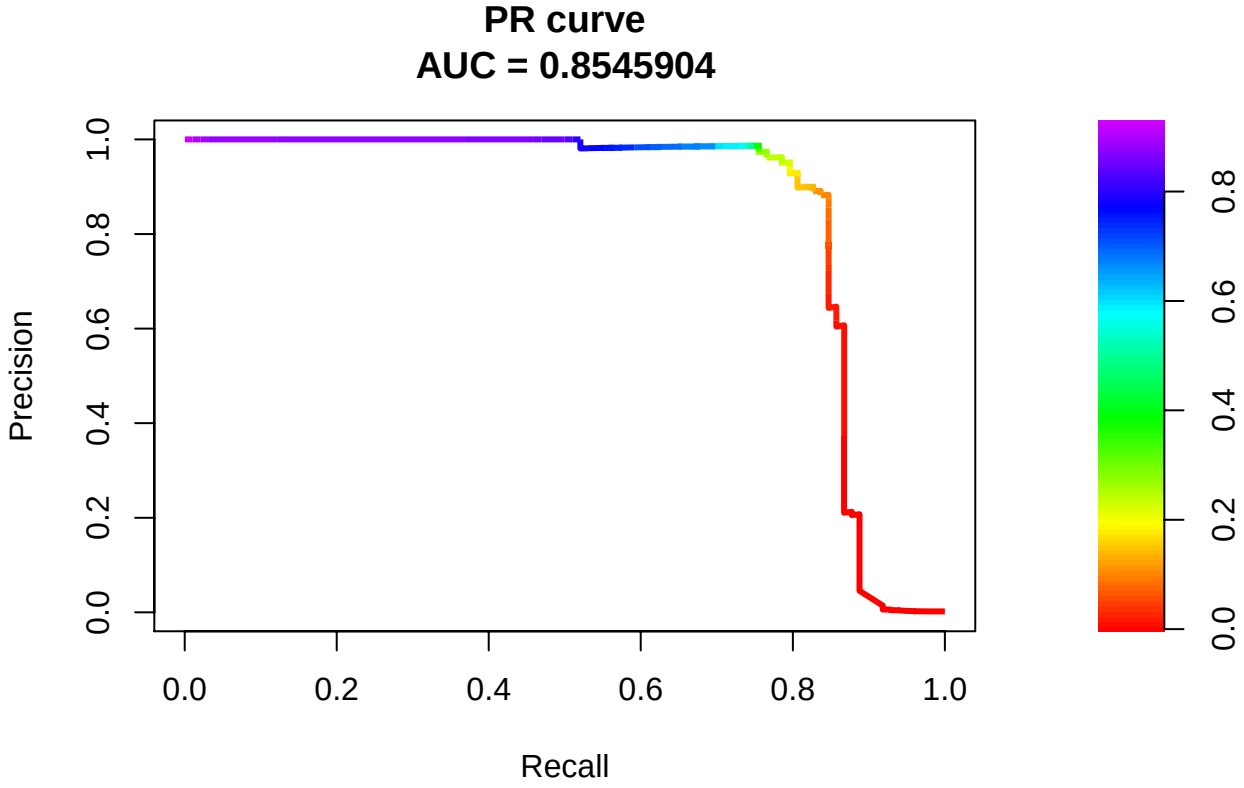
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557
SVM - Support Vector Machine	0.7751585	0.3196189
Random Forest	0.8979328	0.7683457
GBM - Generalized Boosted Regression	0.9538573	0.8421135
XGBoost	0.9770390	0.8618163

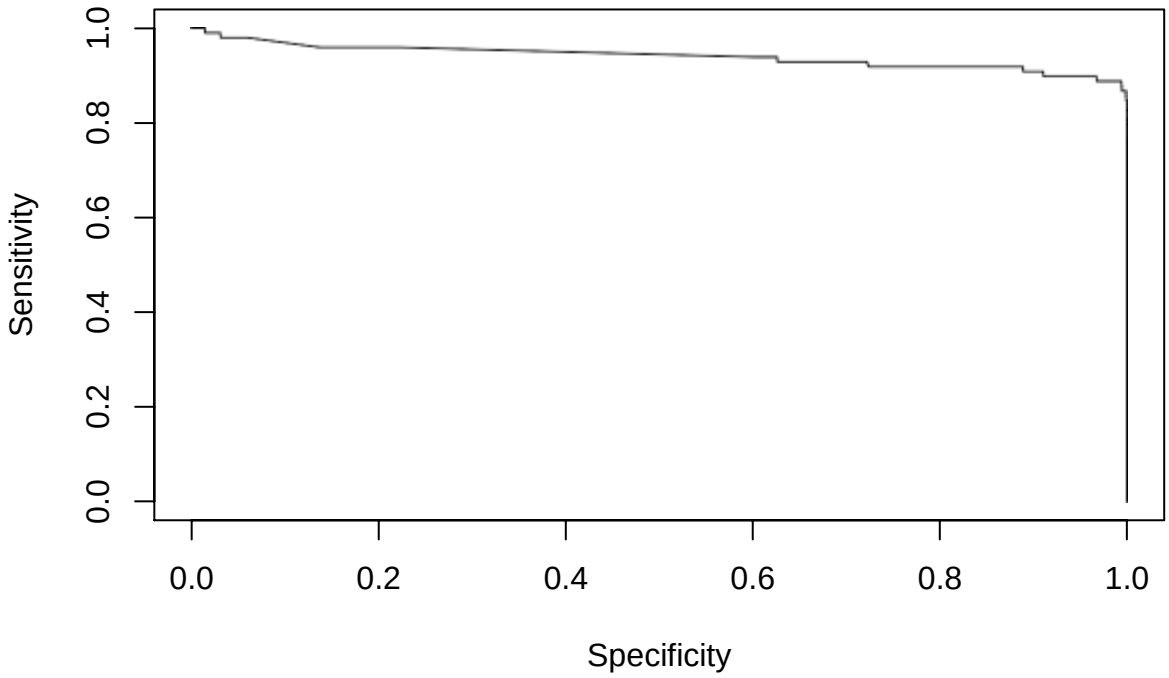
Feature	Gain	Cover	Frequency	Importance
V17	0.3171657	0.3376839	0.0590406	0.3171657
V14	0.2328285	0.4247761	0.0974170	0.2328285
V4	0.0600361	0.0149544	0.0900369	0.0600361
V7	0.0524206	0.0016778	0.0487085	0.0524206
V10	0.0515966	0.0024414	0.0442804	0.0515966
V12	0.0274032	0.1442810	0.0457565	0.0274032
Amount	0.0270669	0.0014754	0.0568266	0.0270669
V27	0.0179538	0.0006398	0.0265683	0.0179538
V28	0.0178111	0.0008319	0.0324723	0.0178111
V20	0.0171806	0.0008593	0.0250923	0.0171806
V26	0.0166046	0.0006860	0.0332103	0.0166046
V9	0.0161372	0.0059450	0.0265683	0.0161372
V19	0.0139521	0.0008483	0.0346863	0.0139521
V3	0.0129482	0.0014248	0.0391144	0.0129482
V8	0.0128923	0.0008873	0.0280443	0.0128923
V5	0.0125336	0.0188990	0.0324723	0.0125336
V2	0.0106854	0.0006103	0.0228782	0.0106854
V21	0.0084312	0.0007444	0.0191882	0.0084312
V23	0.0083561	0.0280382	0.0265683	0.0083561
V24	0.0079779	0.0005232	0.0250923	0.0079779
V22	0.0079069	0.0011115	0.0228782	0.0079069
V13	0.0077632	0.0008035	0.0243542	0.0077632
V1	0.0076040	0.0006159	0.0295203	0.0076040
V16	0.0076017	0.0069315	0.0258303	0.0076017
V11	0.0066428	0.0006218	0.0177122	0.0066428
V18	0.0060901	0.0004219	0.0199262	0.0060901
V6	0.0054157	0.0004609	0.0169742	0.0054157
V25	0.0045781	0.0004818	0.0169742	0.0045781
V15	0.0044156	0.0003236	0.0118081	0.0044156

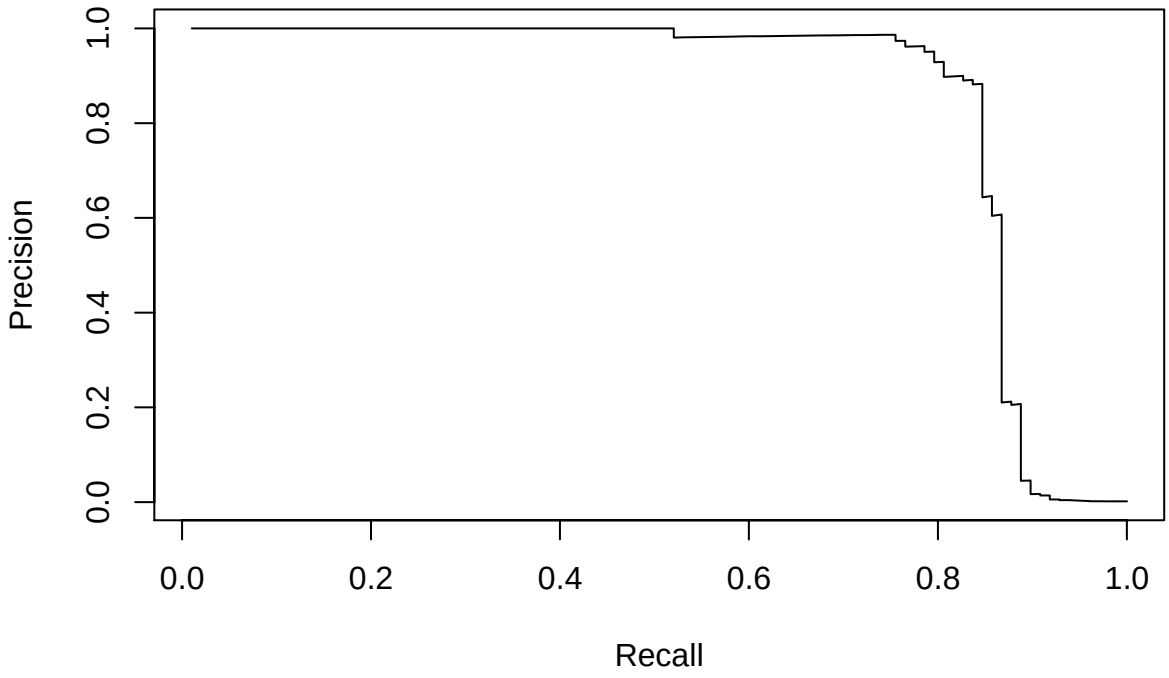
4.8 LightGBM

LightGBM is the fastest and complex implementation of GBM. It has tons of parameters and because of this it has a steep learning curve. With a small changen of the parameters, the LightGBM model is able to reach the performance of XGBoost. Because I'have more experience with the last one, the performance are a little bit worse: AUC of **0.94** and AUCPR of **0.85**, but they are all good.

```
## [1]: test's binary_error:0.00172048 cv's binary_error:0.00172048
## [21]:    test's binary_error:0.0016327    cv's binary_error:0.00156247
## [41]:    test's binary_error:0.000842682  cv's binary_error:0.00080757
## [61]:    test's binary_error:0.000842682  cv's binary_error:0.000790014
## [81]:    test's binary_error:0.000702235  cv's binary_error:0.000719791
## [101]:   test's binary_error:0.000614456  cv's binary_error:0.000667123
## [121]:   test's binary_error:0.000544232  cv's binary_error:0.000579344
## [141]:   test's binary_error:0.000474009  cv's binary_error:0.000561788
## [161]:   test's binary_error:0.000456453  cv's binary_error:0.000526676
## [181]:   test's binary_error:0.000456453  cv's binary_error:0.00050912
## [201]:   test's binary_error:0.000456453  cv's binary_error:0.00050912
```




AUC: 0.940520305338254
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0



Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557
SVM - Support Vector Machine	0.7751585	0.3196189
Random Forest	0.8979328	0.7683457
GBM - Generalized Boosted Regression	0.9538573	0.8421135
XGBoost	0.9770390	0.8618163
LightGBM	0.9405203	0.8545904

Feature	Gain	Cover	Frequency
V14	0.4307962	0.3609848	0.0904762
V7	0.3035386	0.0323388	0.0304348
V12	0.0348256	0.0182142	0.0577640
V26	0.0338785	0.0063473	0.0654244
V10	0.0248953	0.0058810	0.0414079
V4	0.0243032	0.2500562	0.0921325
V20	0.0182291	0.0506729	0.0399586
V1	0.0093899	0.0008671	0.0252588
V18	0.0091918	0.0018870	0.0320911
V2	0.0086183	0.0015763	0.0225673
V16	0.0084501	0.0038963	0.0236025
V13	0.0082319	0.0032468	0.0322981
Amount	0.0071959	0.0159475	0.0465839
V17	0.0068772	0.0408338	0.0225673
V28	0.0068020	0.0016715	0.0337474
V24	0.0062211	0.0023892	0.0293996
V15	0.0061126	0.0019022	0.0289855
V11	0.0050963	0.0335001	0.0260870
V6	0.0048581	0.0029185	0.0188406
V9	0.0048414	0.0010716	0.0287785
V3	0.0048409	0.0020941	0.0273292
V8	0.0047966	0.0138567	0.0207039
V27	0.0047570	0.0344483	0.0395445
V23	0.0046562	0.0377007	0.0333333
V25	0.0046264	0.0002474	0.0113872
V19	0.0043399	0.0126660	0.0182195
V22	0.0037440	0.0587793	0.0213251
V5	0.0032005	0.0024771	0.0229814
V21	0.0026854	0.0015272	0.0167702

5 Results

This is the summary results for all the models builted, trained and validated.

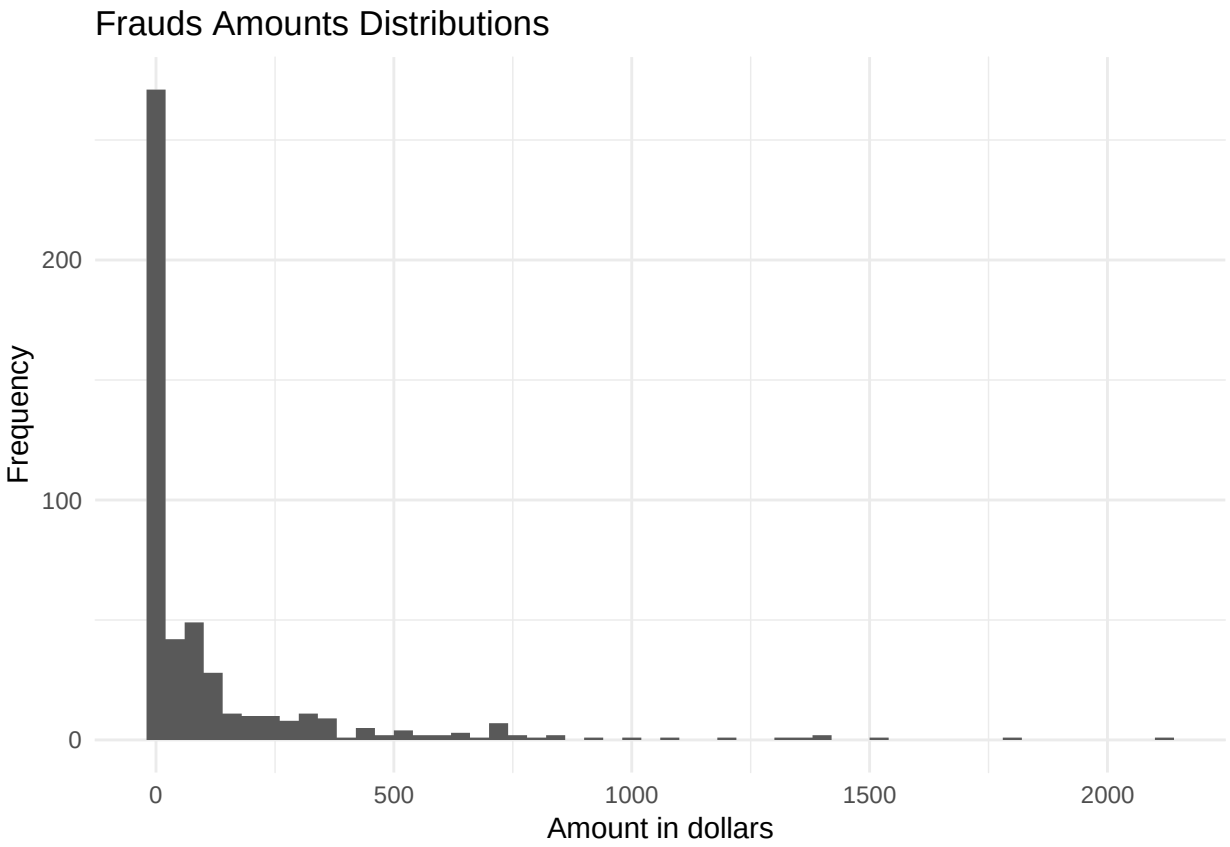
Model	AUC	AUCPR
Naive Baseline - Predict Always Legal	0.5000000	0.0000000
Naive Bayes	0.9175977	0.0548969
K-Nearest Neighbors k=5	0.8162738	0.5797557
SVM - Support Vector Machine	0.7751585	0.3196189
Random Forest	0.8979328	0.7683457
GBM - Generalized Boosted Regression	0.9538573	0.8421135
XGBoost	0.9770390	0.8618163
LightGBM	0.9405203	0.8545904

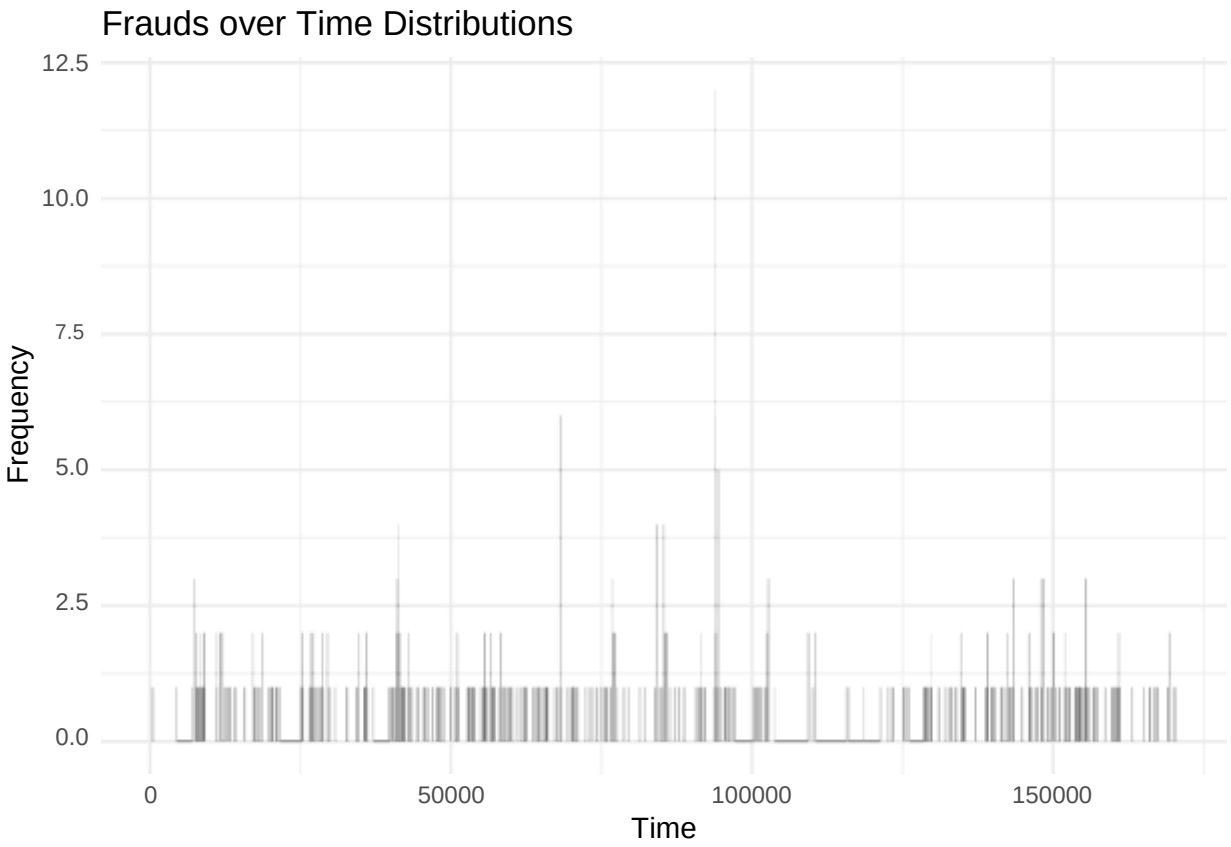
6 Conclusion

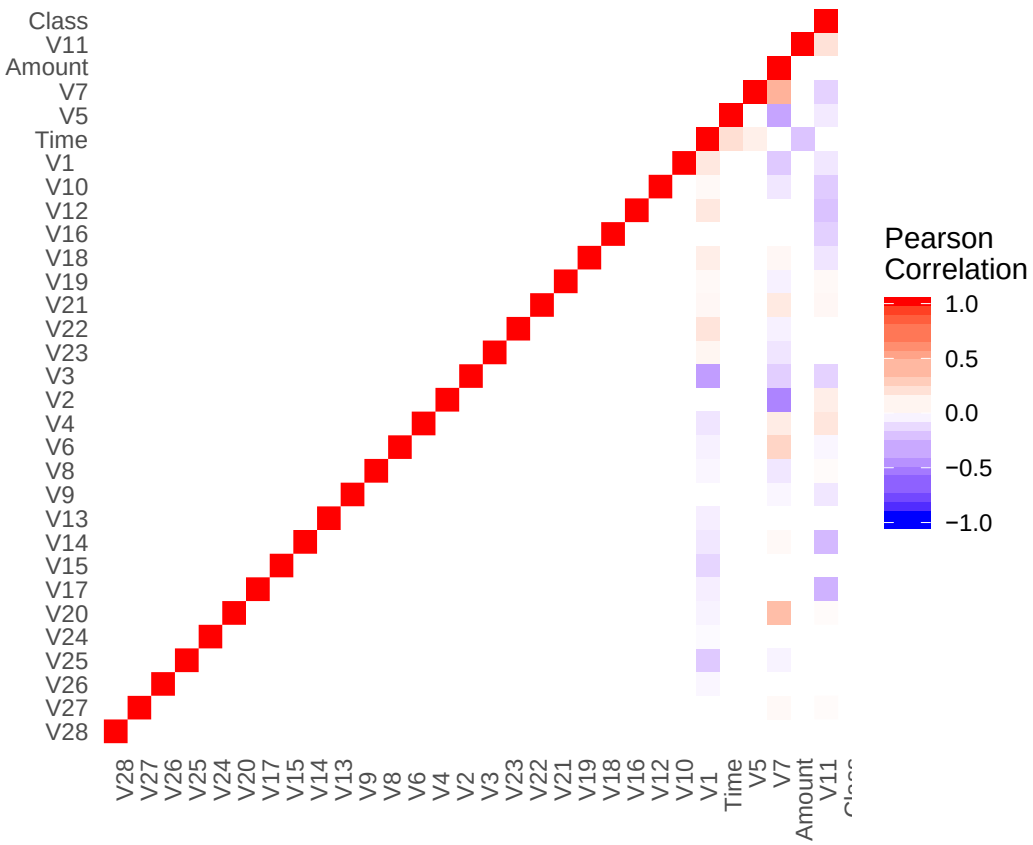
The ensemble methods once again confirm themselves as among the best models out there. It easy to find them as a winners of numerous Kaggle's competitions or on TOP5 of them. In this task, a XGBoost model can achieve a very good AUCPR result of **0.86** and the others ensembe methods are very close to it. As the features importance plots and table show, there are few predictors like **V17** and **V14** that are particularly useful for classifying a fraud. The SMOTE technique (a technique for dealing with imbalanced data) could improve the performance a little bit.

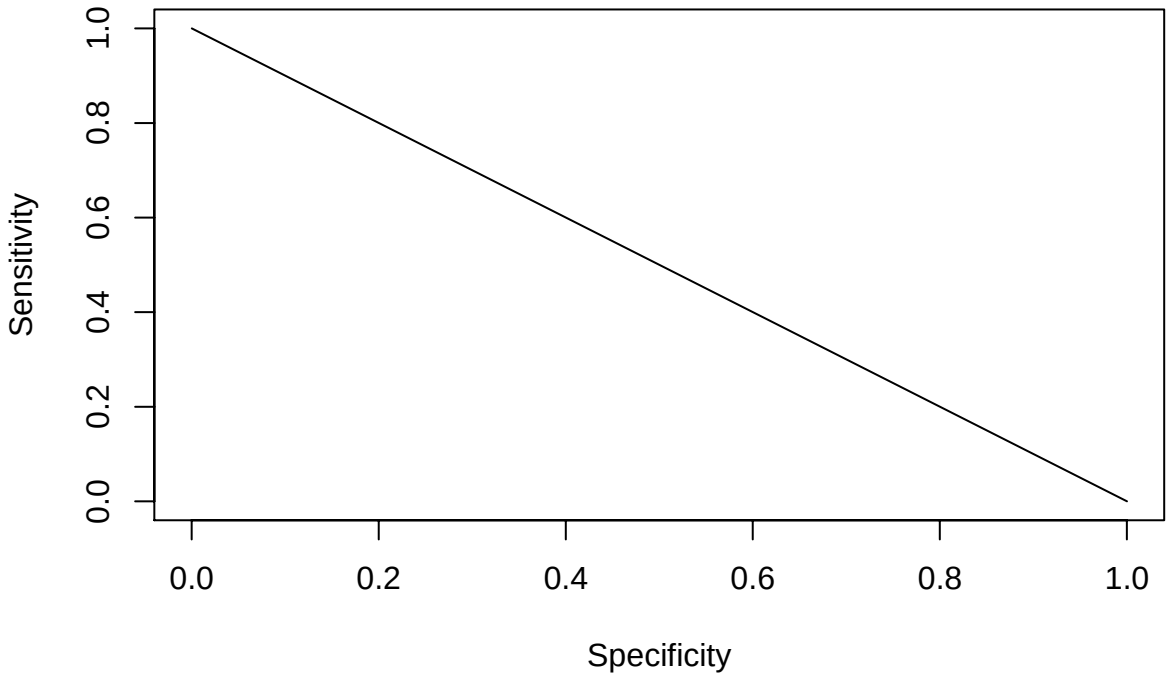
7 Appendix

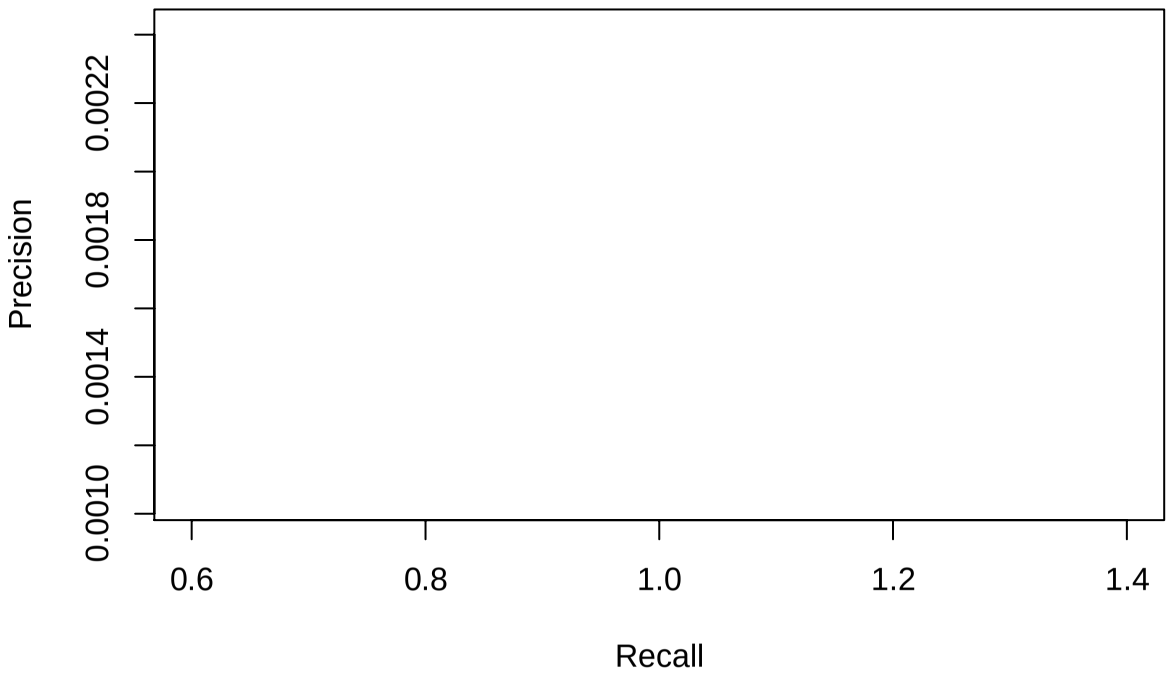
7.1 1a - All visualization

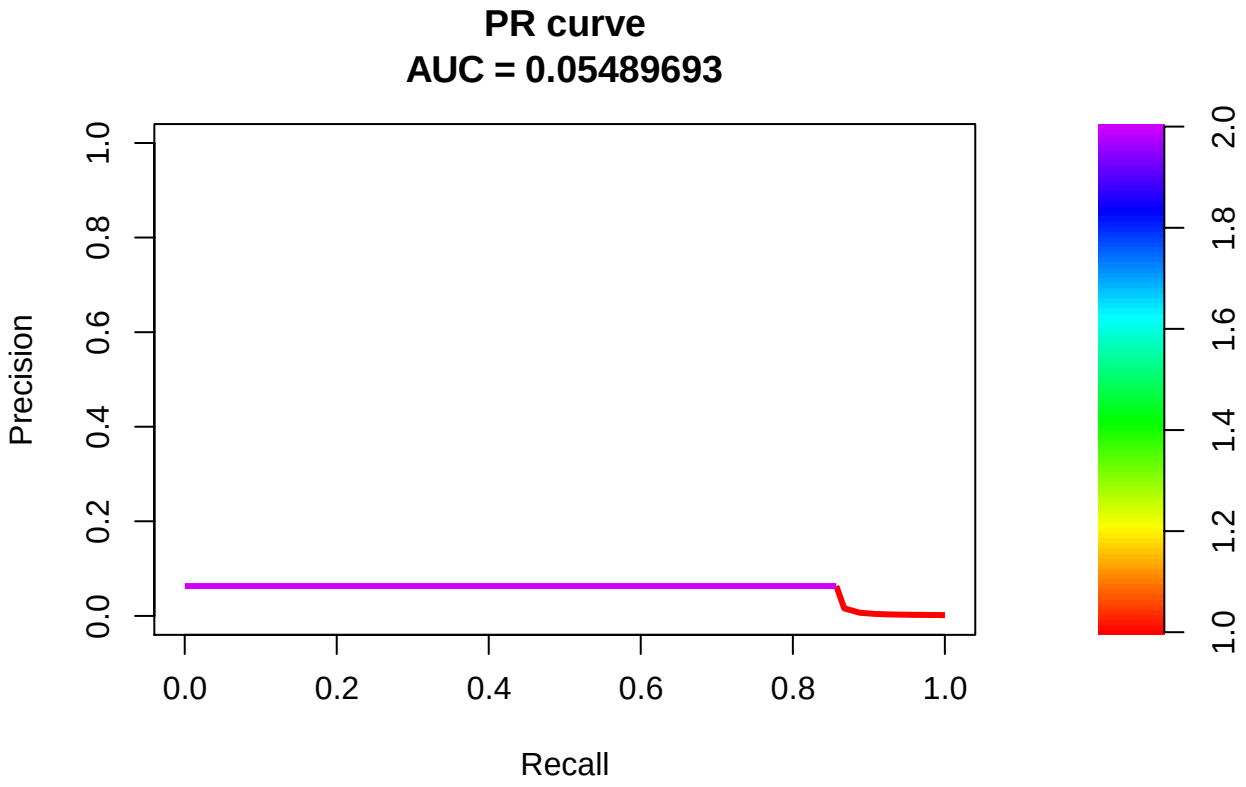

Frauds Amounts Distributions
Frequency
200
100
0
0
500
1000
1500
2000
Amount in dollars

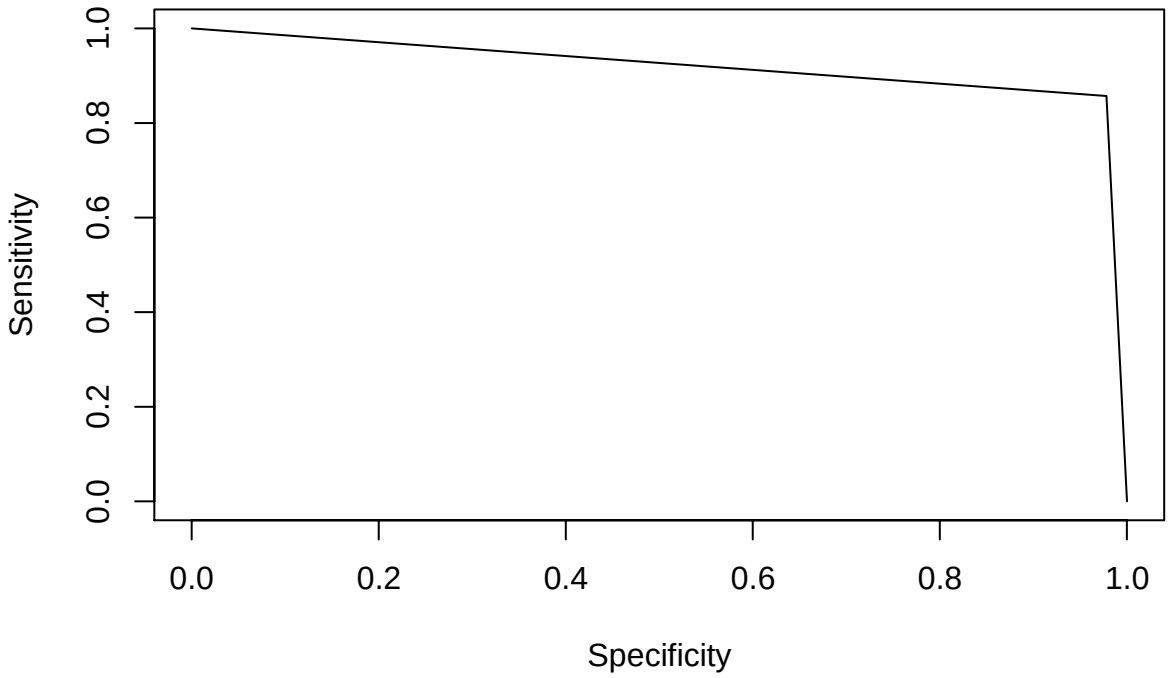

Frauds over Time Distributions
12.5
10.0
7.5
5.0
2.5
0.0
Frequency
0
50000
100000
150000
Time

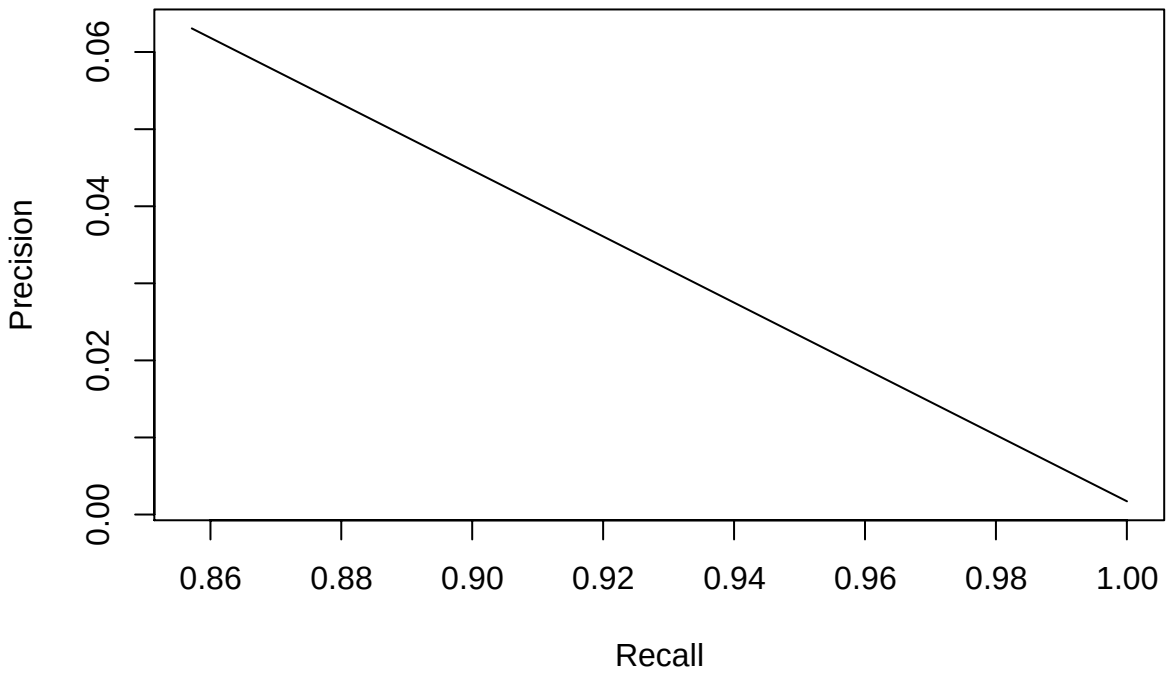

Class
V11
Amount
V7
V5
Time
V1
V10
V12
V16
V18
V19
V21
V22
V23
V3
V2
V4
V6
V8
V9
V13
V14
V15
V17
V20
V24
V25
V26
V27
V28
V28 V27 V26 V25 V24 V20 V17 V15 V14 V13 V9 V8 V6 V4 V2 V3 V23 V22 V21 V19 V18 V16 V12 V10 V1 Time V5 V7 Amount V11
Pearson Correlation
1.0
0.5
0.0
−0.5
−1.0

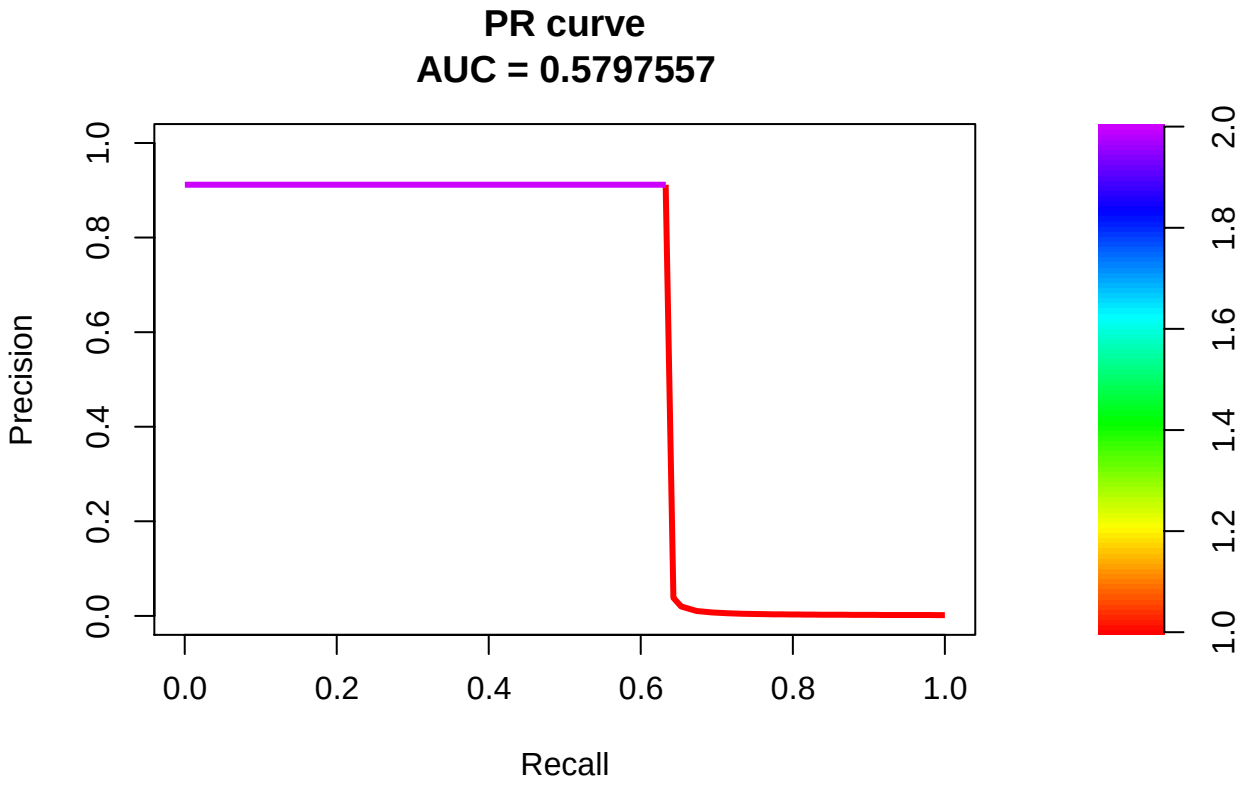

AUC: 0.5
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0

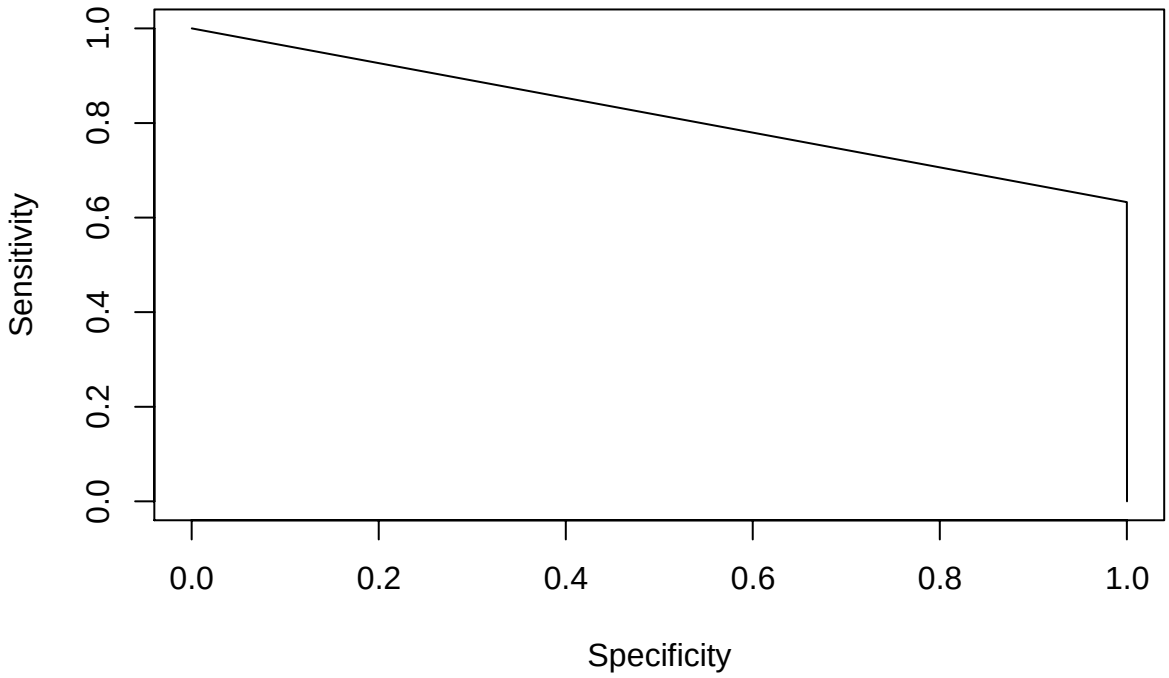

AUCPR: 0
Precision
0.0010
0.0014
0.0018
0.0022
0.6
0.8
1.0
1.2
1.4
Recall

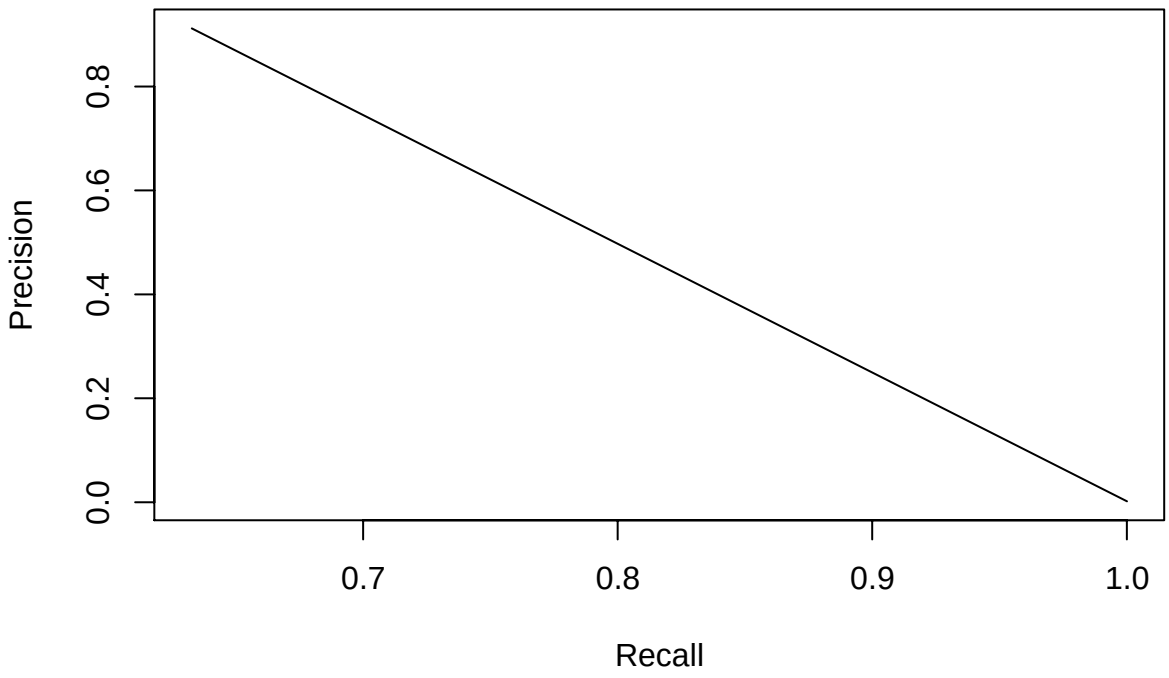

PR curve
AUC = 0.05489693
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0
1.0
1.2
1.4
1.6
1.8
2.0

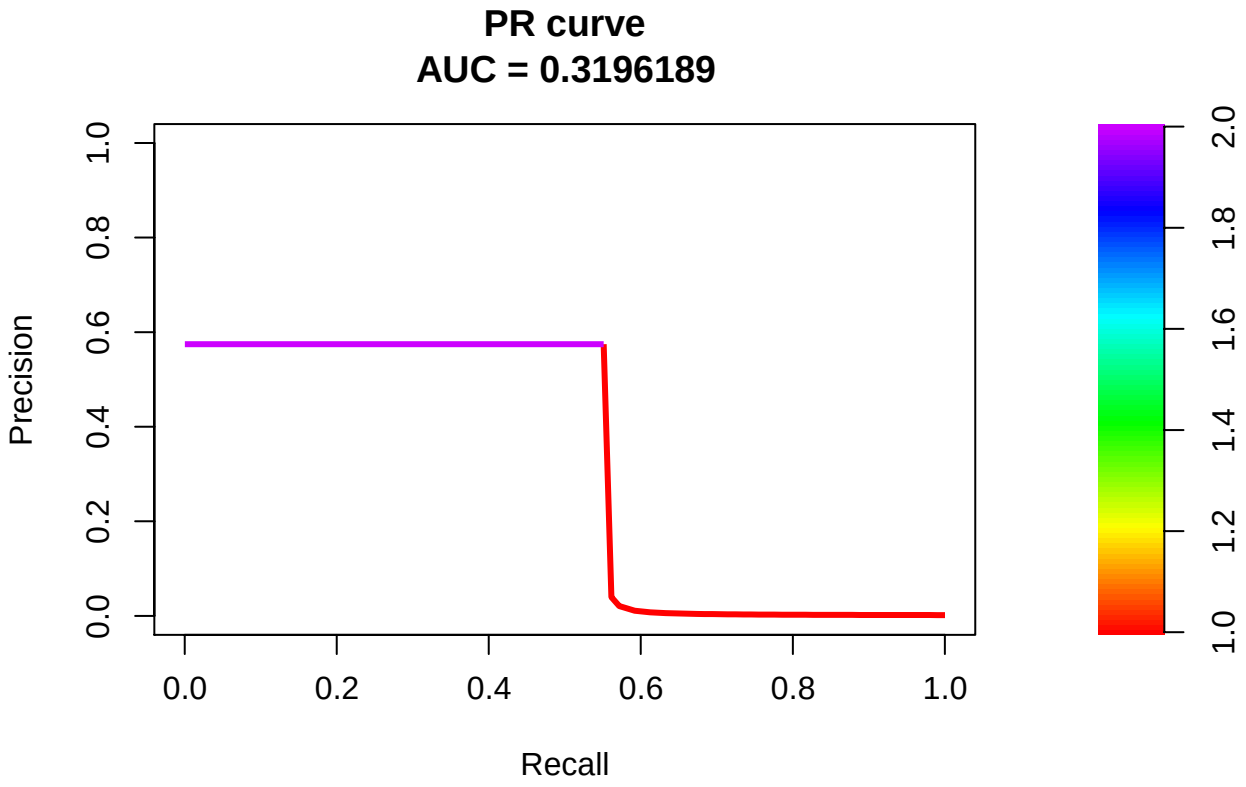

AUC: 0.917597684660626
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0

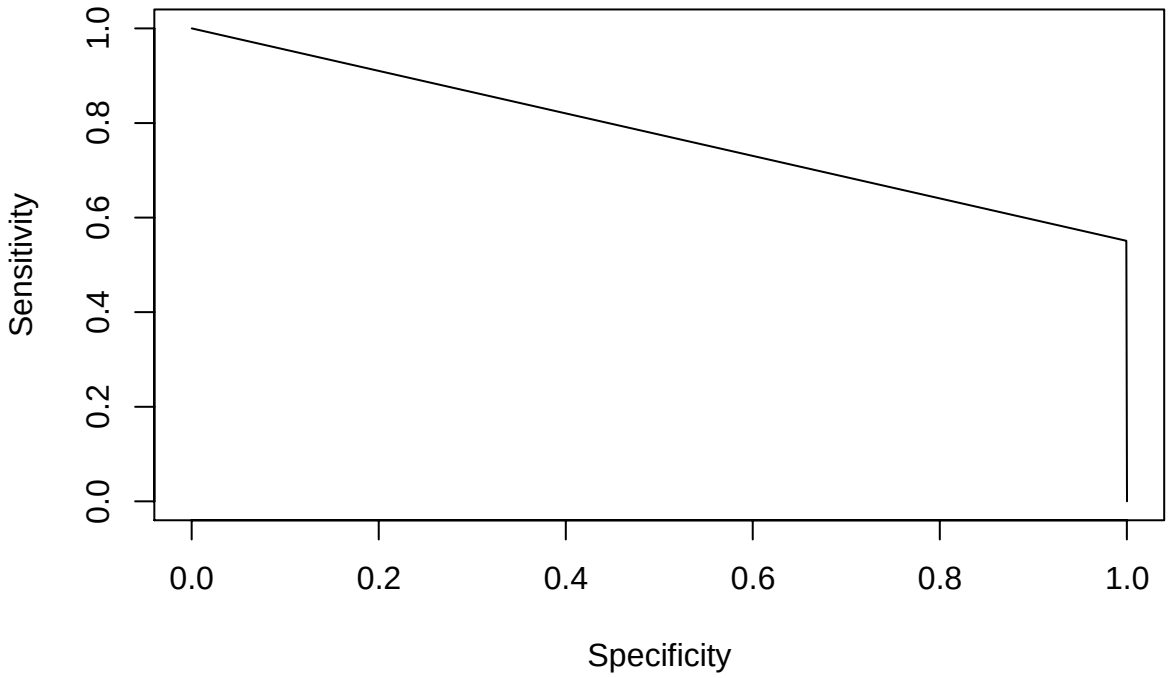

AUCPR: 0.0548969303984264
Precision
0.00
0.02
0.04
0.06
0.86
0.88
0.90
0.92
0.94
0.96
0.98
1.00
Recall

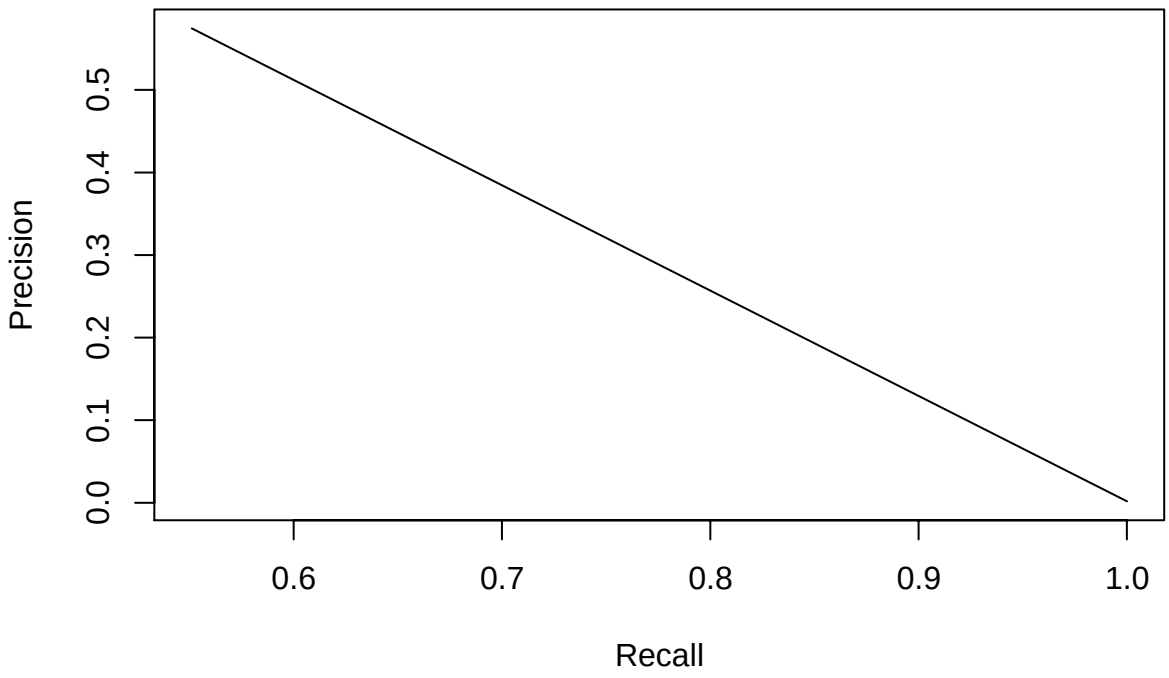

PR curve
AUC = 0.5797557
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0
1.0
1.2
1.4
1.6
1.8
2.0

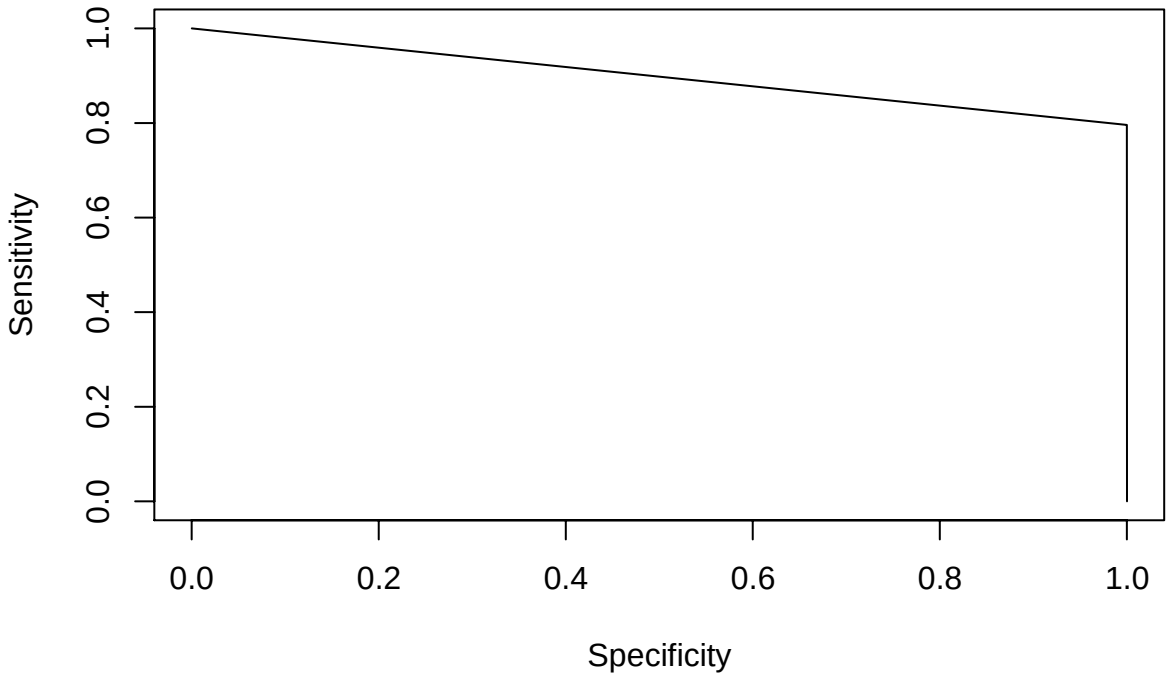

AUC: 0.816273772228058
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0

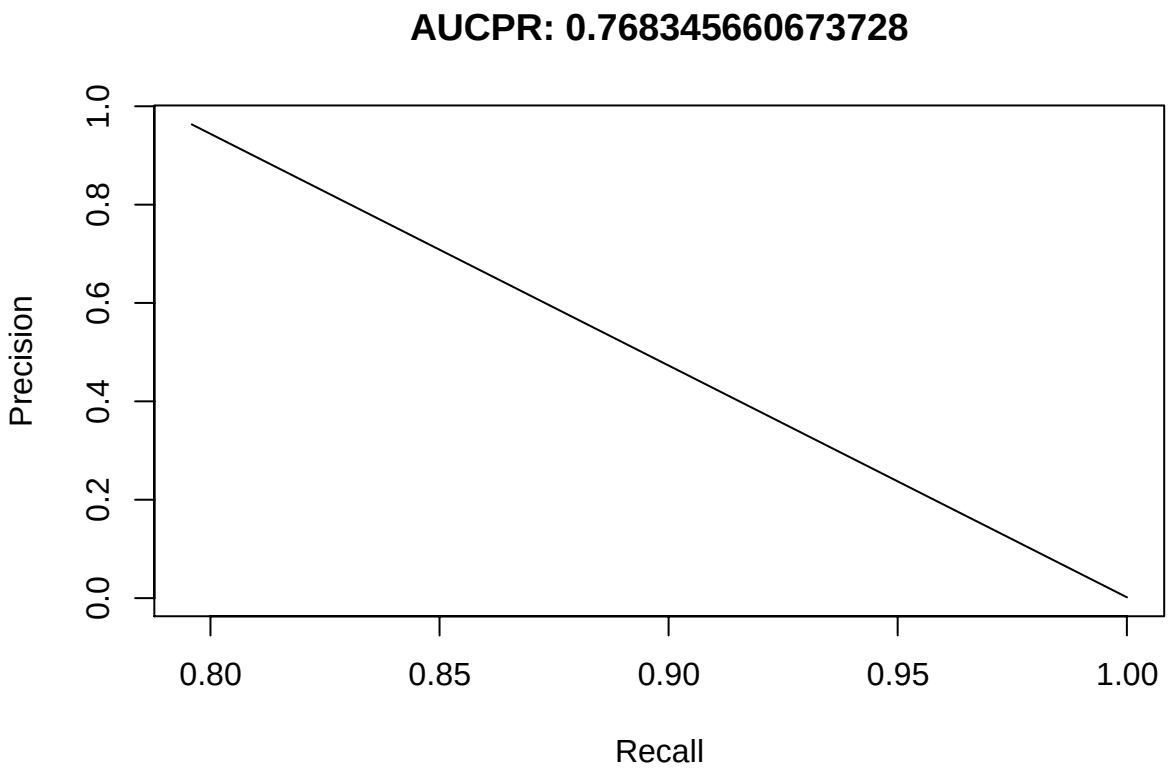

AUCPR: 0.579755719213291
Precision
0.0
0.2
0.4
0.6
0.8
0.7
0.8
0.9
1.0
Recall

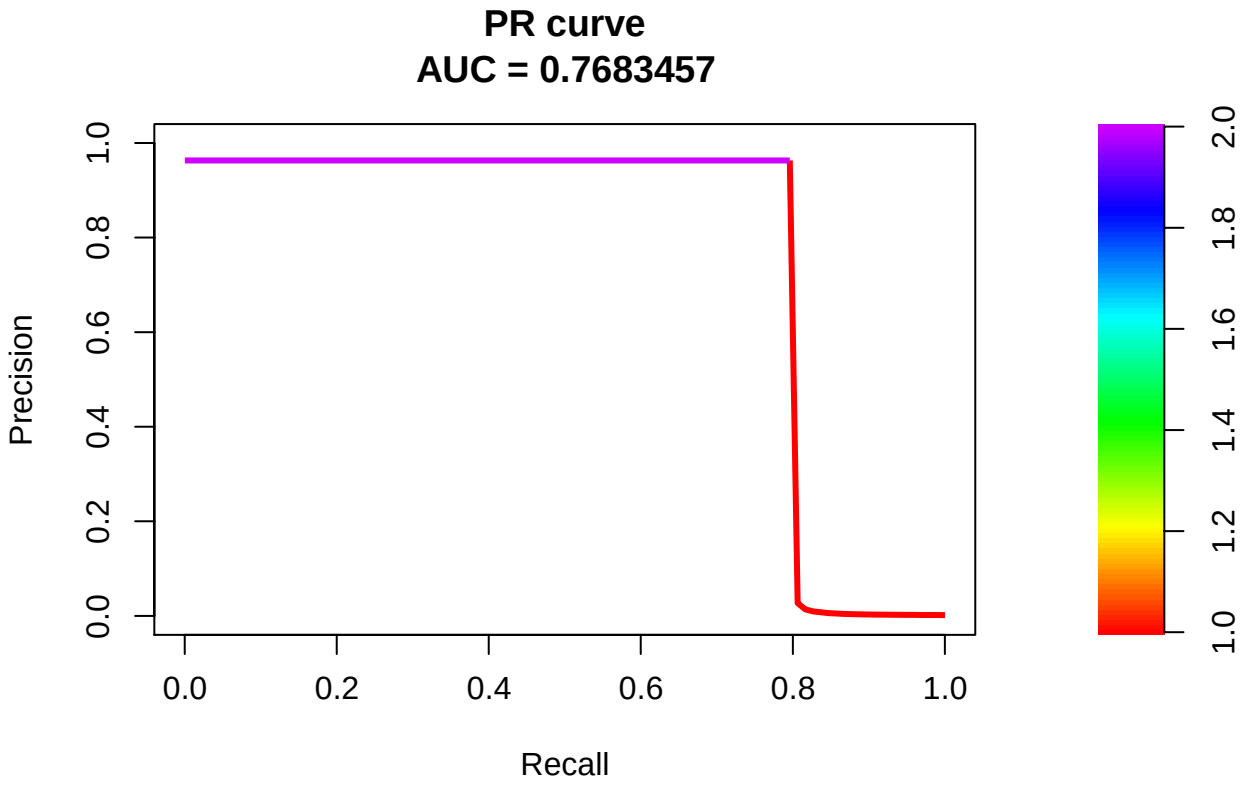

PR curve
AUC = 0.3196189
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0
1.0
1.2
1.4
1.6
1.8
2.0

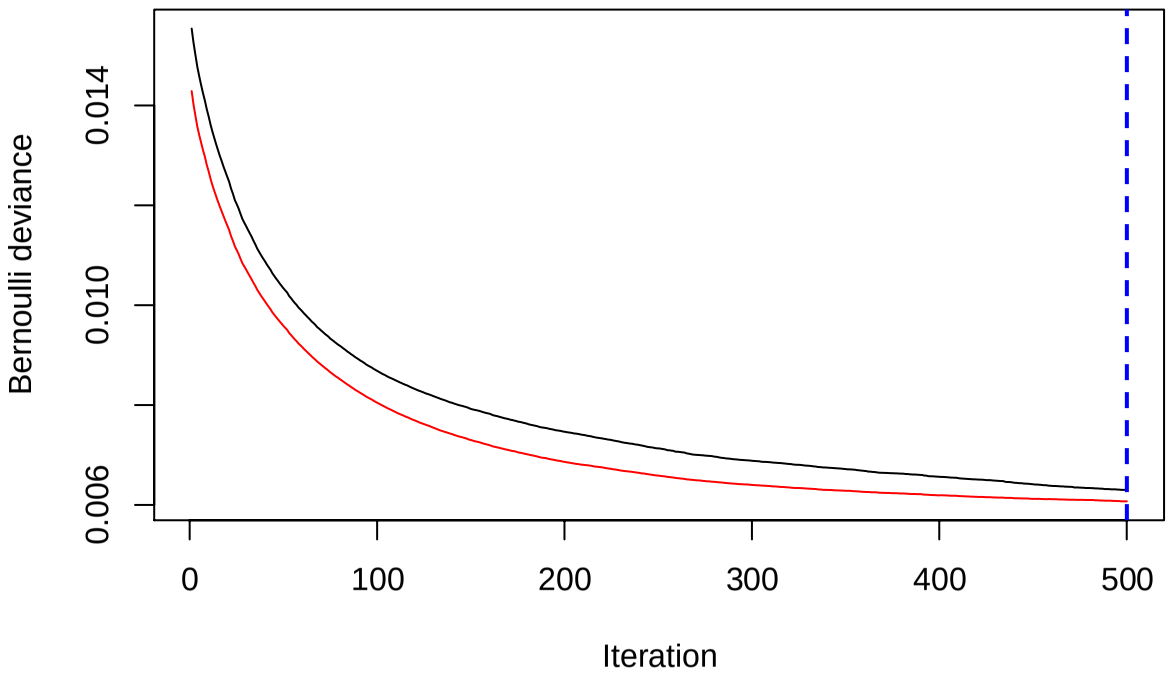

AUC: 0.775158481520389
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0

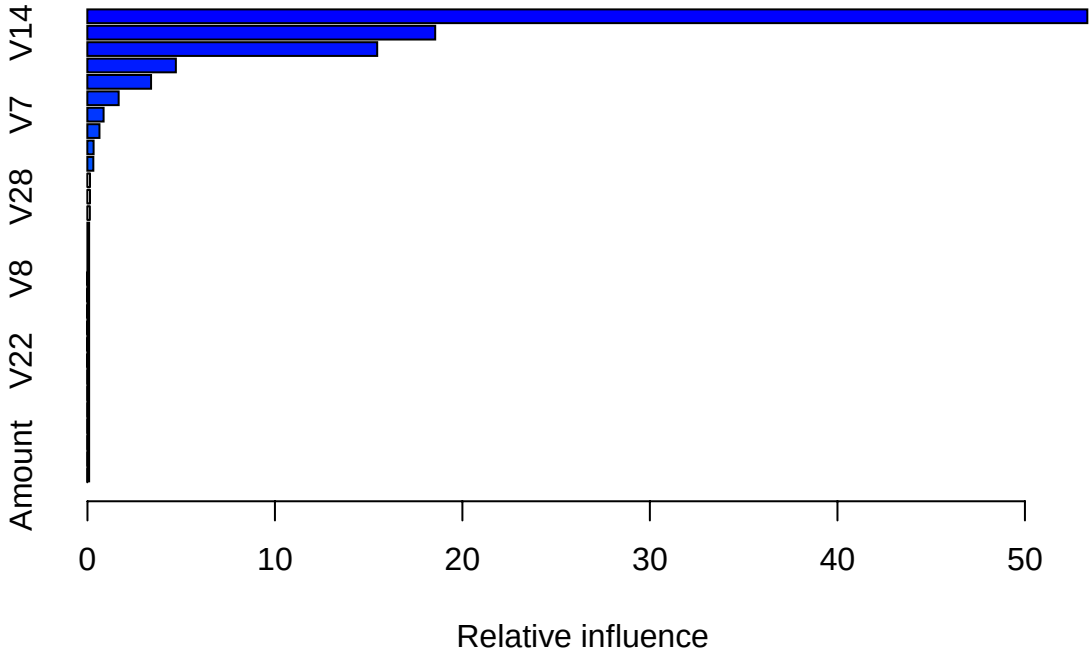

AUCPR: 0.319618862730037
Precision
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Recall

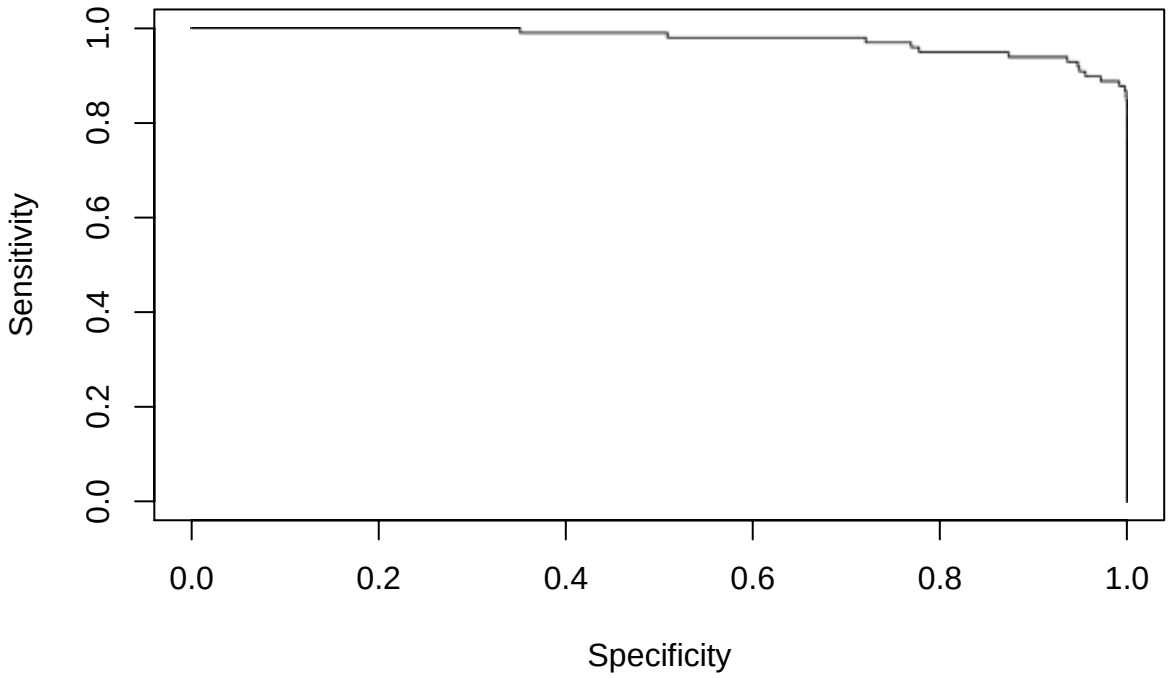

AUC: 0.897932804481376
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity

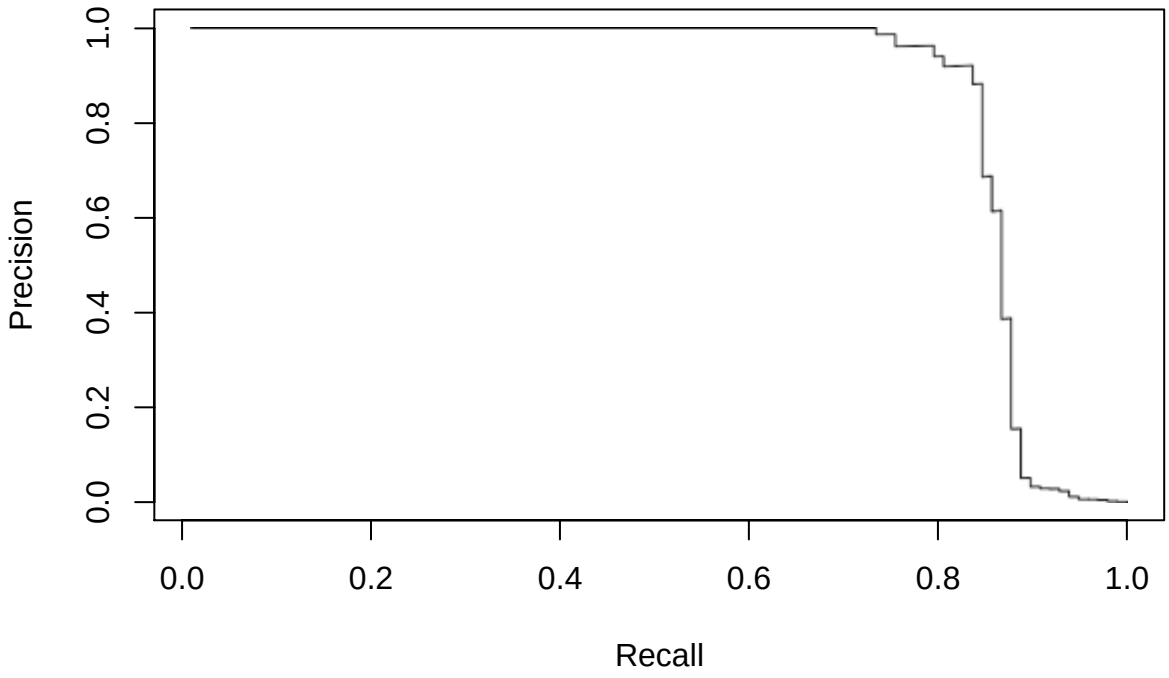

AUCPR: 0.768345660673728
Precision
0.0
0.2
0.4
0.6
0.8
1.0
0.80
0.85
0.90
0.95
1.00
Recall

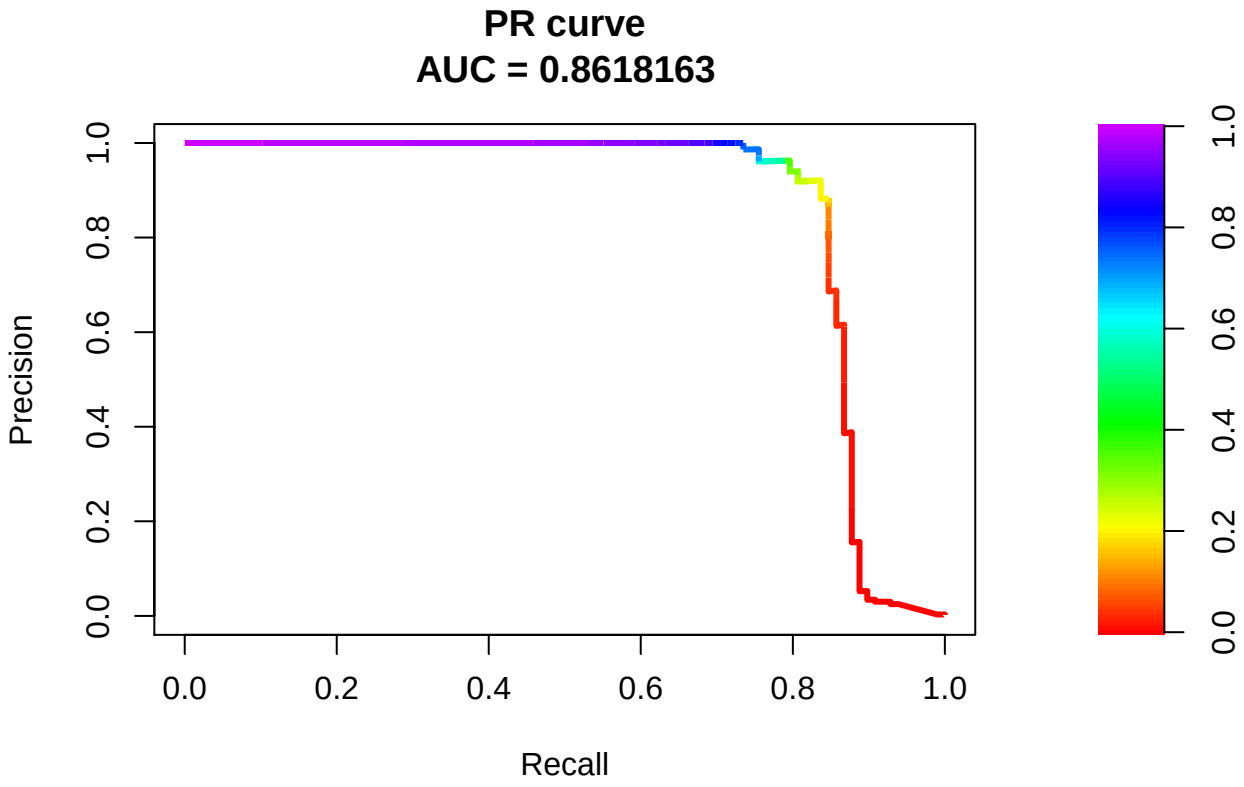

PR curve
AUC = 0.7683457
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0
1.0
1.2
1.4
1.6
1.8
2.0

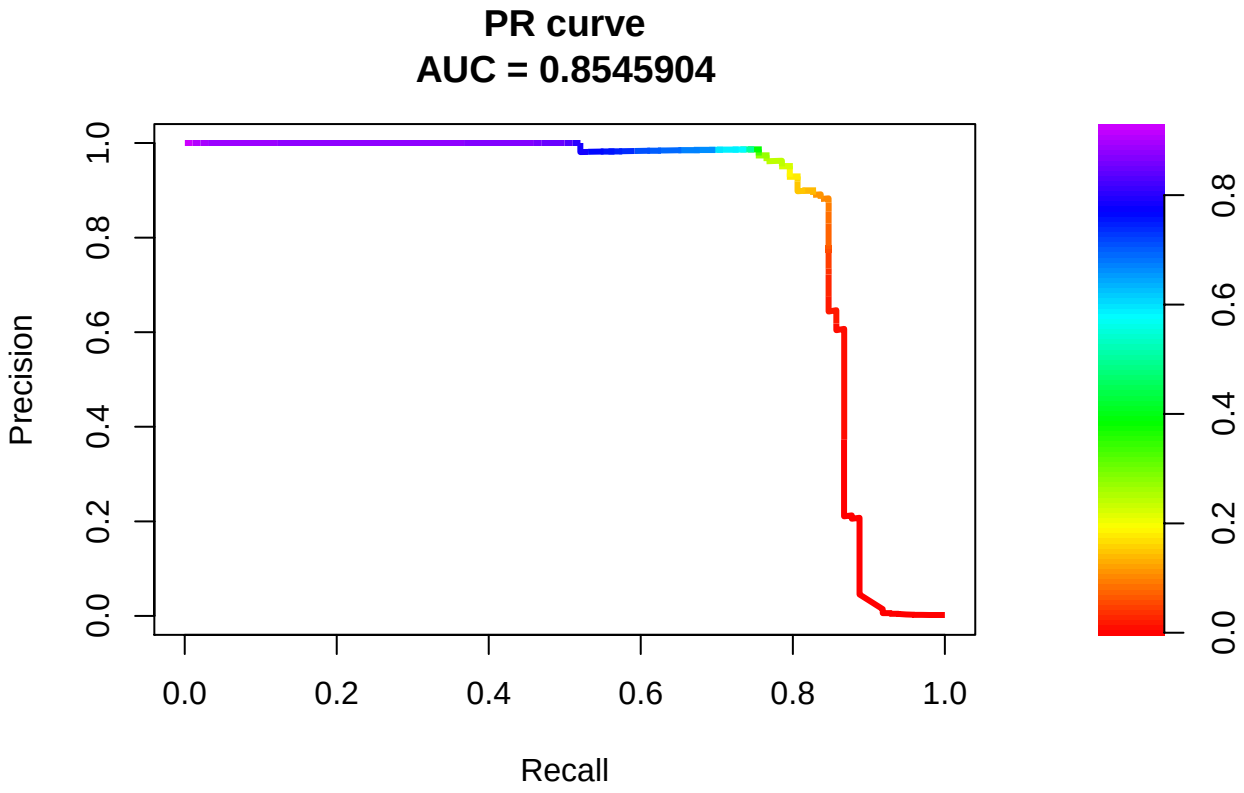

Bernoulli deviance
0.006
0.010
0.014
0
100
200
300
400
500
Iteration

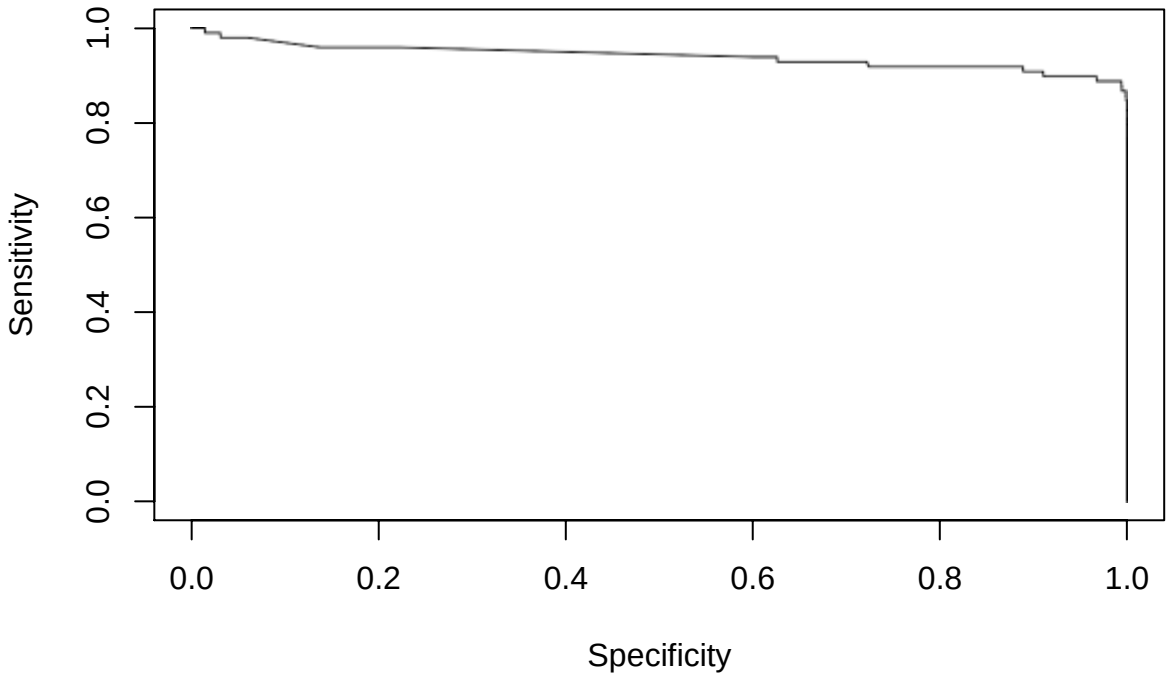

V14
V7
V28
V8
V22
Amount
0
10
20
30
40
50
Relative influence

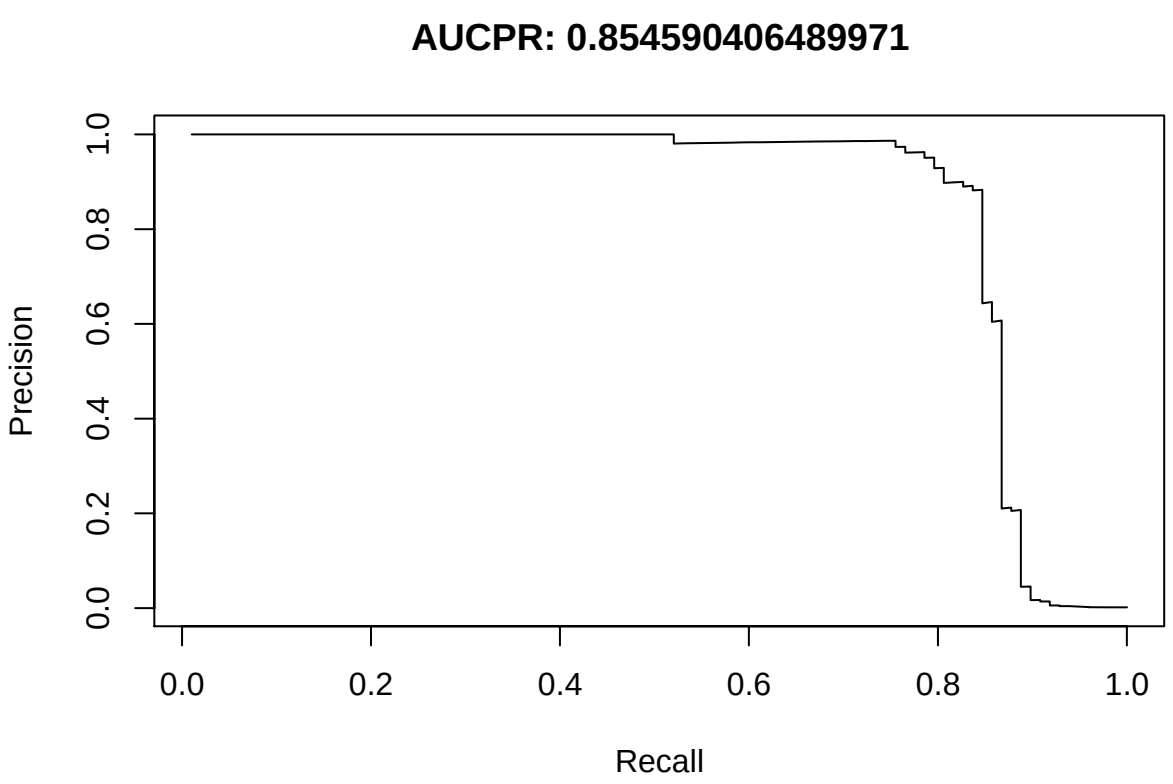

AUC: 0.977038976961337
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0


AUCPR: 0.86181626247754
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0


PR curve
AUC = 0.8618163
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0


PR curve
AUC = 0.8545904
Precision
0.0
0.2
0.4
0.6
0.8
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8


AUC: 0.940520305338254
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
0.0
0.2
0.4
0.6
0.8
1.0



7.2 1b - Code used in this report - Credit Card Fraud Detection Project - Code.R

```
# Install all needed libraries if it is not present

if(!require(tidyverse)) install.packages("tidyverse")
if(!require(kableExtra)) install.packages("kableExtra")
if(!require(tidyr)) install.packages("tidyr")
if(!require(tidyverse)) install.packages("tidyverse")
if(!require(stringr)) install.packages("stringr")
if(!require(ggplot2)) install.packages("ggplot2")
if(!require(gbm)) install.packages("gbm") if(!require(dplyr))
install.packages("dplyr") if(!require(caret))
install.packages("caret") if(!require(xgboost))
install.packages("xgboost") if(!require(e1071))
install.packages("e1071") if(!require(class))
install.packages("class") if(!require(ROCR))
install.packages("ROCR") if(!require(randomForest))
install.packages("randomForest") if(!require(PRROC))
install.packages("PRROC") if(!require(reshape2))
install.packages("reshape2")

# Loading all needed libraries

library(dplyr)
library(tidyverse)
```

```
library(kableExtra)
library(tidyr)
library(ggplot2)
library(gbm)
library(caret)
library(xgboost)
library(e1071)
library(class)
library(lightgbm)
library(ROCR)
library(randomForest)
library(PRROC)
library(reshape2)

## Loading the dataset

creditcard <- read.csv("creditcard.csv") #

Check dimensions

data.frame("Length" = nrow(creditcard), "Columns" = ncol(creditcard))     %>%
kable()  %>%
   kable_styling(bootstrap_options = c("striped", "hover", "condensed", "responsive"),
                 position = "center",
                 font_size = 10,
                 full_width = FALSE)

imbalanced <- data.frame(creditcard)

imbalanced$Class = ifelse(creditcard$Class == 0, 'Legal', 'Fraud')     %>%  as.factor()

# Visualize the proportion between classes

imbalanced  %>%
  ggplot(aes(Class)) +
  theme_minimal()   +
  geom_bar() +
  scale_x_discrete() +
  scale_y_continuous(labels = scales::comma) +
  labs(title = "Proportions between Legal and Frauds Transactions", x =
        "Class",
        y = "Frequency")

# Find missing values

sapply(creditcard, function(x) sum(is.na(x)))    %>%
kable(col.names = c("Missing Values"))    %>%
   kable_styling(bootstrap_options = c("striped", "hover", "condensed", "responsive"),
                 position = "center",
                 font_size = 10,
                 full_width = FALSE)

# Frauds Amount
```

```
creditcard[creditcard$Class == 1,]   %>%
  ggplot(aes(Amount)) + theme_minimal()
                      +
  geom_histogram(binwidth = 40) +
  labs(title = "Frauds Amounts Distributions", x
        = "Amount in dollars",
        y = "Frequency")

creditcard[creditcard$Class == 1,]   %>%
  group_by(Amount)  %>%
  summarise(count = n()) >% %
  arrange(desc(count))  %>%
  head(n=10)  %>%
  kable()  %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed", "responsive"),
                position = "center",
                font_size = 10,
                full_width = FALSE)

# Frauds over Time

creditcard[creditcard$Class == 1,]   %>%
  ggplot(aes(Time)) +
  theme_minimal()   +
  geom_histogram(binwidth = 40) +
  labs(title = "Frauds over Time Distributions", x
        = "Time",
        y = "Frequency")

creditcard[creditcard$Class == 1,]   %>%
  group_by(Time)  %>%
  summarise(count = n()) >% %
  arrange(desc(count))  %>%
  head(n=10)  %>%
  kable()  %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed", "responsive"),
                position = "center",
                font_size = 10,
                full_width = FALSE)

# Get lower triangle of the correlation matrix

get_lower_tri<-function(cormat){
  cormat[upper.tri(cormat)] <- NA
  return(cormat)
}

# Get upper triangle of the correlation matrix

get_upper_tri <- function(cormat){
  cormat[lower.tri(cormat)]<- NA
  return(cormat)
}
```

```
reorder_cormat <- function(cormat){
  # Use correlation between variables as distance dd
  <- as.dist((1-cormat)/2)
  hc <- hclust(dd)
  cormat <-cormat[hc$order, hc$order]
}

corr_matrix <- round(cor(creditcard),2) corr_matrix
<- reorder_cormat(corr_matrix)

upper_tri <- get_upper_tri(corr_matrix)

melted_corr_matrix <- melt(upper_tri, na.rm = TRUE)

ggplot(melted_corr_matrix, aes(Var2, Var1, fill = value)) + geom_tile(color
= "white") +
scale_fill_gradient2(low = "blue", high = "red", mid = "white",
   midpoint = 0, limit = c(-1,1), space = "Lab",
   name="Pearson¥nCorrelation") +
   theme_minimal() +
   theme(axis.text.x = element_text(angle = 90, vjust = 1,
         size = 9, hjust = 1), axis.text.y = element_text(size = 9),                          axis.title.x =
         axis.title.y = element_blank(),
         panel.grid.major = element_blank(),
         panel.border = element_blank(),
         panel.background = element_blank(),
         axis.ticks = element_blank()) +
 coord_fixed()

# Set seed for reproducibility

set.seed(1234)

# Remove the "Time" column from the dataset

creditcard$Class <- as.factor(creditcard$Class)
creditcard <- creditcard  %>%  select(-Time)

# Split the dataset into train, test dataset and cv

train_index <- createDataPartition(
  y = creditcard$Class,
  p = .6,
  list = F
)

train <- creditcard[train_index,]

test_cv <- creditcard[-train_index,]

test_index <- createDataPartition(
  y = test_cv$Class,
  p = .5,
  list = F)
```

```
test <- test_cv[test_index,]
cv <- test_cv[-test_index,]

rm(train_index, test_index, test_cv)

# Create a baseline model that predict always "legal" #
(aka "0") transactions and compute all metrics

# Clone the creditcard dataframe

baseline_model <- data.frame(creditcard) #

Set Class al to Legal (0)

baseline_model$Class = factor(0, c(0,1)) #

Make predictions

pred <- prediction(
  as.numeric(as.character(baseline_model$Class)),                                    as.numeric(as.character(credit
)

# Compute the AUC and AUCPR

auc_val_baseline <- performance(pred, "auc")
auc_plot_baseline <- performance(pred, 'sens', 'spec')
aucpr_plot_baseline <- performance(pred, "prec", "rec")

# Make the relative plot

plot(auc_plot_baseline,
     main=paste("AUC:", auc_val_baseline@y.values[[1]])
)

plot(aucpr_plot_baseline, main="AUCPR: 0")

# Create a dataframe 'results' that contains all metrics #
obtained by the trained models

results <- data.frame(
  Model = "Naive Baseline - Predict Always Legal", AUC
  = auc_val_baseline@y.values[[1]],
  AUCPR = 0
)

# Show results on a table

results %>%
  kable() %>%
  kable_styling(
    bootstrap_options =
      c("striped", "hover", "condensed", "responsive"),
```

```
      position = "center",
      font_size = 10,
      full_width = FALSE
)

# Create a Naive Bayes Model, it will improve a little bit the #
results in AUC and AUCPR

# Set seed 1234 for reproducibility

set.seed(1234)

# Build the model with Class as target and all other variables #
as predictors

naive_model <- naiveBayes(Class ~ ., data = train, laplace=1) #

Predict

predictions <- predict(naive_model, newdata=test) #

Compute the AUC and AUCPR for the Naive Model

pred <- prediction(as.numeric(predictions) , test$Class)

auc_val_naive <- performance(pred, "auc")

auc_plot_naive <- performance(pred, 'sens', 'spec')
aucpr_plot_naive <- performance(pred, "prec", "rec")

aucpr_val_naive <- pr.curve(
  scores.class0 = predictions[test$Class == 1],
  scores.class1 = predictions[test$Class == 0],
  curve = T,
  dg.compute = T
)

# Make the relative plot

plot(aucpr_val_naive)
plot(auc_plot_naive, main=paste("AUC:", auc_val_naive@y.values[[1]])) plot(aucpr_plot_naive,
main=paste("AUCPR:", aucpr_val_naive$auc.integral))

# Adding the respective metrics to the results dataset

results <- results %>% add_row(
  Model = "Naive Bayes",
  AUC = auc_val_naive@y.values[[1]], AUCPR
  = aucpr_val_naive$auc.integral
)

# Show results on a table

results %>%
```

```
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

# Set seed 1234 for reproducibility

set.seed(1234)

# Build a KNN Model with Class as Target and all other #
variables as predictors. k is set to 5

knn_model <- knn(train[,-30], test[,-30], train$Class, k=5, prob = TRUE) #

Compute the AUC and AUCPR for the KNN Model

pred <- prediction(
  as.numeric(as.character(knn_model)),                                    as.numeric(as.character(test$C
)

auc_val_knn <- performance(pred, "auc")

auc_plot_knn <- performance(pred, 'sens', 'spec')
aucpr_plot_knn <- performance(pred, "prec", "rec")

aucpr_val_knn <- pr.curve(
  scores.class0 = knn_model[test$Class == 1],
  scores.class1 = knn_model[test$Class == 0],
  curve = T,
  dg.compute = T
)

# Make the relative plot

plot(aucpr_val_knn)
plot(auc_plot_knn, main=paste("AUC:", auc_val_knn@y.values[[1]]))
plot(aucpr_plot_knn, main=paste("AUCPR:", aucpr_val_knn$auc.integral))

# Adding the respective metrics to the results dataset

results <- results %>% add_row(
  Model = "K-Nearest Neighbors k=5",
  AUC = auc_val_knn@y.values[[1]],
  AUCPR = aucpr_val_knn$auc.integral
)

# Show results on a table

results %>%
   kable() %>%
   kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
       position = "center",
       font_size = 10,
```

```
        full_width = FALSE)

# Set seed 1234 for reproducibility

set.seed(1234)

# Build a SVM Model with Class as Target and all other #
variables as predictors. The kernel is set to sigmoid

svm_model <- svm(Class ~ ., data = train, kernel='sigmoid') #

Make predictions based on this model

predictions <- predict(svm_model, newdata=test) #

Compute AUC and AUCPR

pred <- prediction(
  as.numeric(as.character(predictions)),                                    as.numeric(as.character(test$C
)

auc_val_svm <- performance(pred, "auc")

auc_plot_svm <- performance(pred, 'sens', 'spec')
aucpr_plot_svm <- performance(pred, "prec", "rec")

aucpr_val_svm <- pr.curve(
  scores.class0 = predictions[test$Class == 1],
  scores.class1 = predictions[test$Class == 0],
  curve = T,
  dg.compute = T
)

# Make the relative plot

plot(aucpr_val_svm)
plot(auc_plot_svm, main=paste("AUC:", auc_val_svm@y.values[[1]]))
plot(aucpr_plot_svm, main=paste("AUCPR:", aucpr_val_svm$auc.integral))

# Adding the respective metrics to the results dataset

results <- results %>% add_row(
  Model = "SVM - Support Vector Machine",
  AUC = auc_val_svm@y.values[[1]],
  AUCPR = aucpr_val_svm$auc.integral)

# Show results on a table

results %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)
```

```
# Set seed 1234 for reproducibility

set.seed(1234)

# Build a Random Forest Model with Class as Target and all other #
variables as predictors. The number of trees is set to 500

rf_model <- randomForest(Class ~ ., data = train, ntree = 500) #

Get the feature importance

feature_imp_rf <- data.frame(importance(rf_model)) #

Make predictions based on this model

predictions <- predict(rf_model, newdata=test) #

Compute the AUC and AUPCR

pred <- prediction(
  as.numeric(as.character(predictions)),                                    as.numeric(as.character(test$C
)

auc_val_rf <- performance(pred, "auc") auc_plot_rf

<- performance(pred, 'sens', 'spec')

aucpr_plot_rf <- performance(pred, "prec", "rec", curve = T,      dg.compute = T)

aucpr_val_rf <- pr.curve(scores.class0 = predictions[test$Class == 1], scores.class1 =predictions[test #

make the relative plot

plot(auc_plot_rf, main=paste("AUC:", auc_val_rf@y.values[[1]]))
plot(aucpr_plot_rf, main=paste("AUCPR:", aucpr_val_rf$auc.integral))
plot(aucpr_val_rf)

# Adding the respective metrics to the results dataset

results <- results  %>%  add_row(
  Model = "Random Forest",
  AUC = auc_val_rf@y.values[[1]],
  AUCPR = aucpr_val_rf$auc.integral)

# Show results on a table

results  %>%
  kable()  %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)
```

```
# Show feature importance on a table

feature_imp_rf %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

# Set seet 1234 for reproducibility

set.seed(1234)

# Build a GBM Model with Class as Target and all other #
variables as predictors. Distribution is bernoully, #
number of tree is 500

gbm_model <- gbm(as.character(Class) ~ .,
                 distribution = "bernoulli",
                 data = rbind(train, test),
                 n.trees = 500,
                 interaction.depth = 3,
                 n.minobsinnode = 100,
                 shrinkage = 0.01,
                 train.fraction = 0.7,
)

# Determine the best iteration based on test data

best_iter = gbm.perf(gbm_model, method = "test") #

Make predictions based on this model predictions =

predict.gbm(
  gbm_model,
  newdata = test,
  n.trees = best_iter,
  type="response"
)

# Get feature importance

feature_imp_gbm = summary(gbm_model, n.trees = best_iter) #

Compute the AUC and AUPCR

pred <- prediction(
  as.numeric(as.character(predictions)),                                    as.numeric(as.character(test$C
)

auc_val_gbm <- performance(pred, "auc")

auc_plot_gbm <- performance(pred, 'sens', 'spec')
aucpr_plot_gbm <- performance(pred, "prec", "rec")
```

```
aucpr_val_gbm <- pr.curve(
  scores.class0 = predictions[test$Class == 1],
  scores.class1 = predictions[test$Class == 0],
  curve = T,
  dg.compute = T
)

# Make the relative plot

plot(aucpr_val_gbm)
plot(auc_plot_gbm, main=paste("AUC:", auc_val_gbm@y.values[[1]]))
plot(aucpr_plot_gbm, main=paste("AUCPR:", aucpr_val_gbm$auc.integral))

# Adding the respective metrics to the results dataset

results <- results %>% add_row(
  Model = "GBM - Generalized Boosted Regression", AUC
  = auc_val_gbm@y.values[[1]],
  AUCPR = aucpr_val_gbm$auc.integral)

# Show results on a table

results %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

# Show feature importance on a table

feature_imp_gbm %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

# Set seet 1234 for reproducibility

set.seed(1234)

# Prepare the training dataset

xgb_train <- xgb.DMatrix(
  as.matrix(train[, colnames(train) != "Class"]),
  label = as.numeric(as.character(train$Class))
)

# Prepare the test dataset

xgb_test <- xgb.DMatrix(
  as.matrix(test[, colnames(test) != "Class"]),
```

```
  label = as.numeric(as.character(test$Class))
)

# Prepare the cv dataset

xgb_cv <- xgb.DMatrix(
  as.matrix(cv[, colnames(cv) != "Class"]),
  label = as.numeric(as.character(cv$Class))
)

# Prepare the parameters list.

xgb_params <- list(
  objective = "binary:logistic",
  eta = 0.1,
  max.depth = 3,
  nthread = 6,
  eval_metric = "aucpr"
)

# Train the XGBoost Model

xgb_model <- xgb.train(
  data = xgb_train,
  params = xgb_params,
  watchlist = list(test = xgb_test, cv = xgb_cv),
  nrounds = 500,
  early_stopping_rounds = 40,
  print_every_n = 20
)

# Get feature importance

feature_imp_xgb <- xgb.importance(colnames(train), model = xgb_model)

xgb.plot.importance(feature_imp_xgb, rel_to_first = TRUE, xlab = "Relative importance") #

Make predictions based on this model

predictions = predict(
  xgb_model,
  newdata = as.matrix(test[, colnames(test) != "Class"]),
  ntreelimit = xgb_model$bestInd
)

# Compute the AUC and AUPCR

pred <- prediction(
  as.numeric(as.character(predictions)),                                    as.numeric(as.character(test$C
)

auc_val_xgb <- performance(pred, "auc") auc_plot_xgb

<- performance(pred, 'sens', 'spec')
```

```
aucpr_plot_xgb <- performance(pred, "prec", "rec")

aucpr_val_xgb <- pr.curve(
  scores.class0 = predictions[test$Class == 1],
  scores.class1 = predictions[test$Class == 0],
  curve = T,
  dg.compute = T
)

# Make the relative plot

plot(auc_plot_xgb, main=paste("AUC:", auc_val_xgb@y.values[[1]]))
plot(aucpr_plot_xgb, main=paste("AUCPR:", aucpr_val_xgb$auc.integral))
plot(aucpr_val_xgb)

# Adding the respective metrics to the results dataset

results <- results %>% add_row(
  Model = "XGBoost",
  AUC = auc_val_xgb@y.values[[1]],
  AUCPR = aucpr_val_xgb$auc.integral)

# Show results on a table

results %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

# Show feature importance on a table

feature_imp_xgb %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

# Set seet 1234 for reproducibility

set.seed(1234)

# Prepare the training dataset

lgb_train <- lgb.Dataset(
  as.matrix(train[, colnames(train) != "Class"]),
  label = as.numeric(as.character(train$Class))
)

# Prepare the test dataset

lgb_test <- lgb.Dataset(
```

```
  as.matrix(test[, colnames(test) != "Class"]), label
  = as.numeric(as.character(test$Class))
)

# Prepare the cvtaset

lgb_cv <- lgb.Dataset(
  as.matrix(cv[, colnames(cv) != "Class"]),
  label = as.numeric(as.character(cv$Class))
)

# Prepare the parameters list

lgb_params = list(
    objective = "binary",
    metric = "binary_error"
)

# Train the LightGBM Model

lgb_model <- lgb.train(
        params = lgb_params,
        data = lgb_train,
        valids = list(test = lgb_test, cv = lgb_cv),
        learning_rate = 0.01,
        nrounds = 500,
        early_stopping_rounds = 40,
        eval_freq = 20
)

# Get feature importance

feature_imp_lgb = lgb.importance(lgb_model, percentage = TRUE) #

Make predictions based on this model

predictions = predict(
  lgb_model,
  data = as.matrix(test[, colnames(test) != "Class"]), n
  = lgb_model$best_iter)

# Compute the AUC and AUPCR

pred <- prediction(
  predictions,
  as.numeric(as.character(test$Class))
)

auc_val_lgb <- performance(pred, "auc")

auc_plot_lgb <- performance(pred, 'sens', 'spec')
aucpr_plot_lgb <- performance(pred, "prec", "rec")

aucpr_val_lgb <- pr.curve(
```

```
  scores.class0 = predictions[test$Class == 1],
  scores.class1 = predictions[test$Class == 0],
  curve = T,
  dg.compute = T
)

# Make the relative plot

plot(aucpr_val_lgb)
plot(auc_plot_lgb, main=paste("AUC:", auc_val_lgb@y.values[[1]]))
plot(aucpr_plot_lgb, main=paste("AUCPR:", aucpr_val_lgb$auc.integral))

# Adding the respective metrics to the results dataset

results <- results %>% add_row(
  Model = "LightGBM",
  AUC = auc_val_lgb@y.values[[1]],
  AUCPR = aucpr_val_lgb$auc.integral
  )

# Show results on a table

results %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)

feature_imp_lgb %>%
  kable() %>%
  kable_styling(bootstrap_options = c("striped", "hover", "condensed",                "responsive"),
      position = "center",
      font_size = 10,
      full_width = FALSE)
```

7.3 1c - Enviroment

```
## [1] "Operating System:"
```

```
##                _
## platform       x86_64-w64-mingw32
## arch           x86_64
## os             mingw32
## system         x86_64, mingw32
## status
## major          3
## minor          6.0
## year           2019
## month          04
## day            26
## svn rev        76424
## language       R
## version.string R version 3.6.0 (2019-04-26)
## nickname       Planting of a Tree
```

```
## [1] "All installed packages"
##                Package
## abind          "abind"
## askpass        "askpass"
## assertthat     "assertthat"
## backports      "backports"
## base64enc      "base64enc"
## BH             "BH"
## bitops         "bitops"
## broom          "broom"
## callr          "callr"
## caret          "caret"
## caTools        "caTools"
## cellranger     "cellranger"
## Ckmeans.1d.dp "Ckmeans.1d.dp"
## class          "class"
## cli            "cli"
## clipr          "clipr"
## colorspace     "colorspace"
## crayon         "crayon"
## curl           "curl"
## data.table     "data.table"
## DBI            "DBI"
## dbplyr         "dbplyr"
## digest         "digest"
## DMwR           "DMwR"
## DMwR2          "DMwR2"
## doParallel     "doParallel"
## dplyr          "dplyr"
## dslabs         "dslabs"
## e1071          "e1071"
## ellipsis       "ellipsis"
## evaluate       "evaluate"
## fansi          "fansi"
## forcats        "forcats"
## foreach        "foreach"
## fs             "fs"
## gbm            "gbm"
## gdata          "gdata"
## generics       "generics"
## ggplot2        "ggplot2"
## glue           "glue"
## gower          "gower"
## gplots         "gplots"
## gridExtra      "gridExtra"
## gtable         "gtable"
## gtools         "gtools"
## haven          "haven"
## highr          "highr"
## hms            "hms"
## htmltools      "htmltools"
## httr           "httr"
## ipred          "ipred"
```

```
## iterators     "iterators"
## jsonlite      "jsonlite"
## kableExtra    "kableExtra"
## knitr         "knitr"
## labeling      "labeling"
## lattice       "lattice"
## lava          "lava"
## lazyeval      "lazyeval"
## lightgbm      "lightgbm"
## lubridate     "lubridate"
## magrittr      "magrittr"
## markdown      "markdown"
## mime          "mime"
## ModelMetrics  "ModelMetrics"
## modelr        "modelr"
## munsell       "munsell"
## numDeriv      "numDeriv"
## openssl       "openssl"
## PerfMeas      "PerfMeas"
## pillar        "pillar"
## pkgconfig     "pkgconfig"
## plogr         "plogr"
## plyr          "plyr"
## precrec       "precrec"
## prettyunits   "prettyunits"
## pROC          "pROC"
## processx      "processx"
## prodlim       "prodlim"
## progress      "progress"
## PRROC         "PRROC"
## ps            "ps"
## purrr         "purrr"
## quantmod      "quantmod"
## R6            "R6"
## randomForest  "randomForest"
## RColorBrewer  "RColorBrewer"
## Rcpp          "Rcpp"
## RcppRoll      "RcppRoll"
## readr         "readr"
## readxl        "readxl"
## recipes       "recipes"
## rematch       "rematch"
## reprex        "reprex"
## reshape2      "reshape2"
## rlang         "rlang"
## rmarkdown     "rmarkdown"
## ROCR          "ROCR"
## rprojroot     "rprojroot"
## rstudioapi    "rstudioapi"
## rvest         "rvest"
## scales        "scales"
## selectr       "selectr"
## SQUAREM       "SQUAREM"
## stringi       "stringi"
```

```
## stringr        "stringr"
## sys            "sys"
## tibble         "tibble"
## tidyr          "tidyr"
## tidyselect     "tidyselect"
## tidyverse      "tidyverse"
## timeDate       "timeDate"
## tinytex        "tinytex"
## TTR            "TTR"
## utf8           "utf8"
## vctrs          "vctrs"
## viridisLite    "viridisLite"
## webshot        "webshot"
## whisker        "whisker"
## withr          "withr"
## xfun           "xfun"
## xgboost        "xgboost"
## xml2           "xml2"
## xts            "xts"
## yaml           "yaml"
## zeallot        "zeallot"
## zoo            "zoo"
## base           "base"
## boot           "boot"
## class          "class"
## cluster        "cluster"
## codetools      "codetools"
## compiler       "compiler"
## datasets       "datasets"
## foreign        "foreign"
## graphics       "graphics"
## grDevices      "grDevices"
## grid           "grid"
## KernSmooth     "KernSmooth"
## lattice        "lattice"
## MASS           "MASS"
## Matrix         "Matrix"
## methods        "methods"
## mgcv           "mgcv"
## nlme           "nlme"
## nnet           "nnet"
## parallel       "parallel"
## rpart          "rpart"
## spatial        "spatial"
## splines        "splines"
## stats          "stats"
## stats4         "stats4"
## survival       "survival"
## tcltk          "tcltk"
## tools          "tools"
## translations   "translations"
## utils          "utils"
##                LibPath
## abind          "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"
```

```
## askpass       "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
assertthat     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##
backports       "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##
base64enc    "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##  BH
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
bitops     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## broom
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       callr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       caret
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##     caTools
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    cellranger
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##   Ckmeans.1d.dp
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       class
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"        ##        cli
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
clipr           "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
colorspace    "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##
crayon      "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## curl
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    data.table
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"        ##        DBI
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
dbplyr          "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
digest      "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## DMwR
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       DMwR2
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    doParallel
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       dplyr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      dslabs
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       e1071
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     ellipsis
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     evaluate
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       fansi
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     forcats
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     foreach
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"        ##        fs
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
gbm              "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
gdata           "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
generics        "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##
ggplot2     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## glue
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       gower
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      gplots
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##    gridExtra
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      gtable
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      gtools
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       haven
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       highr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"        ##        hms
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
htmltools   "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## httr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       ipred
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     iterators
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     jsonlite
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    kableExtra
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       knitr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"
```

```
## labeling     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
lattice     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## lava
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     lazyeval
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     lightgbm
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     lubridate
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     magrittr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     markdown
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       mime
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##   ModelMetrics
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      modelr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     munsell
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     numDeriv
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     openssl
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     PerfMeas
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      pillar
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     pkgconfig
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       plogr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       plyr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     precrec
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    prettyunits
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       pROC
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     processx
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     prodlim
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     progress
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       PRROC
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"         ##         ps
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
purrr            "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
quantmod     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##  R6
                  "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
randomForest    "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##
RColorBrewer    "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##
Rcpp             "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
RcppRoll    "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## readr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      readxl
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     recipes
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     rematch
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      reprex
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     reshape2
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      rlang
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     rmarkdown
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       ROCR
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     rprojroot
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    rstudioapi
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       rvest
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      scales
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     selectr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     SQUAREM
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     stringi
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"     ##     stringr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       sys
                  "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
tibble     "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## tidyr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"
```

```
##  tidyselect  "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
tidyverse      "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##
timeDate        "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"   ##
tinytex      "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## TTR
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
utf8       "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## vctrs
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"    ##    viridisLite
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      webshot
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      whisker
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       withr
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       xfun
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"      ##      xgboost
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"       ##       xml2
"C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"        ##        xts
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
yaml            "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6"  ##
zeallot      "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ## zoo
                 "C:/Users/aless/OneDrive/Documenti/R/win-library/3.6" ##
base "C:/Program Files/R/R-3.6.0/library"
## boot          "C:/Program Files/R/R-3.6.0/library"
## class        "C:/Program Files/R/R-3.6.0/library" ##
cluster        "C:/Program  Files/R/R-3.6.0/library"  ##
codetools     "C:/Program  Files/R/R-3.6.0/library"  ##
compiler       "C:/Program  Files/R/R-3.6.0/library"  ##
datasets       "C:/Program  Files/R/R-3.6.0/library"  ##
foreign        "C:/Program  Files/R/R-3.6.0/library"  ##
graphics       "C:/Program  Files/R/R-3.6.0/library"  ##
grDevices  "C:/Program Files/R/R-3.6.0/library" ## grid
"C:/Program   Files/R/R-3.6.0/library"   ##   KernSmooth
"C:/Program    Files/R/R-3.6.0/library"    ##    lattice
"C:/Program     Files/R/R-3.6.0/library"     ##     MASS
"C:/Program    Files/R/R-3.6.0/library"    ##    Matrix
"C:/Program    Files/R/R-3.6.0/library"    ##    methods
"C:/Program     Files/R/R-3.6.0/library"     ##     mgcv
"C:/Program     Files/R/R-3.6.0/library"     ##     nlme
"C:/Program     Files/R/R-3.6.0/library"     ##     nnet
"C:/Program   Files/R/R-3.6.0/library"   ##   parallel
"C:/Program    Files/R/R-3.6.0/library"    ##    rpart
"C:/Program    Files/R/R-3.6.0/library"    ##    spatial
"C:/Program    Files/R/R-3.6.0/library"    ##    splines
"C:/Program     Files/R/R-3.6.0/library"     ##     stats
"C:/Program    Files/R/R-3.6.0/library"    ##    stats4
"C:/Program   Files/R/R-3.6.0/library"   ##   survival
"C:/Program     Files/R/R-3.6.0/library"     ##     tcltk
"C:/Program     Files/R/R-3.6.0/library"     ##     tools
"C:/Program  Files/R/R-3.6.0/library"  ##  translations
"C:/Program     Files/R/R-3.6.0/library"     ##     utils
"C:/Program Files/R/R-3.6.0/library" ##   Version
Priority

## abind          "1.4-5"       NA
## askpass        "1.1"         NA
## assertthat     "0.2.1"       NA
## backports      "1.1.4"       NA
## base64enc      "0.1-3"       NA
```

```
## BH             "1.69.0-1"   NA
## bitops         "1.0-6"      NA
## broom          "0.5.2"      NA
## callr          "3.2.0"      NA
## caret          "6.0-84"     NA
## caTools        "1.17.1.2"   NA
## cellranger     "1.1.0"      NA
## Ckmeans.1d.dp  "4.2.2"      NA
## class          "7.3-15"     "recommended"
## cli            "1.1.0"      NA
## clipr          "0.6.0"      NA
## colorspace     "1.4-1"      NA
## crayon         "1.3.4"      NA
## curl           "3.3"        NA
## data.table     "1.12.2"     NA
## DBI            "1.0.0"      NA
## dbplyr         "1.4.0"      NA
## digest         "0.6.19"     NA
## DMwR           "0.4.1"      NA
## DMwR2          "0.0.2"      NA
## doParallel     "1.0.14"     NA
## dplyr          "0.8.1"      NA
## dslabs         "0.6.0"      NA
## e1071          "1.7-1"      NA
## ellipsis       "0.1.0"      NA
## evaluate       "0.13"       NA
## fansi          "0.4.0"      NA
## forcats        "0.4.0"      NA
## foreach        "1.4.4"      NA
## fs             "1.3.1"      NA
## gbm            "2.1.5"      NA
## gdata          "2.18.0"     NA
## generics       "0.0.2"      NA
## ggplot2        "3.1.1"      NA
## glue           "1.3.1"      NA
## gower          "0.2.1"      NA
## gplots         "3.0.1.1"    NA
## gridExtra      "2.3"        NA
## gtable         "0.3.0"      NA
## gtools         "3.8.1"      NA
## haven          "2.1.0"      NA
## highr          "0.8"        NA
## hms            "0.4.2"      NA
## htmltools      "0.3.6"      NA
## httr           "1.4.0"      NA
## ipred          "0.9-9"      NA
## iterators      "1.0.10"     NA
## jsonlite       "1.6"        NA
## kableExtra     "1.1.0"      NA
## knitr          "1.23"       NA
## labeling       "0.3"        NA
## lattice        "0.20-38"    "recommended"
## lava           "1.6.5"      NA
## lazyeval       "0.2.2"      NA
```

```
## lightgbm       "2.2.4"       NA
## lubridate      "1.7.4"       NA
## magrittr       "1.5"         NA
## markdown       "0.9"         NA
## mime           "0.6"         NA
## ModelMetrics   "1.2.2"       NA
## modelr         "0.1.4"       NA
## munsell        "0.5.0"       NA
## numDeriv       "2016.8-1"    NA
## openssl        "1.3"         NA
## PerfMeas       "1.2.1"       NA
## pillar         "1.4.0"       NA
## pkgconfig      "2.0.2"       NA
## plogr          "0.2.0"       NA
## plyr           "1.8.4"       NA
## precrec        "0.10.1"      NA
## prettyunits    "1.0.2"       NA
## pROC           "1.14.0"      NA
## processx       "3.3.1"       NA
## prodlim        "2018.04.18"  NA
## progress       "1.2.2"       NA
## PRROC          "1.3.1"       NA
## ps             "1.3.0"       NA
## purrr          "0.3.2"       NA
## quantmod       "0.4-14"      NA
## R6             "2.4.0"       NA
## randomForest   "4.6-14"      NA
## RColorBrewer   "1.1-2"       NA
## Rcpp           "1.0.1"       NA
## RcppRoll       "0.3.0"       NA
## readr          "1.3.1"       NA
## readxl         "1.3.1"       NA
## recipes        "0.1.5"       NA
## rematch        "1.0.1"       NA
## reprex         "0.3.0"       NA
## reshape2       "1.4.3"       NA
## rlang          "0.3.4"       NA
## rmarkdown      "1.13"        NA
## ROCR           "1.0-7"       NA
## rprojroot      "1.3-2"       NA
## rstudioapi     "0.10"        NA
## rvest          "0.3.4"       NA
## scales         "1.0.0"       NA
## selectr        "0.4-1"       NA
## SQUAREM        "2017.10-1"   NA
## stringi        "1.4.3"       NA
## stringr        "1.4.0"       NA
## sys            "3.2"         NA
## tibble         "2.1.1"       NA
## tidyr          "0.8.3"       NA
## tidyselect     "0.2.5"       NA
## tidyverse      "1.2.1"       NA
## timeDate       "3043.102"    NA
## tinytex        "0.13"        NA
```

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## TTR            "0.23-4"      NA
## utf8           "1.1.4"       NA
## vctrs          "0.1.0"       NA
## viridisLite    "0.3.0"       NA
## webshot        "0.5.1"       NA
## whisker        "0.3-2"       NA
## withr          "2.1.2"       NA
## xfun           "0.7"         NA
## xgboost        "0.82.1"      NA
## xml2           "1.2.0"       NA
## xts            "0.11-2"      NA
## yaml           "2.2.0"       NA
## zeallot        "0.1.0"       NA
## zoo            "1.8-5"       NA
## base           "3.6.0"       "base"
## boot           "1.3-22"      "recommended"
## class          "7.3-15"      "recommended"
## cluster        "2.0.8"       "recommended"
## codetools      "0.2-16"      "recommended"
## compiler       "3.6.0"       "base"
## datasets       "3.6.0"       "base"
## foreign        "0.8-71"      "recommended"
## graphics       "3.6.0"       "base"
## grDevices      "3.6.0"       "base"
## grid           "3.6.0"       "base"
## KernSmooth     "2.23-15"     "recommended"
## lattice        "0.20-38"     "recommended"
## MASS           "7.3-51.4"    "recommended"
## Matrix         "1.2-17"      "recommended"
## methods        "3.6.0"       "base"
## mgcv           "1.8-28"      "recommended"
## nlme           "3.1-139"     "recommended"
## nnet           "7.3-12"      "recommended"
## parallel       "3.6.0"       "base"
## rpart          "4.1-15"      "recommended"
## spatial        "7.3-11"      "recommended"
## splines        "3.6.0"       "base"
## stats          "3.6.0"       "base"
## stats4         "3.6.0"       "base"
## survival       "2.44-1.1"    "recommended"
## tcltk          "3.6.0"       "base"
## tools          "3.6.0"       "base"
## translations   "3.6.0"       NA
## utils          "3.6.0"       "base"
##                Depends
## abind          "R (>= 1.5.0)"
## askpass        NA
## assertthat     NA
## backports      "R (>= 3.0.0)"
## base64enc      "R (>= 2.9.0)"
## BH             NA
## bitops         NA
## broom          "R (>= 3.1)"
## callr          NA
```

```
## caret          "R (>= 3.2.0), lattice (>= 0.20), ggplot2"
## caTools        "R (>= 2.2.0)"
## cellranger     "R (>= 3.0.0)"
## Ckmeans.1d.dp  NA
## class          "R (>= 3.0.0), stats, utils"
## cli            "R (>= 2.10)"
## clipr          NA
## colorspace     "R (>= 3.0.0), methods"
## crayon         NA
## curl           "R (>= 3.0.0)"
## data.table     "R (>= 3.1.0)"
## DBI            "R (>= 3.0.0), methods"
## dbplyr         "R (>= 3.1)"
## digest         "R (>= 3.1.0)"
## DMwR           "R(>= 2.10), methods, graphics, lattice (>= 0.18-3), grid (>=¥n2.10.1)"
## DMwR2          "R(>= 3.0), methods"
## doParallel     "R (>= 2.14.0), foreach(>= 1.2.0), iterators(>= 1.0.0),¥nparallel, utils"
## dplyr          "R (>= 3.2.0)"
## dslabs         "R (>= 3.1.2)"
## e1071          NA
## ellipsis       "R (>= 3.1)"
## evaluate       "R (>= 3.0.2)"
## fansi          "R (>= 3.1.0)"
## forcats        "R (>= 3.1)"
## foreach        "R (>= 2.5.0)"
## fs             "R (>= 3.1)"
## gbm            "R (>= 2.9.0)"
## gdata          "R (>= 2.3.0)"
## generics       "R (>= 3.1)"
## ggplot2        "R (>= 3.1)"
## glue           "R (>= 3.1)"
## gower          NA
## gplots         "R (>= 3.0)"
## gridExtra      NA
## gtable         "R (>= 3.0)"
## gtools         "methods, stats, utils"
## haven          "R (>= 3.1)"
## highr          "R (>= 3.2.3)"
## hms            NA
## htmltools      "R (>= 2.14.1)"
## httr           "R (>= 3.1)"
## ipred          "R (>= 2.10)"
## iterators      "R (>= 2.5.0), utils"
## jsonlite       "methods"
## kableExtra     "R (>= 3.1.0)"
## knitr          "R (>= 3.2.3)"
## labeling       NA
## lattice        "R (>= 3.0.0)"
## lava           "R (>= 3.0)"
## lazyeval       "R (>= 3.1.0)"
## lightgbm       "R (>= 3.4), R6 (>= 2.0)"
## lubridate      "methods, R (>= 3.0.0)"
## magrittr       NA
## markdown       "R (>= 2.11.1)"
```

```
## mime           NA
## ModelMetrics   "R (>= 3.2.2)"
## modelr         "R (>= 3.1)"
## munsell        NA
## numDeriv       "R (>= 2.11.1)"
## openssl        NA
## PerfMeas       "limma, graph, RBGL"
## pillar         NA
## pkgconfig      NA
## plogr          NA
## plyr           "R (>= 3.1.0)"
## precrec        "R (>= 3.2.1)"
## prettyunits    NA
## pROC           "R (>= 2.14)"
## processx       NA
## prodlim        "R (>= 2.9.0)"
## progress       NA
## PRROC          NA
## ps             "R (>= 3.1)"
## purrr          "R (>= 3.1)"
## quantmod       "R (>= 3.2.0), xts(>= 0.9-0), zoo, TTR(>= 0.2), methods"
## R6             "R (>= 3.0)"
## randomForest   "R (>= 3.2.2), stats"
## RColorBrewer   "R (>= 2.0.0)"
## Rcpp           "R (>= 3.0.0)"
## RcppRoll       "R (>= 2.15.1)"
## readr          "R (>= 3.1)"
## readxl         NA
## recipes        "R (>= 3.1), dplyr"
## rematch        NA
## reprex         "R (>= 3.1)"
## reshape2       "R (>= 3.1)"
## rlang          "R (>= 3.1.0)"
## rmarkdown      "R (>= 3.0)"
## ROCR           "gplots, methods"
## rprojroot      "R (>= 3.0.0)"
## rstudioapi     NA
## rvest          "R (>= 3.2), xml2"
## scales         "R (>= 3.1)"
## selectr        "R (>= 3.0)"
## SQUAREM        "R (>= 3.0)"
## stringi        "R (>= 2.14)"
## stringr        "R (>= 3.1)"
## sys            NA
## tibble         "R (>= 3.1.0)"
## tidyr          "R (>= 3.1)"
## tidyselect     "R (>= 3.1)"
## tidyverse      NA
## timeDate       "R (>= 2.15.1), graphics, utils, stats, methods"
## tinytex        NA
## TTR            NA
## utf8           "R (>= 2.10)"
## vctrs          "R (>= 3.1)"
## viridisLite    "R (>= 2.10)"
```

```
## webshot        "R (>= 3.0)"
## whisker        NA
## withr          "R (>= 3.0.2)"
## xfun           NA
## xgboost        "R (>= 3.3.0)"
## xml2           "R (>= 3.1.0)"
## xts            "zoo (>= 1.7-12)"
## yaml           NA
## zeallot        NA
## zoo            "R (>= 3.1.0), stats"
## base           NA
## boot           "R (>= 3.0.0), graphics, stats"
## class          "R (>= 3.0.0), stats, utils"
## cluster        "R (>= 3.3.0)"
## codetools      "R (>= 2.1)"
## compiler       NA
## datasets       NA
## foreign        "R (>= 3.0.0)"
## graphics       NA
## grDevices      NA
## grid           NA
## KernSmooth     "R (>= 2.5.0), stats"
## lattice        "R (>= 3.0.0)"
## MASS           "R (>= 3.1.0), grDevices, graphics, stats, utils"
## Matrix         "R (>= 3.2.0)"
## methods        NA
## mgcv           "R (>= 2.14.0), nlme (>= 3.1-64)"
## nlme           "R (>= 3.4.0)"
## nnet           "R (>= 2.14.0), stats, utils"
## parallel       NA
## rpart          "R (>= 2.15.0), graphics, stats, grDevices"
## spatial        "R (>= 3.0.0), graphics, stats, utils"
## splines        NA
## stats          NA
## stats4        NA
## survival    "R (>= 2.13.0)" ##
tcltk  NA
## tools       NA ##
translations  NA  ##
utils         NA
##                Imports
## abind          "methods, utils"
## askpass        "sys (>= 2.1)"
## assertthat     "tools"
## backports      "utils"
## base64enc      NA
## BH             NA
## bitops         NA
## broom          "backports, dplyr, generics (>= 0.0.2), methods, nlme, purrr,¥nreshape2, stringr, tibb ##
callr             "processx (>= 3.3.0), R6, utils"
## caret          "foreach, methods, plyr, ModelMetrics (>= 1.1.0), nlme,¥nreshape2, stats, stats4, util ##
caTools           "bitops"
## cellranger     "rematch, tibble"
## Ckmeans.1d.dp "Rcpp (>= 0.12.18)"
```

```
## class          "MASS"
## cli            "assertthat, crayon (>= 1.3.4), methods, utils"
## clipr          "utils"
## colorspace     "graphics, grDevices, stats"
## crayon         "grDevices, methods, utils"
## curl           NA
## data.table     "methods"
## DBI            NA
## dbplyr         "assertthat (>= 0.2.0), DBI (>= 1.0.0), dplyr (>= 0.8.0), glue¥n(>= 1.2.0), methods, p
## digest         NA
## DMwR           "xts (>= 0.6-7), quantmod (>= 0.3-8), zoo (>= 1.6-4), abind (>=¥n1.1-0), rpart (>= 3.1
## DMwR2          "xts (>= 0.9-7), zoo (>= 1.7-10), class (>= 7.3-14), rpart (>=¥n4.1-10), quantmod (>=
## doParallel     NA
## dplyr          "assertthat (>= 0.2.1), glue (>= 1.3.1), magrittr (>= 1.5),¥nmethods, pkgconfig (>= 2.
## dslabs         "ggplot2"
## e1071          "graphics, grDevices, class, stats, methods, utils"
## ellipsis       NA
## evaluate       "methods"
## fansi          NA
## forcats        "ellipsis, magrittr, rlang, tibble"
## foreach        "codetools, utils, iterators"
## fs             "methods, Rcpp"
## gbm            "gridExtra, lattice, parallel, survival"
## gdata          "gtools, stats, methods, utils"
## generics       "methods"
## ggplot2        "digest, grid, gtable (>= 0.1.1), lazyeval, MASS, mgcv, plyr¥n(>= 1.7.1), reshape2, rl ##
glue            "methods"
## gower          NA
## gplots         "gtools, gdata, stats, caTools, KernSmooth"
## gridExtra      "gtable, grid, grDevices, graphics, utils" ##
gtable          "grid"
## gtools         NA
## haven          "forcats (>= 0.2.0), hms, Rcpp (>= 0.11.4), readr (>= 0.1.0),¥ntibble" ##
highr           NA
## hms            "methods, pkgconfig, rlang"
## htmltools      "utils, digest, Rcpp"
## httr           "curl (>= 0.9.1), jsonlite, mime, openssl (>= 0.8), R6" ##
ipred           "rpart (>= 3.1-8), MASS, survival, nnet, class, prodlim"
## iterators      NA
## jsonlite       NA
## kableExtra     "knitr (>= 1.16), magrittr, stringr (>= 1.0), xml2 (>= 1.1.1),¥nrvest, rmarkdown (>= ##
knitr           "evaluate (>= 0.10), highr, markdown, stringr (>= 0.6), yaml¥n(>= 2.1.19), methods, xf ##
labeling        NA
## lattice        "grid, grDevices, graphics, stats, utils"
## lava           "grDevices, graphics, methods, numDeriv, stats, survival,¥nSQUAREM, utils" ##
lazyeval        NA
## lightgbm       "data.table (>= 1.9.6), graphics, jsonlite (>= 1.0), magrittr¥n(>= 1.5), Matrix (>= 1. ##
lubridate       "stringr, Rcpp (>= 0.12.13),"
## magrittr       NA
## markdown       "utils, mime (>= 0.3)"
## mime           "tools"
## ModelMetrics   "Rcpp, data.table"
## modelr         "broom, dplyr, magrittr, purrr (>= 0.2.2), rlang (>= 0.2.0),¥ntibble, tidyr (>= 0.8.0) ##
munsell         "colorspace, methods"
```

```
## numDeriv       NA
## openssl        "askpass"
## PerfMeas       NA
## pillar         "cli (>= 1.1.0), crayon (>= 1.3.4), fansi (>= 0.4.0), methods,¥nrlang (>= 0.3.4), utf8 ##
pkgconfig         "utils"
## plogr          NA
## plyr           "Rcpp (>= 0.11.0)"
## precrec        "Rcpp (>= 0.12.2), ggplot2 (>= 2.1.0), assertthat (>= 0.1),¥ngrid, gridExtra (>= 2.0.0 ##
prettyunits       "magrittr, assertthat, methods"
## pROC           "methods, plyr, Rcpp (>= 0.11.1)"
## processx       "ps (>= 1.2.0), R6, utils"
## prodlim        "Rcpp (>= 0.11.5), stats, graphics, survival, KernSmooth, lava" ##
progress          "hms, prettyunits, R6, crayon"
## PRROC          NA
## ps             "utils"
## purrr          "magrittr (>= 1.5), rlang (>= 0.3.1)"
## quantmod       "curl"
## R6             NA
## randomForest   NA
## RColorBrewer   NA
## Rcpp           "methods, utils"
## RcppRoll       "Rcpp"
## readr          "Rcpp (>= 0.12.0.5), tibble, hms (>= 0.4.1), R6, clipr, crayon,¥nmethods" ##
readxl            "cellranger, Rcpp (>= 0.12.18), tibble (>= 1.3.1), utils"
## recipes        "generics, glue, gower, ipred, lubridate, magrittr, Matrix,¥npurrr (>= 0.2.3), RcppRol ##
rematch           NA
## reprex         "callr (>= 2.0.0), clipr (>= 0.4.0), fs, rlang, rmarkdown,¥nutils, whisker, withr" ##
reshape2          "plyr (>= 1.8.1), Rcpp, stringr"
## rlang          NA
## rmarkdown      "tools, utils, knitr (>= 1.22), yaml (>= 2.1.19), htmltools (>=¥n0.3.5), evaluate (>= ##
ROCR              NA
## rprojroot      "backports"
## rstudioapi     NA
## rvest          "httr (>= 0.5), magrittr, selectr"
## scales         "labeling, munsell (>= 0.5), R6, RColorBrewer, Rcpp,¥nviridisLite" ##
selectr           "methods, stringr, R6"
## SQUAREM        NA
## stringi "tools, utils, stats"
## stringr     "glue (>= 1.2.0), magrittr, stringi (>= 1.1.7)" ##
sys               NA
## tibble      "cli (>= 1.0.1), crayon (>= 1.3.4), fansi (>= 0.4.0), methods,¥npillar (>= 1.3.1), pkg ##
tidyr         "dplyr (>= 0.7.0), glue, magrittr, purrr, Rcpp, rlang, stringi,¥ntibble, tidyselect (> ##
tidyselect "glue (>= 1.3.0), purrr, rlang (>= 0.2.2), Rcpp (>= 0.12.0)"
## tidyverse   "broom (>= 0.4.2), cli (>= 1.0.0), crayon (>= 1.3.4), dplyr (>=¥n0.7.4), dbplyr (>= 1. ##
timeDate  NA
## tinytex        "xfun (>= 0.5)"
## TTR            "xts (>= 0.10-0), zoo, curl"
## utf8           NA
## vctrs          "backports, digest, glue, rlang, zeallot"
## viridisLite    NA
## webshot        "magrittr, jsonlite, callr"
## whisker        NA
## withr          "stats, graphics, grDevices"
## xfun           "tools"
```

```
## xgboost        "Matrix (>= 1.1-0), methods, data.table (>= 1.9.6), magrittr¥n(>= 1.5), stringi (>= 0. ##
xml2             "Rcpp"
## xts            "methods"
## yaml           NA
## zeallot        NA
## zoo            "utils, graphics, grDevices, lattice (>= 0.20-27)"
## base           NA
## boot           NA
## class          "MASS"
## cluster        "graphics, grDevices, stats, utils"
## codetools      NA
## compiler       NA
## datasets       NA
## foreign        "methods, utils, stats"
## graphics       "grDevices"
## grDevices      NA
## grid           "grDevices, utils"
## KernSmooth     NA
## lattice        "grid, grDevices, graphics, stats, utils"
## MASS           "methods"
## Matrix         "methods, graphics, grid, stats, utils, lattice"
## methods        "utils, stats"
## mgcv           "methods, stats, graphics, Matrix, splines, utils"
## nlme           "graphics, stats, utils, lattice"
## nnet           NA
## parallel       "tools, compiler"
## rpart          NA
## spatial        NA
## splines        "graphics, stats"
## stats          "utils, grDevices, graphics"
## stats4         "graphics, methods, stats"
## survival       "graphics, Matrix, methods, splines, stats, utils"
## tcltk          "utils"
## tools       NA ##
translations  NA  ##
utils  NA
##                LinkingTo
## abind          NA
## askpass        NA
## assertthat     NA
## backports      NA
## base64enc      NA
## BH             NA
## bitops         NA
## broom          NA
## callr          NA
## caret          NA
## caTools        NA
## cellranger     NA
## Ckmeans.1d.dp "Rcpp"
## class          NA
## cli            NA
## clipr          NA
## colorspace     NA
```

```
## crayon         NA
## curl           NA
## data.table     NA
## DBI            NA
## dbplyr         NA
## digest         NA
## DMwR           NA
## DMwR2          NA
## doParallel     NA
## dplyr          "BH (>= 1.69.0-1), plogr (>= 0.2.0), Rcpp (>= 1.0.1)"
## dslabs         NA
## e1071          NA
## ellipsis       NA
## evaluate       NA
## fansi          NA
## forcats        NA
## foreach        NA
## fs             "Rcpp"
## gbm            NA
## gdata          NA
## generics       NA
## ggplot2        NA
## glue           NA
## gower          NA
## gplots         NA
## gridExtra      NA
## gtable         NA
## gtools         NA
## haven          "Rcpp"
## highr          NA
## hms            NA
## htmltools      "Rcpp"
## httr           NA
## ipred          NA
## iterators      NA
## jsonlite       NA
## kableExtra     NA
## knitr          NA
## labeling       NA
## lattice        NA
## lava           NA
## lazyeval       NA
## lightgbm       NA
## lubridate      "Rcpp,"
## magrittr       NA
## markdown       NA
## mime           NA
## ModelMetrics   "Rcpp"
## modelr         NA
## munsell        NA
## numDeriv       NA
## openssl        NA
## PerfMeas       NA
## pillar         NA
```

```
## pkgconfig      NA
## plogr          NA
## plyr           "Rcpp"
## precrec        "Rcpp"
## prettyunits    NA
## pROC           "Rcpp"
## processx       NA
## prodlim        "Rcpp"
## progress       NA
## PRROC          NA
## ps             NA
## purrr          NA
## quantmod       NA
## R6             NA
## randomForest   NA
## RColorBrewer   NA
## Rcpp           NA
## RcppRoll       "Rcpp"
## readr          "Rcpp, BH"
## readxl         "progress, Rcpp"
## recipes        NA
## rematch        NA
## reprex         NA
## reshape2       "Rcpp"
## rlang          NA
## rmarkdown      NA
## ROCR           NA
## rprojroot      NA
## rstudioapi     NA
## rvest          NA
## scales         "Rcpp"
## selectr        NA
## SQUAREM        NA
## stringi        NA
## stringr        NA
## sys            NA
## tibble         NA
## tidyr          "Rcpp"
## tidyselect     "Rcpp (>= 0.12.0),"
## tidyverse      NA
## timeDate       NA
## tinytex        NA
## TTR            "xts"
## utf8           NA
## vctrs          NA
## viridisLite    NA
## webshot        NA
## whisker        NA
## withr          NA
## xfun           NA
## xgboost        NA
## xml2           "Rcpp (>= 0.12.12)"
## xts            "zoo"
## yaml           NA
```

```
## zeallot        NA
## zoo            NA
## base           NA
## boot           NA
## class          NA
## cluster        NA
## codetools      NA
## compiler       NA
## datasets       NA
## foreign        NA
## graphics       NA
## grDevices      NA
## grid           NA
## KernSmooth     NA
## lattice        NA
## MASS           NA
## Matrix         NA
## methods        NA
## mgcv           NA
## nlme           NA
## nnet           NA
## parallel       NA
## rpart          NA
## spatial        NA
## splines        NA
## stats          NA
## stats4         NA
## survival       NA
## tcltk          NA
## tools          NA
## translations   NA
## utils          NA
##                Suggests
## abind          NA
## askpass        "testthat"
## assertthat     "testthat, covr"
## backports      NA
## base64enc      NA
## BH             NA
## bitops         NA
## broom          "AER, akima, AUC, bbmle, betareg, biglm, binGroup, boot, brms,¥nbtergm, car, caret, co ##
callr             "cliapp, covr, crayon, pingr, ps, testthat, withr"
## caret          "BradleyTerry2, e1071, earth (>= 2.2-3), fastICA, gam (>=¥n1.15), ipred, kernlab, knit ##
caTools           "MASS, rpart"
## cellranger     "covr, testthat (>= 1.0.0), knitr, rmarkdown"
## Ckmeans.1d.dp "testthat, knitr, rmarkdown"
## class          NA
## cli            "covr, fansi, mockery, testthat, webshot, withr"
## clipr          "covr, knitr, rmarkdown, rstudioapi (>= 0.5), testthat (>=¥n2.0.0)"
## colorspace     "datasets, utils, KernSmooth, MASS, kernlab, mvtnorm, vcd,¥ntcltk, shiny, shinyjs, ggp ##
crayon            "mockery, rstudioapi, testthat, withr"
## curl           "spelling, testthat (>= 1.0.0), knitr, jsonlite, rmarkdown,¥nmagrittr, httpuv (>= 1.4. ##
data.table        "bit64, curl, R.utils, knitr, xts, nanotime, zoo"
## DBI            "blob, covr, hms, knitr, magrittr, rprojroot, rmarkdown,¥nRSQLite (>= 1.1-2), testthat
```

```
## dbplyr         "bit64, covr, knitr, Lahman, nycflights13, RMariaDB (>=¥n1.0.2), rmarkdown, RMySQL (>= ##
digest           "knitr, rmarkdown"
## DMwR          NA
## DMwR2         NA
## doParallel    "caret, mlbench, rpart, RUnit"
## dplyr         "bit64 (>= 0.9-7), callr (>= 3.2.0), covr (>= 3.2.1), DBI (>=¥n1.0.0), dbplyr (>= 1.4. ##
dslabs           NA
## e1071         "cluster, mlbench, nnet, randomForest, rpart, SparseM, xtable,¥nMatrix, MASS, slam" ##
ellipsis         "covr, testthat"
## evaluate      "testthat, lattice, ggplot2"
## fansi         "unitizer, knitr, rmarkdown"
## forcats       "covr, ggplot2, testthat, readr, knitr, rmarkdown, dplyr" ##
foreach          "randomForest"
## fs            "testthat, covr, pillar (>= 1.0.0), crayon, rmarkdown, knitr,¥nwithr, spelling" ##
gbm              "knitr, pdp, RUnit, splines, viridis"
## gdata         "RUnit"
## generics      "covr, pkgload, testthat, tibble"
## ggplot2       "covr, dplyr, ggplot2movies, hexbin, Hmisc, lattice, mapproj,¥nmaps, maptools, multcom ##
glue             "testthat, covr, magrittr, crayon, knitr, rmarkdown, DBI,¥nRSQLite, R.utils, forcats, ##
gower            "tinytest (>= 0.9.3),"
## gplots        "grid, MASS"
## gridExtra     "ggplot2, egg, lattice, knitr, testthat"
## gtable        "covr, testthat, knitr, rmarkdown, ggplot2, profvis"
## gtools        NA
## haven         "covr, fs, knitr, rmarkdown, testthat, pillar (>= 1.1.1), cli,¥ncrayon" ##
highr            "knitr, testit"
## hms           "crayon, lubridate, pillar (>= 1.1.0), testthat"
## htmltools     "markdown, testthat"
## httr          "covr, httpuv, jpeg, knitr, png, readr, rmarkdown, testthat¥n(>= 0.8.0), xml2" ##
ipred            "mvtnorm, mlbench, TH.data"
## iterators     "RUnit, foreach"
## jsonlite      "httr, curl, plyr, testthat, knitr, rmarkdown, R.rsp, sp" ##
kableExtra       "testthat, magick, formattable, dplyr"
## knitr         "formatR, testit, digest, rgl (>= 0.95.1201), codetools,¥nrmarkdown, htmlwidgets (>= 0 ##
labeling         NA
## lattice       "KernSmooth, MASS, latticeExtra"
## lava          "KernSmooth, Matrix, Rgraphviz, data.table, ellipse, fields,¥nforeach, geepack, gof (> ##
lazyeval         "knitr, rmarkdown (>= 0.2.65), testthat, covr"
## lightgbm      "Ckmeans.1d.dp (>= 3.3.1), DiagrammeR (>= 0.8.1), ggplot2 (>=¥n1.0.1), igraph (>= 1.0. ##
lubridate        "testthat, knitr, covr"
## magrittr      "testthat, knitr"
## markdown      "knitr, RCurl"
## mime          NA
## ModelMetrics  "testthat"
## modelr        "compiler, covr, ggplot2, testthat"
## munsell       "ggplot2, testthat"
## numDeriv      NA
## openssl       "testthat, digest, knitr, rmarkdown, jsonlite, jose"
## PerfMeas      NA
## pillar        "knitr (>= 1.22), lubridate (>= 1.7.4), testthat (>= 2.1.1),¥nwithr (>= 2.1.2)" ##
pkgconfig        "covr, testthat, disposables (>= 1.0.3)"
## plogr         "Rcpp"
## plyr          "abind, testthat, tcltk, foreach, doParallel, itertools,¥niterators, covr" ##
precrec          "testthat (>= 0.11.0), knitr (>= 1.11), rmarkdown (>= 0.8.1)"
```

```
## prettyunits    "testthat"
## pROC           "microbenchmark, tcltk, MASS, logcondens, doParallel,¥ntestthat, vdiffr, ggplot2" ##
processx         "callr, covr, crayon, curl, debugme, parallel, testthat, withr"
## prodlim        NA
## progress       "Rcpp, testthat, withr" ##
PRROC            "testthat, ggplot2, ROCR"
## ps             "callr, covr, curl, pingr, processx (>= 3.1.0), R6, rlang,¥ntestthat, tibble"
## purrr          "covr, crayon, dplyr (>= 0.7.8), knitr, rmarkdown, testthat,¥ntibble, tidyselect" ##
quantmod         "DBI,RMySQL,RSQLite,timeSeries,XML,downloader,jsonlite(>= 1.1)"
## R6             "knitr, microbenchmark, pryr, testthat, ggplot2, scales"
## randomForest   "RColorBrewer, MASS"
## RColorBrewer   NA
## Rcpp           "RUnit, inline, rbenchmark, knitr, rmarkdown, pinp, pkgKitten¥n(>= 0.1.2)" ##
RcppRoll         "zoo, testthat"
## readr          "curl, testthat, knitr, rmarkdown, stringi, covr, spelling" ##
readxl           "covr, knitr, rmarkdown, rprojroot (>= 1.1), testthat"
## recipes        "covr, ddalpha, dimRed (>= 0.2.2), fastICA, ggplot2, igraph,¥nkernlab, knitr, NMF, pls ##
rematch          "covr, testthat"
## reprex         "covr, devtools, fortunes, knitr, miniUI, rprojroot,¥nrstudioapi, shiny, styler (>= 1. ##
reshape2         "covr, lattice, testthat (>= 0.8.0)"
## rlang          "covr, crayon, magrittr, methods, pillar, rmarkdown, testthat¥n(>= 2.0.0)"
## rmarkdown      "shiny (>= 0.11), tufte, testthat, digest, dygraphs, tibble,¥nfs, callr (>= 2.0.0)" ##
ROCR             NA
## rprojroot      "testthat, mockr, knitr, withr, rmarkdown"
## rstudioapi     "testthat, knitr, rmarkdown"
## rvest          "covr, knitr, png, rmarkdown, spelling, stringi (>= 0.3.1),¥ntestthat" ##
scales           "dichromat, bit64, covr, hms, testthat (>= 2.0)"
## selectr        "testthat, XML, xml2"
## SQUAREM        "setRNG"
## stringi        NA
## stringr        "covr, htmltools, htmlwidgets, knitr, rmarkdown, testthat" ##
sys              "unix (>= 1.4), spelling, testthat"
## tibble         "bench (>= 1.0.1), covr (>= 3.2.1), dplyr (>= 0.7.8),¥nhtmltools (>= 0.3.6), import (> ##
tidyr            "covr, gapminder, knitr, rmarkdown, testthat"
## tidyselect     "covr, dplyr, testthat"
## tidyverse      "feather (>= 0.3.1), knitr (>= 1.17), rmarkdown (>= 1.7.4)" ##
timeDate         "date, RUnit"
## tinytex        "testit, rstudioapi"
## TTR            "RUnit"
## utf8           "knitr, rmarkdown, testthat"
## vctrs          "covr, generics, knitr, pillar, pkgdown, rmarkdown, testthat,¥ntibble" ##
viridisLite      "hexbin (>= 1.27.0), ggplot2 (>= 1.0.1), testthat, covr"
## webshot        "httpuv, knitr, rmarkdown, shiny"
## whisker        "markdown"
## withr          "testthat, covr, lattice, DBI, RSQLite, methods, knitr,¥nrmarkdown"
## xfun           "testit, parallel, rstudioapi, tinytex, mime, markdown, knitr,¥nhtmltools, base64enc, ##
xgboost          "knitr, rmarkdown, ggplot2 (>= 1.0.1), DiagrammeR (>= 0.9.0),¥nCkmeans.1d.dp (>= 3.3.1 ##
xml2             "testthat, curl, covr, knitr, rmarkdown, magrittr, httr"
## xts            "timeSeries, timeDate, tseries, chron, fts, tis, RUnit"
## yaml           "RUnit"
## zeallot        "testthat, knitr, rmarkdown, purrr, magrittr"
## zoo            "coda, chron, DAAG, fts, ggplot2, mondate, scales,¥nstrucchange, timeDate, timeSeries, ##
base             "methods"
## boot           "MASS, survival"
```

```
## class          NA
## cluster        "MASS, Matrix"
## codetools      NA
## compiler       NA
## datasets       NA
## foreign        NA
## graphics       NA
## grDevices      "KernSmooth"
## grid           "lattice"
## KernSmooth     "MASS"
## lattice        "KernSmooth, MASS, latticeExtra"
## MASS           "lattice, nlme, nnet, survival"
## Matrix         "expm, MASS"
## methods        "codetools"
## mgcv           "parallel, survival, MASS"
## nlme           "Hmisc, MASS"
## nnet           "MASS"
## parallel       "methods"
## rpart          "survival"
## spatial        "MASS"
## splines        "Matrix, methods"
## stats          "MASS, Matrix, SuppDists, methods, stats4"
## stats4         NA
## survival       NA
## tcltk          NA
## tools          "codetools, methods, xml2, curl, commonmark"
## translations   NA
## utils          "methods, xml2, commonmark"
##                Enhances
## abind          NA
## askpass        NA
## assertthat     NA
## backports      NA
## base64enc      "png"
## BH             NA
## bitops         NA
## broom          NA
## callr          NA
## caret          NA
## caTools        NA
## cellranger   NA ##
Ckmeans.1d.dp  NA ##
class         NA
## cli            NA
## clipr          NA
## colorspace     NA
## crayon         NA
## curl           NA
## data.table     NA
## DBI            NA
## dbplyr         NA
## digest         NA
## DMwR           NA
## DMwR2          NA
```

```
## doParallel     "compiler"
## dplyr          NA
## dslabs         NA
## e1071          NA
## ellipsis       NA
## evaluate       NA
## fansi          NA
## forcats        NA
## foreach        "compiler, doMC, RUnit, doParallel"
## fs             NA
## gbm            NA
## gdata          NA
## generics       NA
## ggplot2        "sp"
## glue           NA
## gower          NA
## gplots         NA
## gridExtra      NA
## gtable         NA
## gtools         NA
## haven          NA
## highr          NA
## hms            NA
## htmltools      "knitr"
## httr           NA
## ipred          NA
## iterators      NA
## jsonlite       NA
## kableExtra     NA
## knitr          NA
## labeling       NA
## lattice        "chron"
## lava           NA
## lazyeval       NA
## lightgbm       NA
## lubridate      "chron, fts, timeSeries, timeDate, tis, tseries, xts, zoo"
## magrittr       NA
## markdown       NA
## mime           NA
## ModelMetrics   NA
## modelr         NA
## munsell        NA
## numDeriv       NA
## openssl        NA
## PerfMeas       NA
## pillar         NA
## pkgconfig      NA
## plogr          NA
## plyr           NA
## precrec        NA
## prettyunits    NA
## pROC           NA
## processx       NA
## prodlim        NA
```

```
## progress       NA
## PRROC          NA
## ps             NA
## purrr          NA
## quantmod       NA
## R6             NA
## randomForest   NA
## RColorBrewer   NA
## Rcpp           NA
## RcppRoll       NA
## readr          NA
## readxl         NA
## recipes        NA
## rematch        NA
## reprex         NA
## reshape2       NA
## rlang          NA
## rmarkdown      NA
## ROCR           NA
## rprojroot      NA
## rstudioapi     NA
## rvest          NA
## scales         NA
## selectr        NA
## SQUAREM        NA
## stringi        NA
## stringr        NA
## sys            NA
## tibble         NA
## tidyr          NA
## tidyselect     NA
## tidyverse      NA
## timeDate       NA
## tinytex        NA
## TTR            "quantmod"
## utf8           NA
## vctrs          NA
## viridisLite    NA
## webshot        NA
## whisker        NA
## withr          NA
## xfun           NA
## xgboost        NA
## xml2           NA
## xts            NA
## yaml           NA
## zeallot        NA
## zoo            NA
## base           NA
## boot           NA
## class          NA
## cluster        NA
## codetools      NA
## compiler       NA
```

```
## datasets       NA
## foreign        NA
## graphics       NA
## grDevices      NA
## grid           NA
## KernSmooth     NA
## lattice        "chron"
## MASS           NA
## Matrix         "MatrixModels, graph,  SparseM, sfsmisc"
## methods        NA
## mgcv           NA
## nlme           NA
## nnet           NA
## parallel       "snow, nws, Rmpi"
## rpart          NA
## spatial        NA
## splines        NA
## stats          NA
## stats4         NA
## survival       NA
## tcltk          NA
## tools          NA
## translations   NA
## utils          NA
##                License                                 License_is_FOSS
## abind          "LGPL (>= 2)"                           NA
## askpass        "MIT + file LICENSE"                    NA
## assertthat     "GPL-3"                                 NA
## backports      "GPL-2"                                 NA
## base64enc      "GPL-2 | GPL-3"                         NA
## BH             "BSL-1.0"                               NA
## bitops         "GPL (>= 2)"                            NA
## broom          "MIT + file LICENSE"                    NA
## callr          "MIT + file LICENSE"                    NA
## caret          "GPL (>= 2)"                            NA
## caTools        "GPL-3"                                 NA
## cellranger     "MIT + file LICENSE"                    NA
## Ckmeans.1d.dp  "LGPL (>= 3)"                           NA
## class          "GPL-2 | GPL-3"                         NA
## cli            "MIT + file LICENSE"                    NA
## clipr          "GPL-3"                                 NA
## colorspace     "BSD_3_clause + file  LICENSE"          NA
## crayon         "MIT + file LICENSE"                    NA
## curl           "MIT + file LICENSE"                    NA
## data.table     "MPL-2.0 | file LICENSE"                NA
## DBI            "LGPL (>= 2)"                           NA
## dbplyr         "MIT + file LICENSE"                    NA
## digest         "GPL (>= 2)"                            NA
## DMwR           "GPL (>= 2)"                            NA
## DMwR2          "GPL (>= 2)"                            NA
## doParallel     "GPL-2"                                 NA
## dplyr          "MIT + file LICENSE"                    NA
## dslabs         "Artistic-2.0"                          NA
## e1071          "GPL-2"                                 NA
```

```
## ellipsis       "GPL-3"                                NA
## evaluate       "MIT + file LICENSE"                   NA
## fansi          "GPL (>= 2)"                           NA
## forcats        "GPL-3"                                NA
## foreach        "Apache License (== 2.0)"              NA
## fs             "GPL-3"                                NA
## gbm            "GPL (>= 2) | file LICENSE"            NA
## gdata          "GPL-2"                                NA
## generics       "GPL-2"                                NA
## ggplot2        "GPL-2 | file LICENSE"                 NA
## glue           "MIT + file LICENSE"                   NA
## gower          "GPL-3"                                NA
## gplots         "GPL-2"                                NA
## gridExtra      "GPL (>= 2)"                           NA
## gtable         "GPL-2"                                NA
## gtools         "GPL-2"                                NA
## haven          "MIT + file LICENSE"                   NA
## highr          "GPL"                                  NA
## hms            "GPL-3"                                NA
## htmltools      "GPL (>= 2)"                           NA
## httr           "MIT + file LICENSE"                   NA
## ipred          "GPL (>= 2)"                           NA
## iterators      "Apache License (== 2.0)"              NA
## jsonlite       "MIT + file LICENSE"                   NA
## kableExtra     "MIT + file LICENSE"                   NA
## knitr          "GPL"                                  NA
## labeling       "MIT + file LICENSE | Unlimited"       NA
## lattice        "GPL (>= 2)"                           NA
## lava           "GPL-3"                                NA
## lazyeval       "GPL-3"                                NA
## lightgbm       "MIT + file LICENSE"                   NA
## lubridate      "GPL (>= 2)"                           NA
## magrittr       "MIT + file LICENSE"                   NA
## markdown       "GPL-2"                                NA
## mime           "GPL"                                  NA
## ModelMetrics   "GPL (>= 2)"                           NA
## modelr         "GPL-3"                                NA
## munsell        "MIT + file LICENSE"                   NA
## numDeriv       "GPL-2"                                NA
## openssl        "MIT + file LICENSE"                   NA
## PerfMeas       "GPL (>= 2)"                           NA
## pillar         "GPL-3"                                NA
## pkgconfig      "MIT + file LICENSE"                   NA
## plogr          "MIT + file LICENSE"                   NA
## plyr           "MIT + file LICENSE"                   NA
## precrec        "GPL-3"                                NA
## prettyunits    "MIT + file LICENSE"                   NA
## pROC           "GPL (>= 3)"                           NA
## processx       "MIT + file LICENSE"                   NA
## prodlim        "GPL (>= 2)"                           NA
## progress       "MIT + file LICENSE"                   NA
## PRROC          "GPL-3"                                NA
## ps             "BSD_3_clause + file LICENSE"          NA
## purrr          "GPL-3 | file LICENSE"                 NA
```

```
## quantmod       "GPL-3"                                    NA
## R6             "MIT + file LICENSE"                       NA
## randomForest   "GPL (>= 2)"                               NA
## RColorBrewer   "Apache License 2.0"                       NA
## Rcpp           "GPL (>= 2)"                               NA
## RcppRoll       "GPL (>= 2)"                               NA
## readr          "GPL (>= 2) | file LICENSE"                NA
## readxl         "GPL-3"                                    NA
## recipes        "GPL-2"                                    NA
## rematch        "MIT + file LICENSE"                       NA
## reprex         "MIT + file LICENSE"                       NA
## reshape2       "MIT + file LICENSE"                       NA
## rlang          "GPL-3"                                    NA
## rmarkdown      "GPL-3"                                    NA
## ROCR           "GPL (>= 2)"                               NA
## rprojroot      "GPL-3"                                    NA
## rstudioapi     "MIT + file LICENSE"                       NA
## rvest          "GPL-3"                                    NA
## scales         "MIT + file LICENSE"                       NA
## selectr        "BSD_3_clause + file LICENCE"              NA
## SQUAREM        "GPL (>= 2)"                               NA
## stringi        "file LICENSE"                             "yes"
## stringr        "GPL-2 | file LICENSE"                     NA
## sys            "MIT + file LICENSE"                       NA
## tibble         "MIT + file LICENSE"                       NA
## tidyr          "MIT + file LICENSE"                       NA
## tidyselect     "GPL-3"                                    NA
## tidyverse      "GPL-3 | file LICENSE"                     NA
## timeDate       "GPL (>= 2)"                               NA
## tinytex        "MIT + file LICENSE"                       NA
## TTR            "GPL-2"                                    NA
## utf8           "Apache License (== 2.0)  | file  LICENSE" NA
## vctrs          "GPL-3"                                    NA
## viridisLite    "MIT + file LICENSE"                       NA
## webshot        "GPL-2"                                    NA
## whisker        "GPL-3"                                    NA
## withr          "GPL (>= 2)"                               NA
## xfun           "MIT + file LICENSE"                       NA
## xgboost        "Apache License (== 2.0) | file   LICENSE" NA
## xml2           "GPL (>= 2)"                               NA
## xts            "GPL (>= 2)"                               NA
## yaml           "BSD_3_clause + file LICENSE"              NA
## zeallot        "MIT + file LICENSE"                       NA
## zoo            "GPL-2 | GPL-3"                            NA
## base           "Part of R 3.6.0"                          NA
## boot           "Unlimited"                                NA
## class          "GPL-2 | GPL-3"                            NA
## cluster        "GPL (>= 2)"                               NA
## codetools      "GPL"                                      NA
## compiler       "Part of R 3.6.0"                          NA
## datasets       "Part of R 3.6.0"                          NA
## foreign        "GPL (>= 2)"                               NA
## graphics       "Part of R 3.6.0"                          NA
## grDevices      "Part of R 3.6.0"                          NA
```

```
## grid          "Part of R 3.6.0"                          NA
## KernSmooth    "Unlimited"                                NA
## lattice       "GPL (>= 2)"                               NA
## MASS          "GPL-2 | GPL-3"                            NA
## Matrix        "GPL (>= 2) | file LICENCE"                NA
## methods       "Part of R 3.6.0"                          NA
## mgcv          "GPL (>= 2)"                               NA
## nlme          "GPL (>= 2) | file LICENCE"                NA
## nnet          "GPL-2 | GPL-3"                            NA
## parallel      "Part of R 3.6.0"                          NA
## rpart         "GPL-2 | GPL-3"                            NA
## spatial       "GPL-2 | GPL-3"                            NA
## splines       "Part of R 3.6.0"                          NA
## stats         "Part of R 3.6.0"                          NA
## stats4        "Part of R 3.6.0"                          NA
## survival      "LGPL (>= 2)"                              NA
## tcltk         "Part of R 3.6.0"                          NA
## tools         "Part of R 3.6.0"                          NA
## translations  "Part of R 3.6.0"                          NA
## utils         "Part of R 3.6.0"                          NA
##               License_restricts_use OS_type MD5sum NeedsCompilation
## abind         NA                    NA      NA     "no"
## askpass       NA                    NA      NA     "yes"
## assertthat    NA                    NA      NA     "no"
## backports     NA                    NA      NA     "yes"
## base64enc     NA                    NA      NA     "yes"
## BH            NA                    NA      NA     "no"
## bitops        NA                    NA      NA     "yes"
## broom         NA                    NA      NA     "no"
## callr         NA                    NA      NA     "no"
## caret         NA                    NA      NA     "yes"
## caTools       NA                    NA      NA     "yes"
## cellranger    NA                    NA      NA     "no"
## Ckmeans.1d.dp NA                    NA      NA     "yes"
## class         NA                    NA      NA     "yes"
## cli           NA                    NA      NA     "no"
## clipr         NA                    NA      NA     "no"
## colorspace    NA                    NA      NA     "yes"
## crayon        NA                    NA      NA     "no"
## curl          NA                    NA      NA     "yes"
## data.table    NA                    NA      NA     "yes"
## DBI           NA                    NA      NA     "no"
## dbplyr        NA                    NA      NA     "no"
## digest        NA                    NA      NA     "yes"
## DMwR          NA                    NA      NA     "no"
## DMwR2         NA                    NA      NA     "no"
## doParallel    NA                    NA      NA     "no"
## dplyr         NA                    NA      NA     "yes"
## dslabs        NA                    NA      NA     "no"
## e1071         NA                    NA      NA     "yes"
## ellipsis      NA                    NA      NA     "yes"
## evaluate      NA                    NA      NA     "no"
## fansi         NA                    NA      NA     "yes"
## forcats       NA                    NA      NA     "no"
```

```
## foreach        NA                  NA      NA     "no"
## fs             NA                  NA      NA     "yes"
## gbm            NA                  NA      NA     "yes"
## gdata          NA                  NA      NA     "no"
## generics       NA                  NA      NA     "no"
## ggplot2        NA                  NA      NA     "no"
## glue           NA                  NA      NA     "yes"
## gower          NA                  NA      NA     "yes"
## gplots         NA                  NA      NA     "no"
## gridExtra      NA                  NA      NA     "no"
## gtable         NA                  NA      NA     "no"
## gtools         NA                  NA      NA     "yes"
## haven          NA                  NA      NA     "yes"
## highr          NA                  NA      NA     "no"
## hms            NA                  NA      NA     "no"
## htmltools      NA                  NA      NA     "yes"
## httr           NA                  NA      NA     "no"
## ipred          NA                  NA      NA     "yes"
## iterators      NA                  NA      NA     "no"
## jsonlite       NA                  NA      NA     "yes"
## kableExtra     NA                  NA      NA     "no"
## knitr          NA                  NA      NA     "no"
## labeling       NA                  NA      NA     "no"
## lattice        NA                  NA      NA     "yes"
## lava           NA                  NA      NA     "no"
## lazyeval       NA                  NA      NA     "yes"
## lightgbm       NA                  NA      NA     "yes"
## lubridate      NA                  NA      NA     "yes"
## magrittr       NA                  NA      NA     "no"
## markdown       NA                  NA      NA     "yes"
## mime           NA                  NA      NA     "yes"
## ModelMetrics   NA                  NA      NA     "yes"
## modelr         NA                  NA      NA     "no"
## munsell        NA                  NA      NA     "no"
## numDeriv       NA                  NA      NA     "no"
## openssl        NA                  NA      NA     "yes"
## PerfMeas       NA                  NA      NA     "yes"
## pillar         NA                  NA      NA     "no"
## pkgconfig      NA                  NA      NA     "no"
## plogr          NA                  NA      NA     "no"
## plyr           NA                  NA      NA     "yes"
## precrec        NA                  NA      NA     "yes"
## prettyunits    NA                  NA      NA     "no"
## pROC           NA                  NA      NA     "yes"
## processx       NA                  NA      NA     "yes"
## prodlim        NA                  NA      NA     "yes"
## progress       NA                  NA      NA     "no"
## PRROC          NA                  NA      NA     "no"
## ps             NA                  NA      NA     "yes"
## purrr          NA                  NA      NA     "yes"
## quantmod       NA                  NA      NA     "no"
## R6             NA                  NA      NA     "no"
## randomForest   NA                  NA      NA     "yes"
## RColorBrewer   NA                  NA      NA     "no"
```

```
## Rcpp          NA                    NA      NA      "yes"
## RcppRoll      NA                    NA      NA      "yes"
## readr         NA                    NA      NA      "yes"
## readxl        NA                    NA      NA      "yes"
## recipes       NA                    NA      NA      "no"
## rematch       NA                    NA      NA      "no"
## reprex        NA                    NA      NA      "no"
## reshape2      NA                    NA      NA      "yes"
## rlang         NA                    NA      NA      "yes"
## rmarkdown     NA                    NA      NA      "no"
## ROCR          NA                    NA      NA      "no"
## rprojroot     NA                    NA      NA      "no"
## rstudioapi    NA                    NA      NA      "no"
## rvest         NA                    NA      NA      "no"
## scales        NA                    NA      NA      "yes"
## selectr       NA                    NA      NA      "no"
## SQUAREM       NA                    NA      NA      "no"
## stringi       NA                    NA      NA      "yes"
## stringr       NA                    NA      NA      "no"
## sys           NA                    NA      NA      "yes"
## tibble        NA                    NA      NA      "yes"
## tidyr         NA                    NA      NA      "yes"
## tidyselect    NA                    NA      NA      "yes"
## tidyverse     NA                    NA      NA      "no"
## timeDate      NA                    NA      NA      "no"
## tinytex       NA                    NA      NA      "no"
## TTR           NA                    NA      NA      "yes"
## utf8          NA                    NA      NA      "yes"
## vctrs         NA                    NA      NA      "yes"
## viridisLite   NA                    NA      NA      "no"
## webshot       NA                    NA      NA      "no"
## whisker       NA                    NA      NA      "no"
## withr         NA                    NA      NA      "no"
## xfun          NA                    NA      NA      "no"
## xgboost       NA                    NA      NA      "yes"
## xml2          NA                    NA      NA      "yes"
## xts           NA                    NA      NA      "yes"
## yaml          NA                    NA      NA      "yes"
## zeallot       NA                    NA      NA      "no"
## zoo           NA                    NA      NA      "yes"
## base          NA                    NA      NA      NA
## boot          NA                    NA      NA      "no"
## class         NA                    NA      NA      "yes"
## cluster       NA                    NA      NA      "yes"
## codetools     NA                    NA      NA      "no"
## compiler      NA                    NA      NA      NA
## datasets      NA                    NA      NA      NA
## foreign       NA                    NA      NA      "yes"
## graphics      NA                    NA      NA      "yes"
## grDevices     NA                    NA      NA      "yes"
## grid          NA                    NA      NA      "yes"
## KernSmooth    NA                    NA      NA      "yes"
## lattice       NA                    NA      NA      "yes"
## MASS          NA                    NA      NA      "yes"
```

```
## Matrix          NA                    NA      NA      "yes"
## methods         NA                    NA      NA      "yes"
## mgcv            NA                    NA      NA      "yes"
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7.4 2 - Acknowledgement

- Andrea Dal Pozzolo, Olivier Caelen, Reid A. Johnson and Gianluca Bontempi. Calibrating Probability with Undersampling for Unbalanced Classification. In Symposium on Computational Intelligence and Data Mining (CIDM), IEEE, 2015
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- Dal Pozzolo, Andrea Adaptive Machine learning for credit card fraud detection ULB MLG PhD thesis (supervised by G. Bontempi)
- Carcillo, Fabrizio; Dal Pozzolo, Andrea; Le Borgne, Yann-Aël; Caelen, Olivier; Mazzer, Yannis; Bontempi, Gianluca. Scarff: a scalable framework for streaming credit card fraud detection with Spark, Information fusion,41, 182-194,2018,Elsevier
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