

Report on the German credit dataset

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2022-05-20

Executive Summary

Data analysis is now a fundamental tool in the general understanding of business. In the current case, the objective would be to understand and profile the different historical and current customers of a bank, in order to better identify them. For this, we need to proceed in several steps: The first is to collect available data, check its relevance and see if it is accurate. Indeed, it is possible to deal with erroneous data. Therefore, it is necessary to check each feature and instance collected. The second step is to clean and understand the data in order to proceed to a more complete analysis. Finally, the goal is to answer the problem by using different analytical methods and synthesising the best model to provide a solution.

Introduction

In the bank industry many bankers have to decide whether or not they should issue a loan to a new coming applicant. In this report, we will use the data set called **German Credit data** which was given to us.

The German credit data set contains 1000 observations of past credit applicants, described by 30 variables. The applicants are described as **Good Credit** risk or **Bad Credit** risk: Therefore, the response variable, studied, is the credit rating.

Response variable: **RESPONSE** in the dataset:

- 0 : Bad credit. In case of bad credit, the banker would not want to issue loan to this person.
- 1 : Good credit. In case of good credit, the banker will want to issue loan to this applicant as it is more likely that the company will benefit from it.

All the other observations are features of the applicants that are going to be studied. It will allow us to perform several machine learning models and deploy a CRISP-DM model to come up with the best classifying model with the highest accuracy as possible. We want to determine whether the new applicant has a 'Good' credit risk, in which case the loan should be issued, or a 'Bad' credit risk, in which case it is not advisable to give him a loan.

The tasks required to perform our analysis is stated as follow.

1/ We first proceeded to some data cleaning, meaning that we sorted the dataset to make it ready for the analysis.

2/ Then we followed by an exploratory data analysis (EDA) where we studied the dataset and the different variables, one by one, and we made an principal component analysis.

3/ Next, came the models analysis, the steps are listed below:

- a) Splitting the dataset
- b) Balancing the data
- c) Fitting the models
- d) Accuracy study (scoring)
- e) Variable selection and importance
- f) Cross-validation / Bootstrap

g) Final Best model

Our very first steps once we received the **German Credit data** was to dig into it and get to know the observations and features we were going to work with.

Get to know the data

The title of the dataset is *German credit data* and the name of the file is **GermanCredit.csv**.

As said in the introduction, the German Credit data has data on 1000 observations on past credit applicants and it is described by 30 attributes. Each applicant is rated as “Good” or “Bad” credit (encoded as 1 and 0 respectively in the **RESPONSE** variable). The definitions of all the attributes are stated in the annex under ‘Appendix A’.

We looked at the attribute Information :

Table 1: Summary of the German Credit dataset (continued below)

OBS.	CHK_ACC	DURATION	HISTORY	NEW_CAR	USED_CAR	FURNITUR	RADIO	TV	EDUCATION
Min. : 1.0	Min. :0.000	Min. : 4.0	Min. :0.000	Min. :0.000	Min. :0.000	Min. :0.000	Min. :0.00	Min. :-1.000	
1st Qu.: 250.8	1st Qu.:0.000	1st Qu.:12.0	1st Qu.:2.000	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:0.00	1st Qu.: 0.000	
Median : 500.5	Median :1.000	Median :18.0	Median :2.000	Median :0.000	Median :0.000	Median :0.000	Median :0.00	Median : 0.000	
Mean : 500.5	Mean :1.577	Mean :20.9	Mean :2.545	Mean :0.234	Mean :0.103	Mean :0.181	Mean :0.28	Mean : 0.048	
3rd Qu.: 750.2	3rd Qu.:3.000	3rd Qu.:24.0	3rd Qu.:4.000	3rd Qu.:0.000	3rd Qu.:0.000	3rd Qu.:0.000	3rd Qu.:1.00	3rd Qu.: 0.000	
Max. :1000.0	Max. :3.000	Max. :72.0	Max. :4.000	Max. :1.000	Max. :1.000	Max. :1.000	Max. :1.00	Max. : 1.000	

Table 2: Table continues below

RETRAINING	AMOUNT	SAV_ACC	EMPLOYMENT	INSTALL_RATE	DI	MALE_SINGLE	MALE_MAR	CREDIT	APPLICANT
Min. :0.000	Min. : 250	Min. :0.000	Min. :0.000	Min. :1.000	Min. :0.00	Min. :0.000	Min. :0.000	Min. :0.000	
1st Qu.:0.000	1st Qu.: 1366	1st Qu.:0.000	1st Qu.:2.000	1st Qu.:2.000	1st Qu.:0.00	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:0.000	
Median :0.000	Median : 2320	Median :0.000	Median :2.000	Median :3.000	Median :0.00	Median :1.000	Median :0.000	Median :0.000	
Mean :0.097	Mean : 3271	Mean :1.105	Mean :2.384	Mean :2.973	Mean :0.05	Mean :0.548	Mean :0.092	Mean :0.041	
3rd Qu.:0.000	3rd Qu.: 3972	3rd Qu.:2.000	3rd Qu.:4.000	3rd Qu.:4.000	3rd Qu.:0.00	3rd Qu.:1.000	3rd Qu.:0.000	3rd Qu.:0.000	
Max. :1.000	Max. :18424	Max. :4.000	Max. :4.000	Max. :4.000	Max. :1.00	Max. :1.000	Max. :1.000	Max. :1.000	

Table 3: Table continues below

GUARANTOR	PRESENT	RESIDENT	ESTABLISHED	TOP_UNKN	NONE	OTHER	INSURANCE	OWN_RES	NUM_CREDITS
Min. :0.000	Min. :1.000	Min. :0.000	Min. :0.000	Min. : 19.0	Min. :0.000	Min. :0.000	Min. :0.000	Min. :0.000	Min. :1.000
1st Qu.:0.000	1st Qu.:2.000	1st Qu.:0.000	1st Qu.:0.000	1st Qu.: 27.0	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:1.000
Median :0.000	Median :3.000	Median :0.000	Median :0.000	Median : 33.0	Median :0.000	Median :0.000	Median :0.000	Median :1.000	Median :1.000
Mean :0.053	Mean :2.845	Mean :0.282	Mean :0.154	Mean : 35.6	Mean :0.186	Mean :0.179	Mean :0.179	Mean :0.713	Mean :1.407
3rd Qu.:0.000	3rd Qu.:4.000	3rd Qu.:1.000	3rd Qu.:0.000	3rd Qu.: 42.0	3rd Qu.:0.000	3rd Qu.:0.000	3rd Qu.:1.000	3rd Qu.:1.000	3rd Qu.:2.000
Max. :2.000	Max. :4.000	Max. :1.000	Max. :1.000	Max. :125.0	Max. :1.000	Max. :1.000	Max. :1.000	Max. :1.000	Max. :4.000

JOB	NUM_DEPENDENTS	TELEPHONE	FOREIGN	RESPONSE
Min. :0.000	Min. :1.000	Min. :0.000	Min. :0.000	Min. :0.0
1st Qu.:2.000	1st Qu.:1.000	1st Qu.:0.000	1st Qu.:0.000	1st Qu.:0.0
Median :2.000	Median :1.000	Median :0.000	Median :0.000	Median :1.0
Mean :1.904	Mean :1.155	Mean :0.404	Mean :0.037	Mean :0.7
3rd Qu.:2.000	3rd Qu.:1.000	3rd Qu.:1.000	3rd Qu.:0.000	3rd Qu.:1.0
Max. :3.000	Max. :2.000	Max. :1.000	Max. :1.000	Max. :1.0

We noticed that the variable **EDUCATION** has a minimum value of ‘-1’ but it should be ‘0’ since there are only 2 levels (0 and 1). Indeed, the observation 37 indicate a value of ‘-1’ for **EDUCATION**. We notice another strange value, in the variable **GUARANTOR**, the maximum value is of ‘2’ while it does not mean anything in our data set.

After discussion with the Banker, he gave us the correct values to these 2 mistakes. Observation 37 of **EDUCATION** and observation 234 of **GUARANTOR** should be equal to 1. We corrected these two values.

We also saw that the variable **AGE** has a maximum of 125. This is strange because it is very unlikely that someone lives to the age of 125. We talked to the banker again and he confirmed our doubts by telling us that a mistake has been made. At the observation 537, the correct age of the client is 75 years old. He asked us to correct this value in our data set.

After looking at the different attributes, we concluded that there were no missing values.

The response variable is identified as being the column named ‘**Response**’ and it appears to be the last column on the data.

It is a dummy variable with 0/1.

1. 0 : No, the credit rating is bad.
2. 1 : Yes, the credit rating is good.

We had to make sure that the class of the variables are correct. First when we imported the data, all the variables were defined as *integer* but we know that we should have numerical and categorical variables in our dataset. Therefore, we transformed the class of some of them.

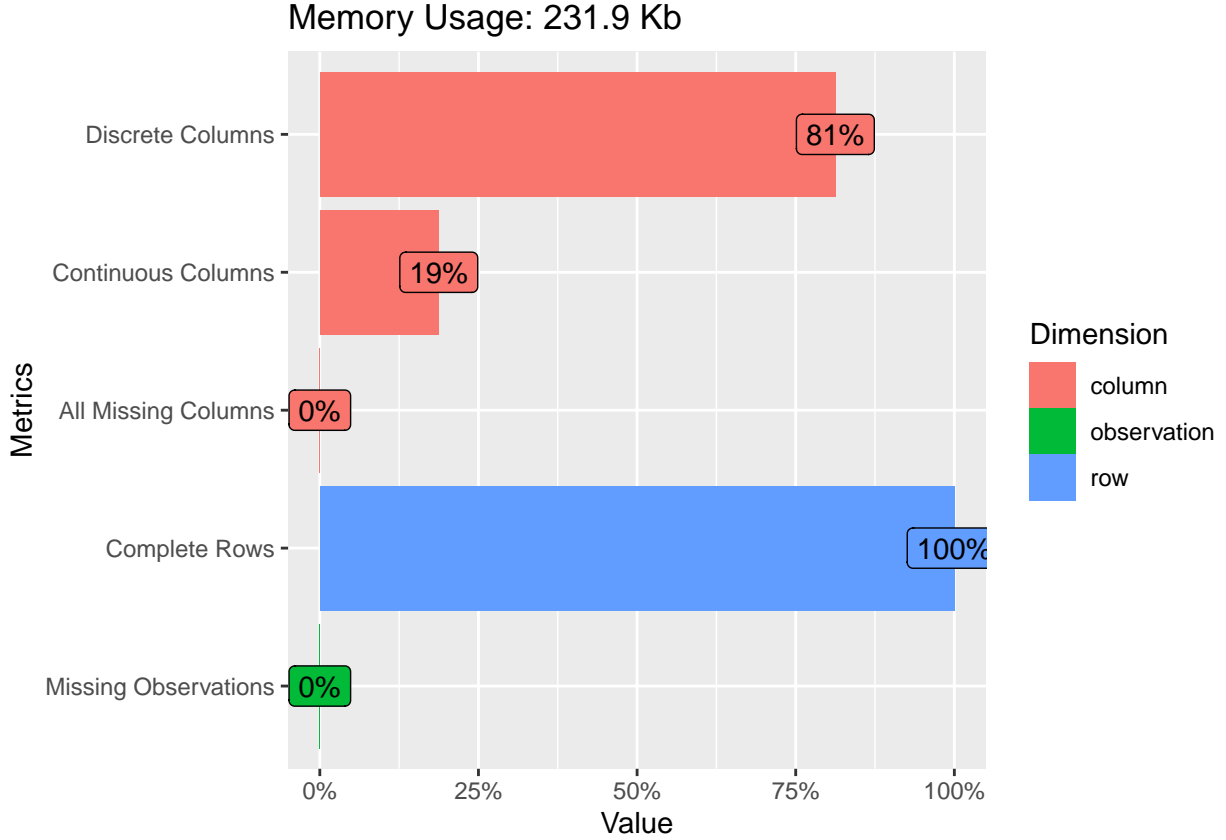
The binomial and categorical data are set as factors and the others as numerical.

We then described the variables one more time with the function **describe** from the **Hmisc** package because we should get better results as our computer now recognizes the factor variables and the numerical ones.

Table 5: Table continues below

rows	columns	discrete_columns	continuous_columns	all_missing_columns
1000	32	26	6	0

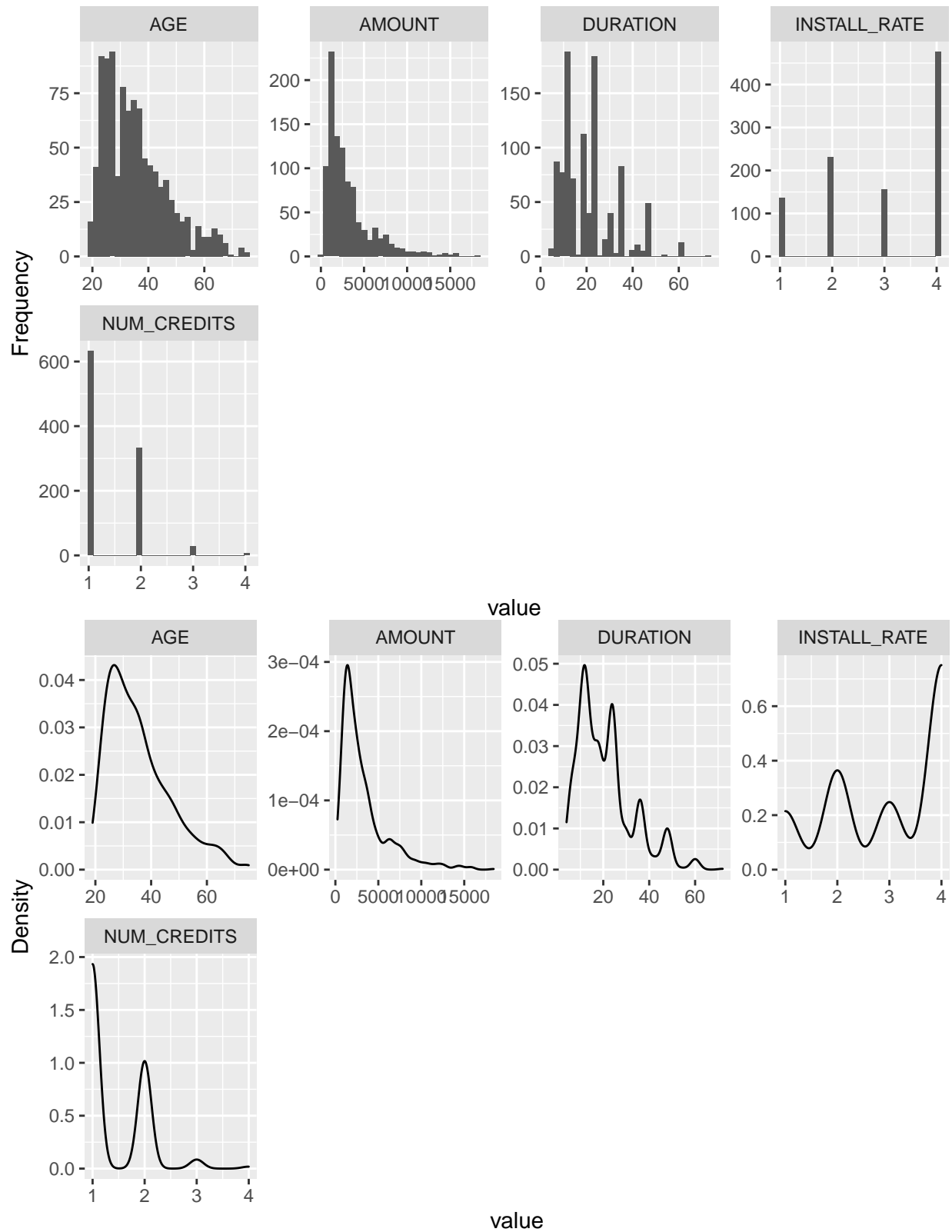
total_missing_values	complete_rows	total_observations	memory_usage
0	1000	32000	237424



The plot helps us to see the percentage of continuous variable, the percentage of discrete variables and whether or not some observations are missing. Here it states that we have 81% of discrete columns and 19% of continuous one.

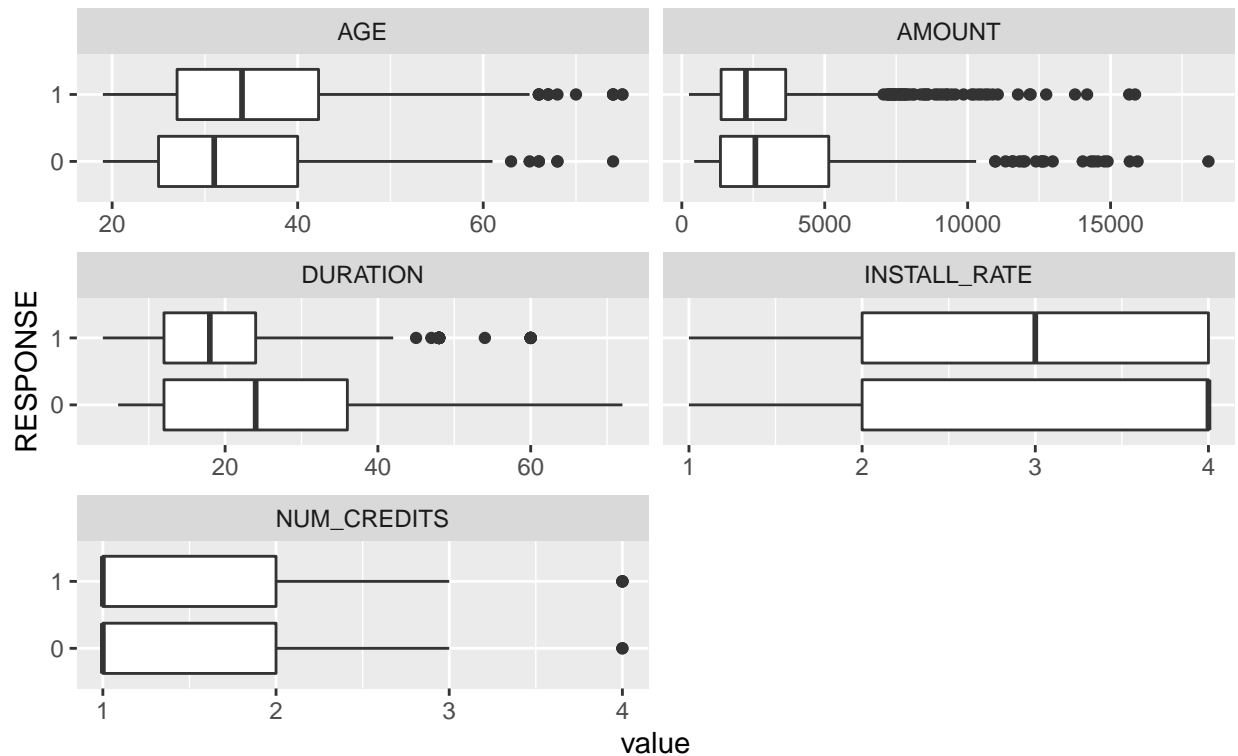
Visualization of the data

First, we plot all the continuous variables into histograms and their corresponding density plots.



Our first notice is that the data are not really normally distributed. Some of them are right-tailed. We can look at the tails and outliers more in deep through boxplots.

Side-by-side boxplots



This seems not to be disturbing. It makes sense that only a few people has a big credit amount. However it seems that the 'bad' clients tends to ask for bigger credit amount than 'good' clients.

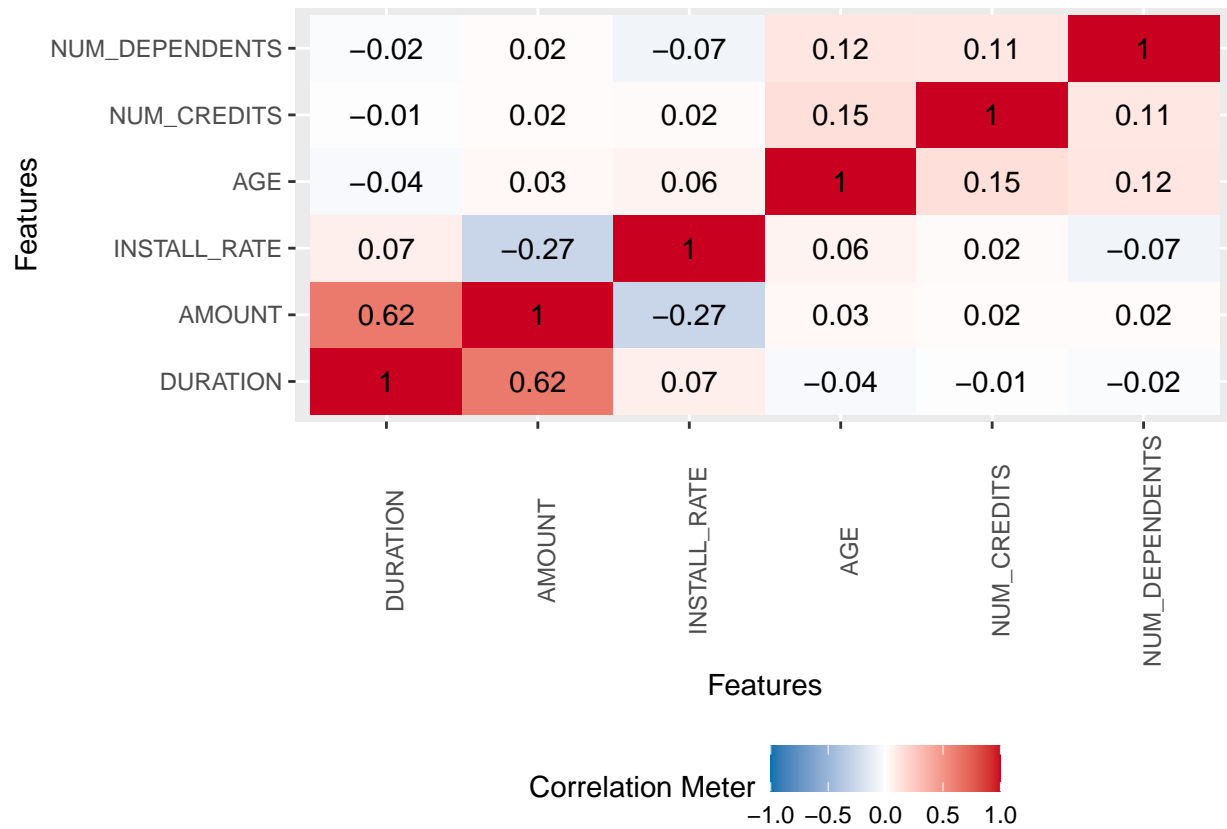
Then, we made some barplots of the categorical variables (appendix B).

From these barplots we saw:

- The majority of people do not have a checking account. (CHK_ACCT)
- Most people have an average balance of less than < 100 DM in their saving account. (SAV_ACCT)
- Most of the applicants has its own residence. (OWN_RES)
- Almost none of the applicants is a foreign worker. (FOREIGN)
- We have more information on people that are 'good' applicants and less information on 'bad' applicants. It would be better to have more information on 'bad' applicants as well in order to make good predictions with models. We will have to take this into account later. (RESPONSE)

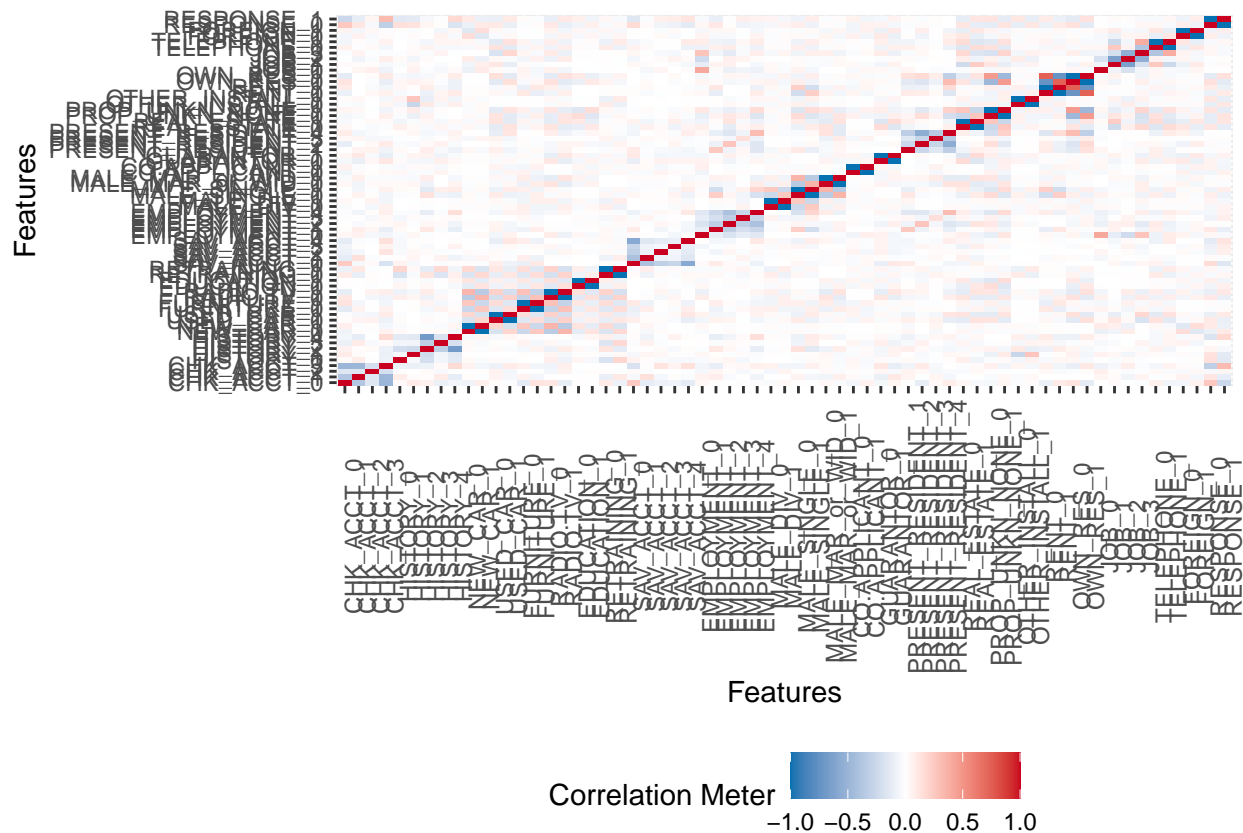
To wrap up, we looked at a general summary of the data with the command `dfSummary` to make sure that the right class was applied to the columns, and to see their distribution and frequency (Appendix C). We concluded that our data were well structured.

Correlation Analysis : Correlation plot between continuous variables :



There are little correlation between the continuous variables. We can notice that there is a correlation of 62% between the variable **DURATION** and **AMOUNT**. This makes sense and is known by the bankers that the bigger the amount of credit, the longer the duration of the credit in months will last.

Correlation plot between categorical variables :



It is difficult to look at the correlation since there are a lot of variables on the graph. We can still see higher correlation between **RESPONSE 1**:

- and people that do not have check account (CHK_ACCT_3)
- and people that have a critical historical account (HISTORY_4)
- and the variable *REAL_ESTATE* (REAL_ESTATE)
- and applicant that does not have their own property (PROP_UNKN_NONE_0)
- and applicant that have their own residence (OWN_RES_1)

We can also see some correlation between **RESPONSE 0**:

- and people that have a checking account status < 0 DM (CHK_ACCT_0)
- and people that have an average balance in savings account < 100 DM (SAV_ACCT_0)
- and the variable *REAL_ESTATE* (REAL_ESTATE)

Principal Component Analysis Exploration: It is good to perform a PCA Exploration in order to reduce the dimensions or/and see which variables to select.

We start by selecting the numerical values because the PCA only works on numerical variables.

Importance of components:

##	PC1	PC2	PC3	PC4	PC5	PC6
## Standard deviation	1.2873	1.1208	1.0443	0.9318	0.9193	0.53164
## Proportion of Variance	0.2762	0.2094	0.1818	0.1447	0.1409	0.04711
## Cumulative Proportion	0.2762	0.4856	0.6673	0.8120	0.9529	1.00000

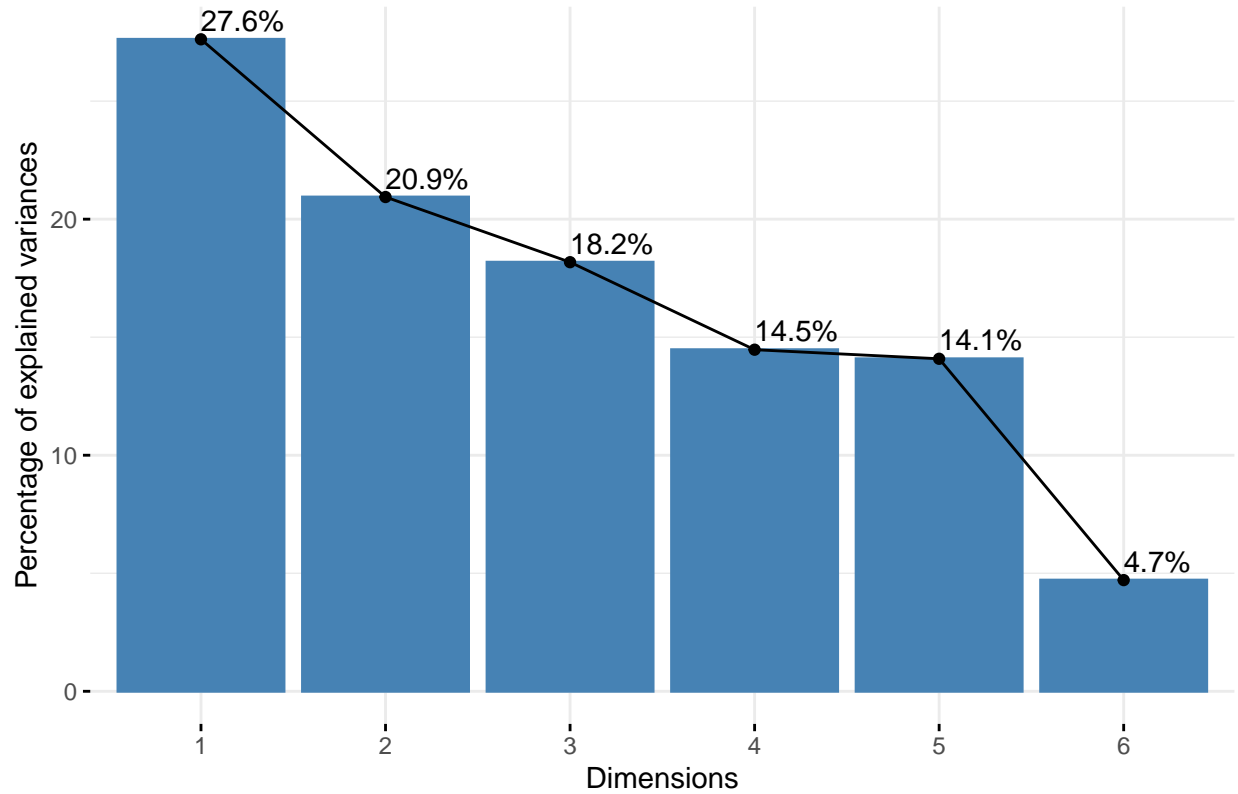
From the PCA summary we can see 4 principal components should be taken into account in order to explain approximately 81% of the variation of the data.

Eigenvalue analysis:

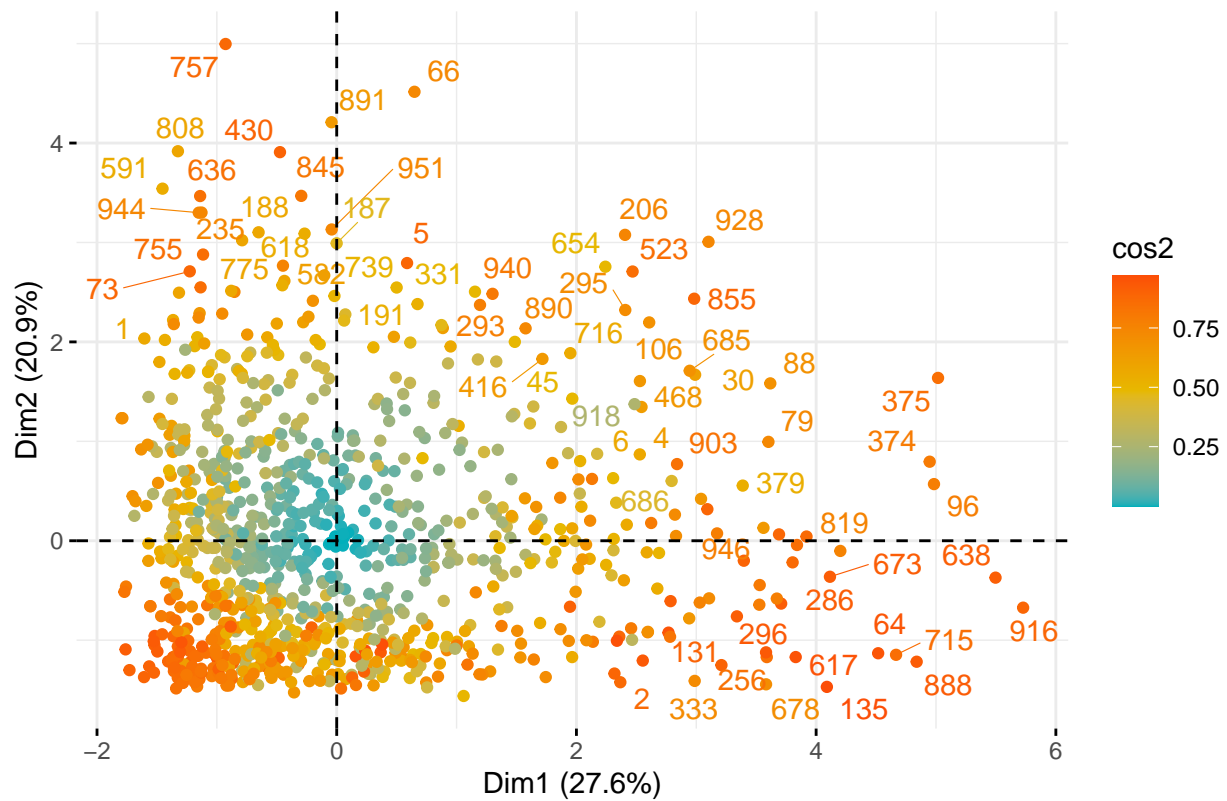
##	eigenvalue	variance.percent	cumulative.variance.percent
## Dim.1	1.6570953	27.618256	27.61826
## Dim.2	1.2562810	20.938016	48.55627
## Dim.3	1.0906419	18.177365	66.73364
## Dim.4	0.8682109	14.470181	81.20382
## Dim.5	0.8451277	14.085462	95.28928
## Dim.6	0.2826431	4.710719	100.00000

Then from this eigenvalues table, we know that we need to choose 3 dimensions because the first 3 dimensions are higher than the value 1.

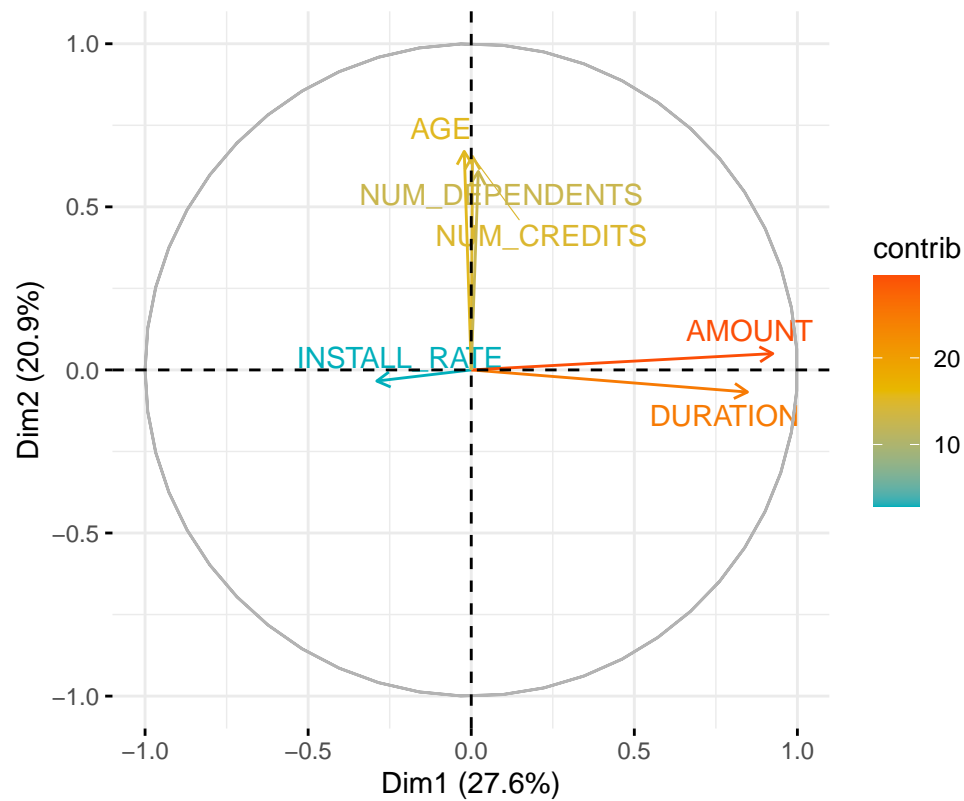
Scree plot



Individuals – PCA



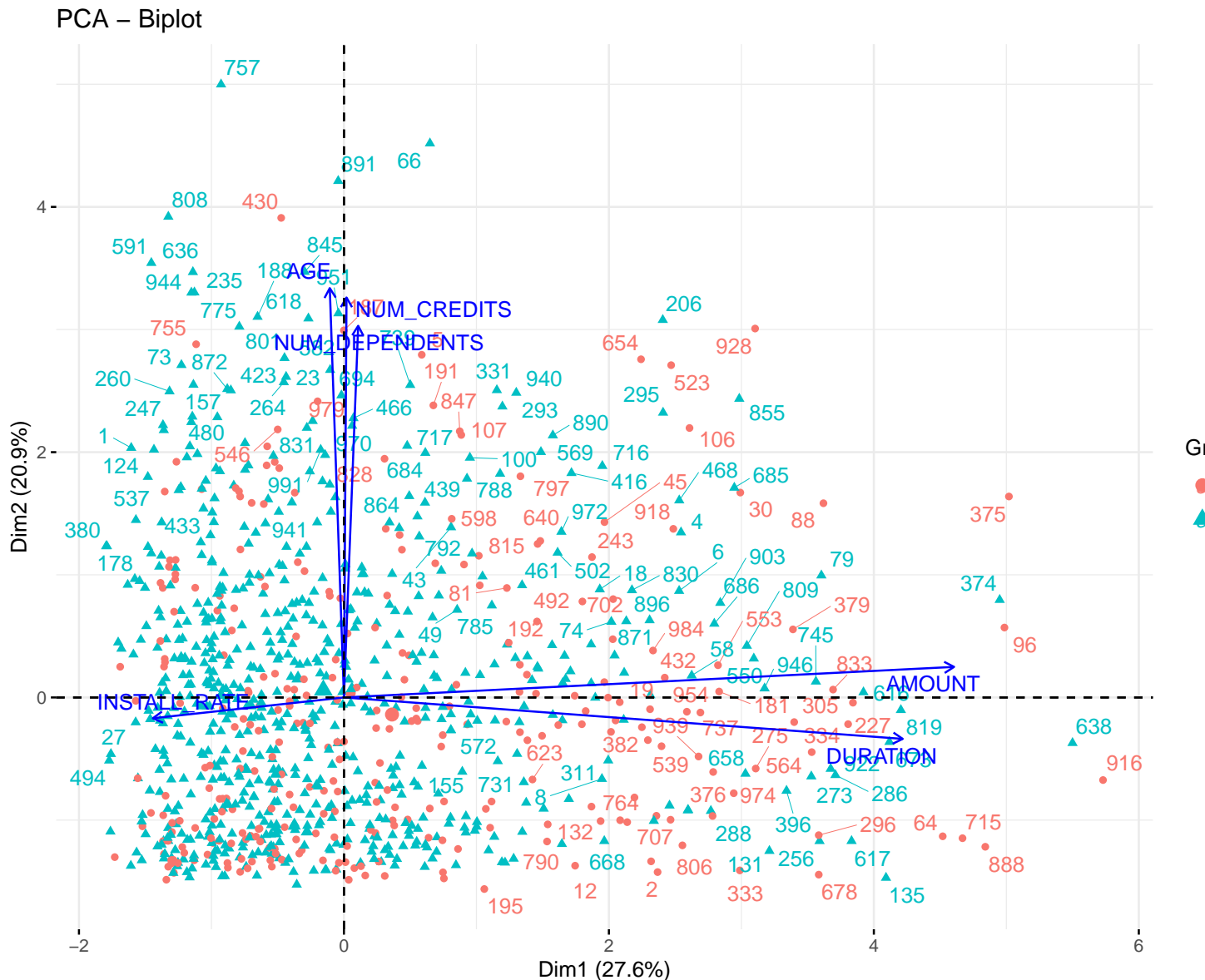
Variables – PCA



From this circle of correlations, we see that :

- The first principal component PC1 is strongly positively correlated with the variables **AMOUNT** and **DURATION**. So the larger PC1, the larger these features. It is also a little bit negatively correlated with **INSTALL_RATE**.
- The second principal component PC2 is strongly positively correlated with **AGE**, **NUM_CREDITS**, **NUM_DEPENDENTS** and **NUM_CREDITS**.

From the below biplot, we can see some characteristics of the observations.



Here, we see the distribution of the response variables (0-1) according to the reduced dimension. What we can observe, is that the “Bad credits: 0”, look a little bit more positively correlated to dimension 1. Therefore, more correlated to Amount and Duration. Compared to Good Credits, it looks positively correlated to dimension 2; **AGE**, **NUM_CREDITS**, **NUM_DEPENDENTS**.

After having cleaned the dataset and looked at all the different features, we created a new dataset, named **GermandCredit_cleaned.csv**, that contains our modifications in order to use it for our analysis.

Methodology

In this section we will talk about the methodology that has been used and the different models analysis that has been conducted.

Traning set and Test set

First of all we started by splitting our dataset into 2 sets: **training set** (`German_credit.tr`) and **test set** (`German_credit.te`). We do not forget to take the first variable **OBS.** out as it represents the index number for each observation. These two sets will allow us to train some models on the **training set** and then test the accuracy of the model fit on the **test set**.

Balancing the dataset

Then, we applied the balancing data technique in order to improve the predictions of **Good Credit** and **Bad Credit**, since we have more observations on the **Good Credit**.

The table below reveals the unbalanced problem.

Indeed, we observe that the “Good Credit” (1) response appears **527** times in the training set and “Bad Credit” (0) **223**, two times less. Since there are many more “Good Credit” than “Bad Credit”, any model favors the prediction of the “Good Credit”. It results a good accuracy but the specificity is low, as well as the balanced accuracy.

Sub-sampling Balancing using sub-sampling consists of taking all the cases in the smallest class (here “Bad Credit”) and extract at random the same amount of cases in the largest category (here “Good”).

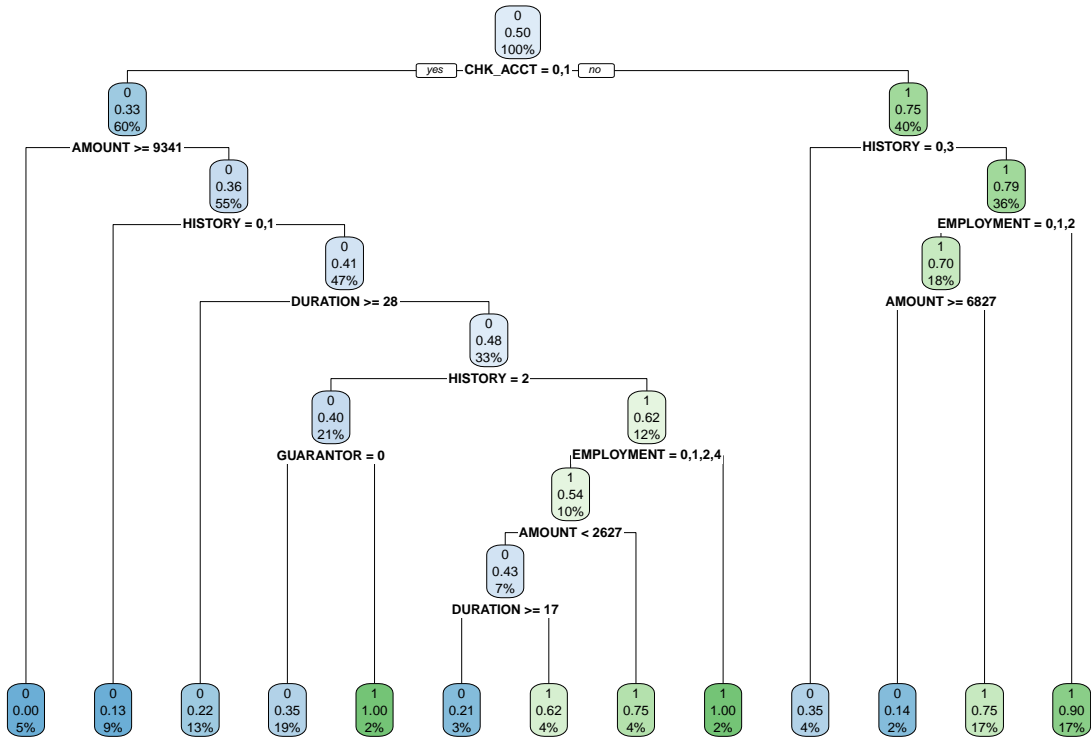
The **training set** is now balanced, we have 223 observations for both “Good Credit” (1) and “Bad Credit” (0). The new balanced training set is called `German_Credit.tr.subs`.

Models Fitting

Once we had our training set and test set, we could fit some models and compare them with together to choose the best model.

1. Classification Tree (Decision Tree) We first started with a decision tree and more specifically we chose the classification tree as we want to classify the applicants. The model was build on our previously balanced training set `German_Credit.tr.subs`. We used the R function `rpart`.

We obtained the following large tree.



We could see that among the 31 explanatory variables, this model uses 6 of them: **CHK_ACCT**, **AMOUNT**, **HISTORY**, **DURATION**, **GUARANTOR** and **EMPLOYMENT**.

Table 7: Confusion Matrix of the Big classification tree

	Bad credit risk	Good credit risk
Bad credit risk	58	70
Good credit risk	19	103

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.7532468      0.5953757      0.4531250
##      Neg Pred Value      Precision      Recall
##      0.8442623      0.4531250      0.7532468
##      F1      Prevalence      Detection Rate
##      0.5658537      0.3080000      0.2320000
## Detection Prevalence      Balanced Accuracy
##      0.5120000      0.6743112
```

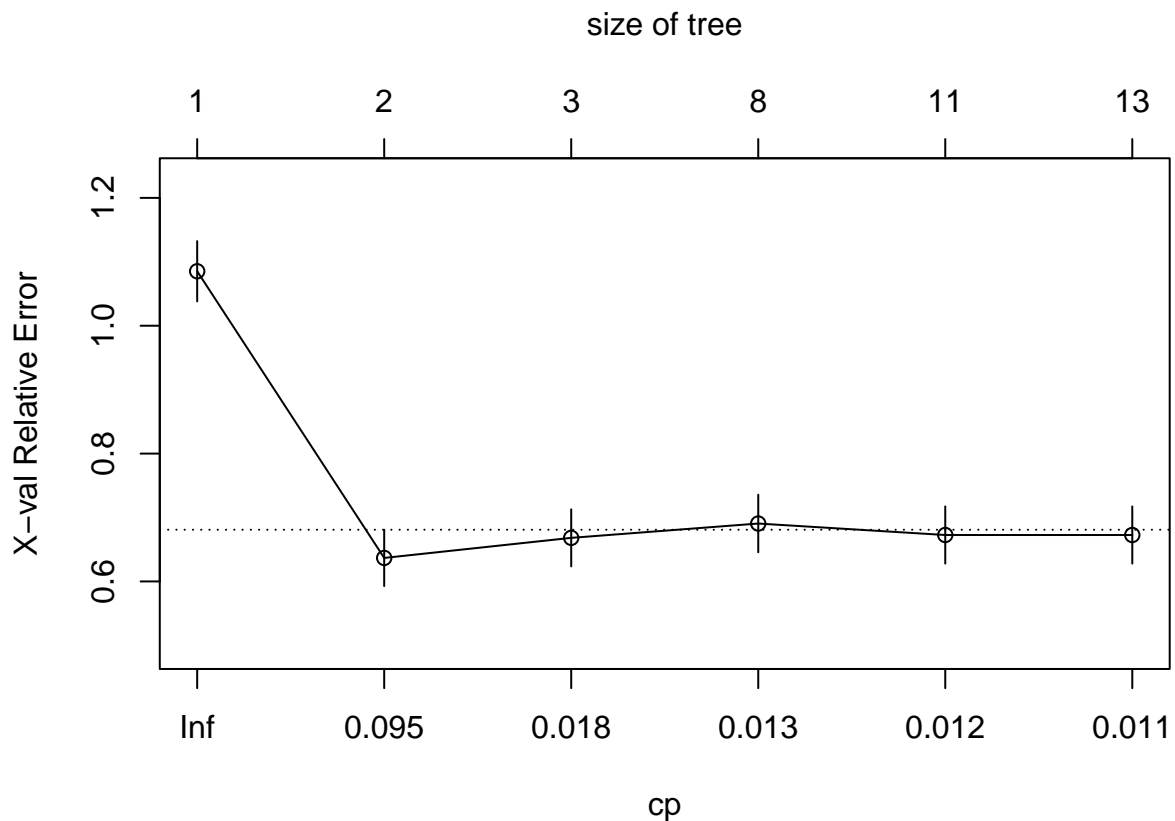
We first have an insight on how well it predict the test set (`German_credit.te`). We recall that 0 means a “Bad Credit” risk and 1 means a “Good Credit” risk. It seems that this model has difficulty to predict the “Bad Credit” risk applicants. Indeed from the table have 70 observations that were misclassified as being “Bad credit” while it was in fact a “Good credit”.

As the tree is quite big and we want to know if we can prune it. To do so, we decided to use the `printcp` and `plotcp` commands and choose the best `cp` (complexity parameter) value to prune our tree.

Pruning the tree

```
##
## Classification tree:
## rpart(formula = RESPONSE ~ ., data = German_Credit.tr.subs, method = "class")
```

```
##
## Variables actually used in tree construction:
## [1] AMOUNT      CHK_ACCT   DURATION   EMPLOYMENT  GUARANTOR  HISTORY
##
## Root node error: 223/446 = 0.5
##
## n= 446
##
##      CP nsplit rel error  xerror   xstd
## 1 0.399103     0   1.00000 1.08520 0.047179
## 2 0.022422     1   0.60090 0.63677 0.044117
## 3 0.014574     2   0.57848 0.66816 0.044668
## 4 0.011958     7   0.48430 0.69058 0.045028
## 5 0.011211    10   0.44843 0.67265 0.044742
## 6 0.010000    12   0.42601 0.67265 0.044742
```

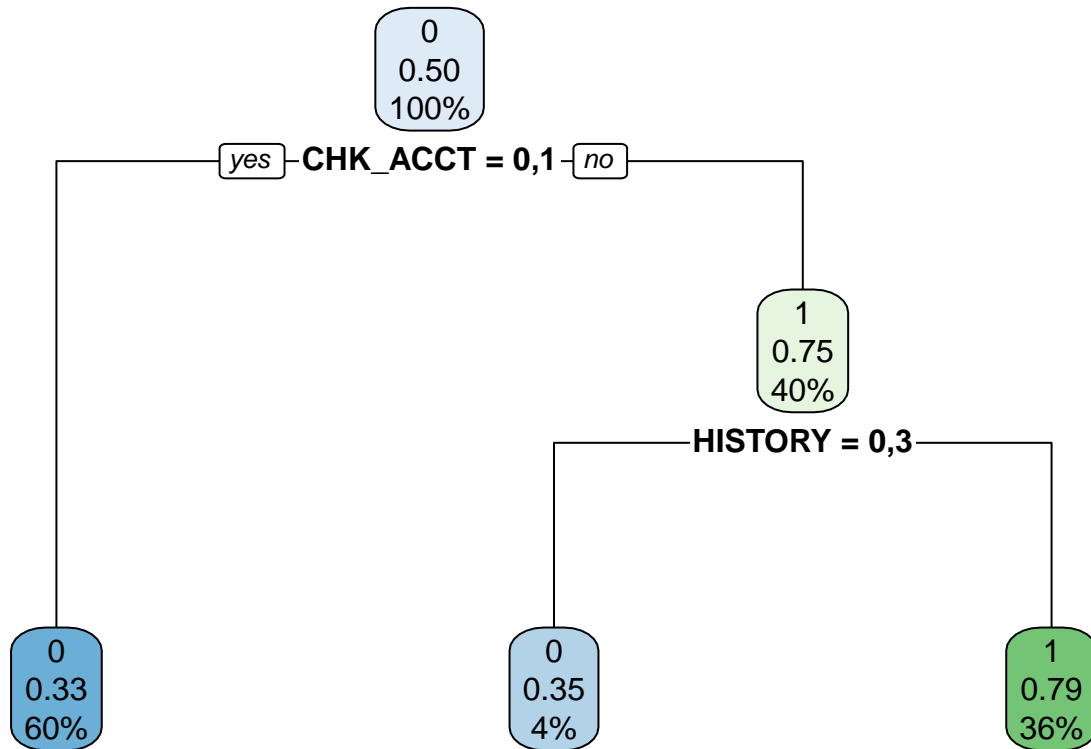


From the list of **cp** (complexity parameter), we would choose the line that has the lowest cross validation error. This can be seen on the column **xerror**. So the best cp would be 0.022422 with one split.

From the graph, we can identify that, according to the 1-SE rule, the tree with 2 and 3 are equivalent. The tree with 3 nodes should be preferred. It appears below the dotted-line.

The value of cp can be chosen arbitrarily between 0.018 and 0.095. So we decided to go with the suggested cp of 0.022 from the summary.

With these value, we obtain a very small tree.



This pruned decision tree with a cp of 0.022 uses the variables **CHK_ACCT** and **HISTORY**.

Using this pruned tree, we can compute the prediction and build a confusion matrix to see the performance of the model.

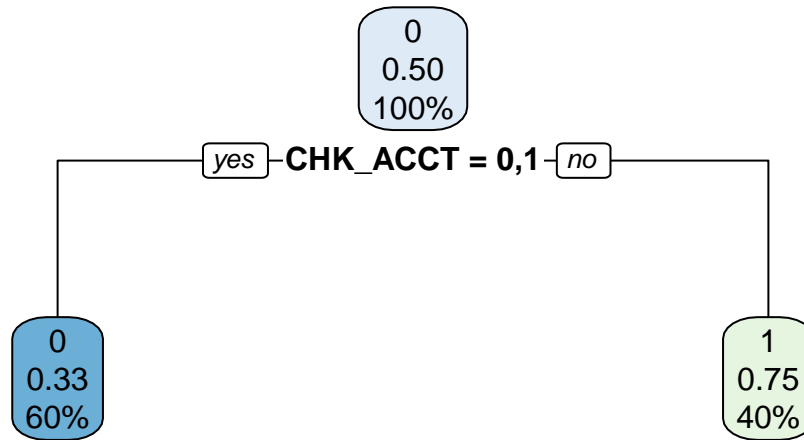
Table 8: Confusion Matrix of the Pruned classification tree

	Bad credit risk	Good credit risk
Bad credit risk	63	95
Good credit risk	14	78

##	Sensitivity	Specificity	Pos Pred Value
##	0.8181818	0.4508671	0.3987342
##	Neg Pred Value	Precision	Recall
##	0.8478261	0.3987342	0.8181818
##	F1	Prevalence	Detection Rate
##	0.5361702	0.3080000	0.2520000
##	Detection Prevalence	Balanced Accuracy	
##	0.6320000	0.6345244	

Here again, this model has difficulty to predict the “Bad credit” cases. The model also decreased in its precision values.

We also decided to look at what would an automatically pruned using 1-SE rule would give us and whether or not it is better than the pruned tree we made by looking at the cp.



Here, only the variable **CHK_ACCT** is used. As we prune the tree more information are lost.

Table 9: Confusion Matrix of the Autoruned classification tree

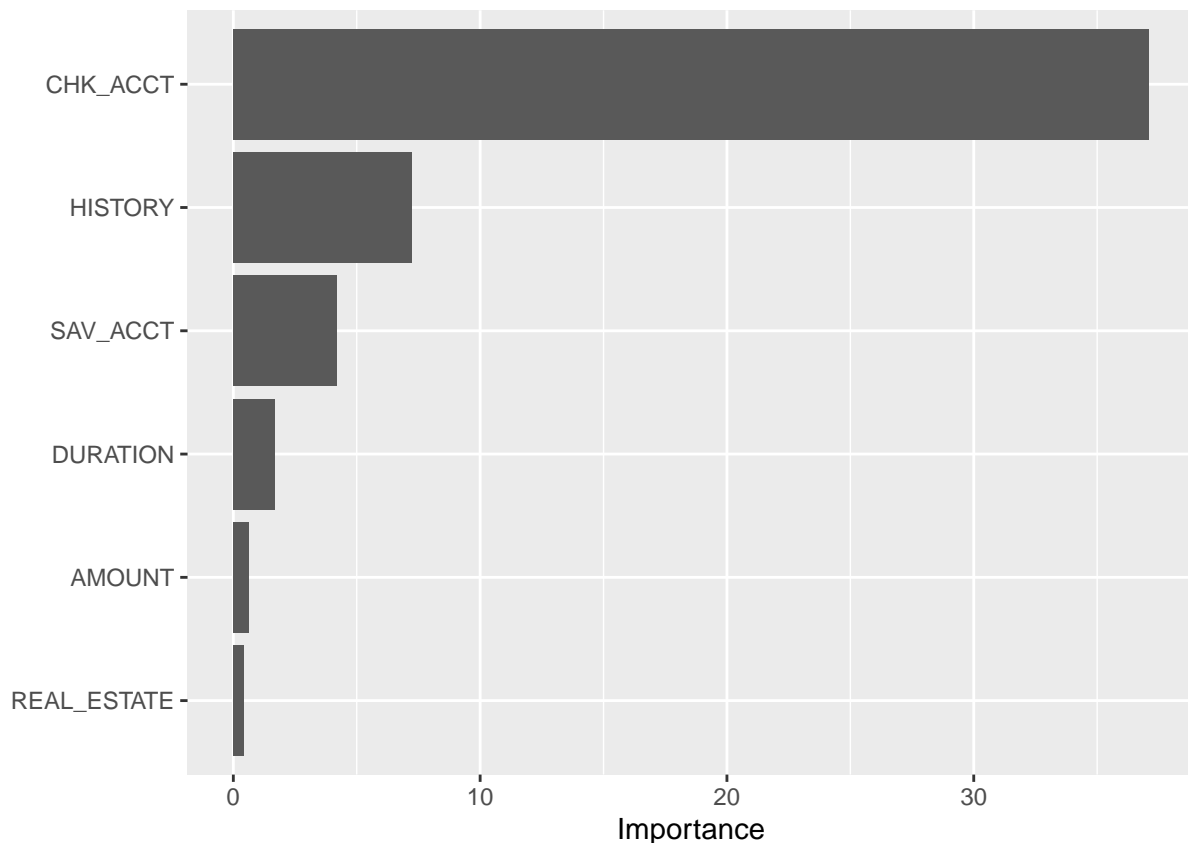
	Bad credit risk	Good credit risk
Bad credit risk	61	88
Good credit risk	16	85

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.7922078      0.4913295      0.4093960
##      Neg Pred Value      Precision      Recall
##      0.8415842      0.4093960      0.7922078
##      F1      Prevalence      Detection Rate
##      0.5398230      0.3080000      0.2440000
## Detection Prevalence      Balanced Accuracy
##      0.5960000      0.6417686
```

Again, it seems that in general the classification trees we performed have difficulty to predict the “Bad credit” cases.

Variable importance of the classification tree Then we analysed the variable importance of one of the models. We decided to compute the variable importance of the **pruned classification tree** `german.ct.prune` by applying the function `varImp` on the model.

It is summarized below on the plot.



From this plot, we see that the variables that influences the most are **CHK_ACCT**, **HISTORY**, **SAV_ACCT**, **DURATION**, **AMOUNT** and **REAL_ESTATE**. They are not exactly the same as the one we saw above.

The variable **CHK_ACCT** and **HISTORY** were already noticed though.

2. Logistic Regression The next model we performed is a logistic regression.

```
##
## Call:
## glm(formula = RESPONSE ~ ., family = binomial, data = German_Credit.tr.subs)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.34578  -0.68043   0.00049   0.65178   2.74937
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    1.1911402   1.7958756   0.663 0.507161
## CHK_ACCT1      0.5692882   0.3363406   1.693 0.090533 .
## CHK_ACCT2      0.8404451   0.5339512   1.574 0.115485
## CHK_ACCT3      2.4337691   0.3770606   6.455 1.09e-10 ***
## DURATION      -0.0123731   0.0142153  -0.870 0.384078
## HISTORY1      -1.0734853   0.8514386  -1.261 0.207384
## HISTORY2       0.0865599   0.6747882   0.128 0.897930
## HISTORY3      -0.0598560   0.7410028  -0.081 0.935619
## HISTORY4       1.1072483   0.6576414   1.684 0.092246 .
## NEW_CAR1      -0.4538649   0.5853211  -0.775 0.438096
```

```

## USED_CAR1      1.6322817  0.7540134  2.165 0.030404 *
## FURNITURE1     0.0509645  0.6182782  0.082 0.934305
## RADIO_TV1      0.5261147  0.5896893  0.892 0.372291
## EDUCATION1     0.5441469  0.7499724  0.726 0.468111
## RETRAINING1    -0.4293160  0.6787931 -0.632 0.527080
## AMOUNT         -0.0002155  0.0000739 -2.916 0.003550 **
## SAV_ACCT1      0.6181742  0.4475399  1.381 0.167195
## SAV_ACCT2     -0.2531524  0.5541205 -0.457 0.647776
## SAV_ACCT3      0.7292579  0.6813687  1.070 0.284492
## SAV_ACCT4      1.4221687  0.4243610  3.351 0.000804 ***
## EMPLOYMENT1    0.7574673  0.7956778  0.952 0.341108
## EMPLOYMENT2    1.4785839  0.7640267  1.935 0.052959 .
## EMPLOYMENT3    1.9691166  0.7947873  2.478 0.013229 *
## EMPLOYMENT4    1.8560330  0.7511387  2.471 0.013475 *
## INSTALL_RATE   -0.3367533  0.1411404 -2.386 0.017035 *
## MALE_DIV1      -0.5653453  0.5705857 -0.991 0.321775
## MALE_SINGLE1   0.1618525  0.3327207  0.486 0.626647
## MALE_MAR_or_WID1 -0.5551862  0.5312986 -1.045 0.296041
## CO.APPLICANT1  -0.6994379  0.6920599 -1.011 0.312179
## GUARANTOR1     1.7126786  0.6556150  2.612 0.008993 **
## PRESENT_RESIDENT2 -1.1195205  0.4773294 -2.345 0.019008 *
## PRESENT_RESIDENT3 -0.2590309  0.5313455 -0.487 0.625904
## PRESENT_RESIDENT4 -0.9082582  0.4793144 -1.895 0.058104 .
## REAL_ESTATE1   -0.0137202  0.3384983 -0.041 0.967669
## PROP_UNKN_NONE1 -1.4578770  0.6505748 -2.241 0.025032 *
## AGE            0.0167050  0.0141041  1.184 0.236255
## OTHER_INSTALL1 -0.6758552  0.3404321 -1.985 0.047113 *
## RENT1          -1.2066453  0.8244600 -1.464 0.143315
## OWN_RES1       -0.4707135  0.7665544 -0.614 0.539173
## NUM_CREDITS     -0.3634820  0.3011721 -1.207 0.227474
## JOB1           -0.7402802  1.1619781 -0.637 0.524069
## JOB2           -1.2142377  1.1317833 -1.073 0.283337
## JOB3           -1.4358446  1.1604352 -1.237 0.215964
## NUM_DEPENDENTS  0.1270172  0.3832474  0.331 0.740325
## TELEPHONE1     0.6259633  0.3143236  1.991 0.046430 *
## FOREIGN1       1.2496315  0.8543880  1.463 0.143576
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
## Null deviance: 618.29 on 445 degrees of freedom
## Residual deviance: 390.97 on 400 degrees of freedom
## AIC: 482.97
##
## Number of Fisher Scoring iterations: 5

```

We see that a lot of variables are not statistically significant for the model so we can think of a model reduction.

Before doing a reduction of the model, we fitted the model and predicted on the test set.

Table 10: Confusion Matrix of the Logistic Regression

	Bad credit risk	Good credit risk
Bad credit risk	49	46
Good credit risk	28	127

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.6363636      0.7341040      0.5157895
##      Neg Pred Value      Precision      Recall
##      0.8193548      0.5157895      0.6363636
##      F1      Prevalence      Detection Rate
##      0.5697674      0.3080000      0.1960000
## Detection Prevalence      Balanced Accuracy
##      0.3800000      0.6852338
```

From the confusion matrix, we see again the the model has difficulty to predict the “Bad credit” although the wronged classified amount of observation is lower when it comes to the “Bad credit” one.

Variable selection and interpretation with step method (AIC criteria) In order to reduce the logistic regression we used a stepwise variable selection. This has been done with the command `step`.

The final reduced model is as follow.

```
##
## Call:
## glm(formula = RESPONSE ~ CHK_ACCT + HISTORY + NEW_CAR + USED_CAR +
##      RETRAINING + AMOUNT + SAV_ACCT + EMPLOYMENT + INSTALL_RATE +
##      GUARANTOR + PRESENT_RESIDENT + PROP_UNKN_NONE + AGE + OTHER_INSTALL +
##      RENT + TELEPHONE + FOREIGN, family = binomial, data = German_Credit.tr.subs)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.39343  -0.68768  -0.02628   0.71315   2.60726
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  -0.6339113  1.1570626  -0.548  0.583786
## CHK_ACCT1      0.5970566  0.3291383   1.814  0.069678 .
## CHK_ACCT2      1.1123874  0.5042812   2.206  0.027392 *
## CHK_ACCT3      2.4109175  0.3597629   6.701  2.06e-11 ***
## HISTORY1     -0.6393459  0.8007632  -0.798  0.424626
## HISTORY2      0.3153810  0.6295178   0.501  0.616379
## HISTORY3      0.0245812  0.7411154   0.033  0.973541
## HISTORY4      1.0638624  0.6476870   1.643  0.100475
## NEW_CAR1     -0.7159178  0.3141611  -2.279  0.022678 *
## USED_CAR1      1.3489217  0.5579072   2.418  0.015614 *
## RETRAINING1   -0.8489518  0.4619050  -1.838  0.066072 .
## AMOUNT       -0.0002631  0.0000595  -4.421  9.81e-06 ***
## SAV_ACCT1      0.5675624  0.4173990   1.360  0.173906
## SAV_ACCT2     -0.0693577  0.5399345  -0.128  0.897788
## SAV_ACCT3      0.5603771  0.6437202   0.871  0.384011
## SAV_ACCT4      1.3592948  0.4069584   3.340  0.000837 ***
## EMPLOYMENT1    0.5542570  0.6967423   0.795  0.426324
## EMPLOYMENT2    1.2338686  0.6524020   1.891  0.058588 .
```

```

## EMPLOYMENT3      1.7999683  0.6887566   2.613 0.008966 **
## EMPLOYMENT4      1.5521376  0.6518729   2.381 0.017264 *
## INSTALL_RATE    -0.3278020  0.1249721  -2.623 0.008716 **
## GUARANTOR1      1.6927223  0.6068573   2.789 0.005282 **
## PRESENT_RESIDENT2 -1.1117822  0.4641005  -2.396 0.016595 *
## PRESENT_RESIDENT3 -0.3408387  0.5041109  -0.676 0.498966
## PRESENT_RESIDENT4 -0.7613632  0.4531619  -1.680 0.092935 .
## PROP_UNKN_NONE1 -1.0532655  0.3848454  -2.737 0.006203 **
## AGE              0.0181856  0.0128738   1.413 0.157769
## OTHER_INSTALL1   -0.6281982  0.3256821  -1.929 0.053747 .
## RENT1            -0.8736712  0.3412119  -2.560 0.010452 *
## TELEPHONE1       0.5251823  0.2863172   1.834 0.066614 .
## FOREIGN1         1.2896516  0.8049248   1.602 0.109111
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
## Null deviance: 618.29  on 445  degrees of freedom
## Residual deviance: 403.37  on 415  degrees of freedom
## AIC: 465.37
##
## Number of Fisher Scoring iterations: 5

```

The variables that have been removed are : **FURNITURE**, **RADIO.TV**, **EDUCATION**, **RE-TRAINING**, **MALE_DIV**, **MALE_SINGLE**, **MALE_MAR_or_WID**, **CO.APPLICANT**, **REAL_ESTATE**, **OWN_RES**, **NUM_CREDITS**, **JOB** and **NUM_DEPENDENTS**

In the end, we get the most significant model:

$$RESPONSE = -0.6339113 + 0.5970566 * CHK_{ACCT1} + 1.1123874 * CHK_{ACCT2} + 2.4109175 * CHK_{ACCT3} - 0.6393459 * HISTO$$

$$p = (e^{RESPONSE}) / (1 + e^{RESPONSE})$$

It means that :

- The predicted probability of being a good applicant for **CHCK_ACCT3** is higher than for **CHK_ACCT0** (and also higher than for **CHK_ACCT1** and **CHK_ACCT2**).
- The predicted probability of being a good applicant for **HISTORY1** is lower than for **HISTORY0**.
- The predicted probability of being a good applicant for **HISTORY4** is higher than for **HISTORY0** (and also higher than for **HISTORY2** and **HISTORY3**).
- The predicted probability of being a good applicant for **NEW_CAR1** is lower than for **NEW_CAR0**.
- The predicted probability of being a good applicant for **USED_CAR1** is higher than for **USED_CAR0**.
- The predicted probability of being a good applicant for **RETRAINING1** is lower than for **RE-TRAINING0**.
- **AMOUNT** is negatively associated with **RESPONSE**.
- The predicted probability of being a good applicant for **SAV_ACCT4** is higher than for **SAV_ACCT0** (and also higher than for **SAV_ACCT1** and **SAV_ACCT3**).
- The predicted probability of being a good applicant for **SAV_ACCT2** lower than for **SAV_ACCT0**.
- The predicted probability of being a good applicant for **EMPLOYMENT3** is higher than for **Employment0** (and also higher than for **EMPLOYMENT1**, **EMPLOYMENT2** and **EMPLOYMENT4**).
- **INSTALL_RATE** is negatively associated with **RESPONSE**.

- The predicted probability of being a good applicant for **GUARANTOR1** is higher than for **GUARANTOR0**.
- The predicted probability of being a good applicant for **PRESENT_RESIDENT2** is lower than for **PRESENT_RESIDENT0** (and also lower than **PRESENT_RESIDENT3** and **PRESENT_RESIDENT4**).
- The predicted probability of being a good applicant for **PROP_UNKN_NONE1** is lower than for **PROP_UNKN_NONE0**.
- **AGE** is positively associated with **RESPONSE**.
- The predicted probability of being a good applicant for **OTHER_INSTALL1** is lower than for **OTHER_INSTALL0**.
- The predicted probability of being a good applicant for **RENT1** is lower than for **RENT0**.
- The predicted probability of being a good applicant for **TELEPHONE1** is higher than for **TELEPHONE0**.
- The predicted probability of being a good applicant for **FOREIGN1** is higher than for **FOREIGN0**.

Table 11: Confusion Matrix of the AIC reduced Logistic regression

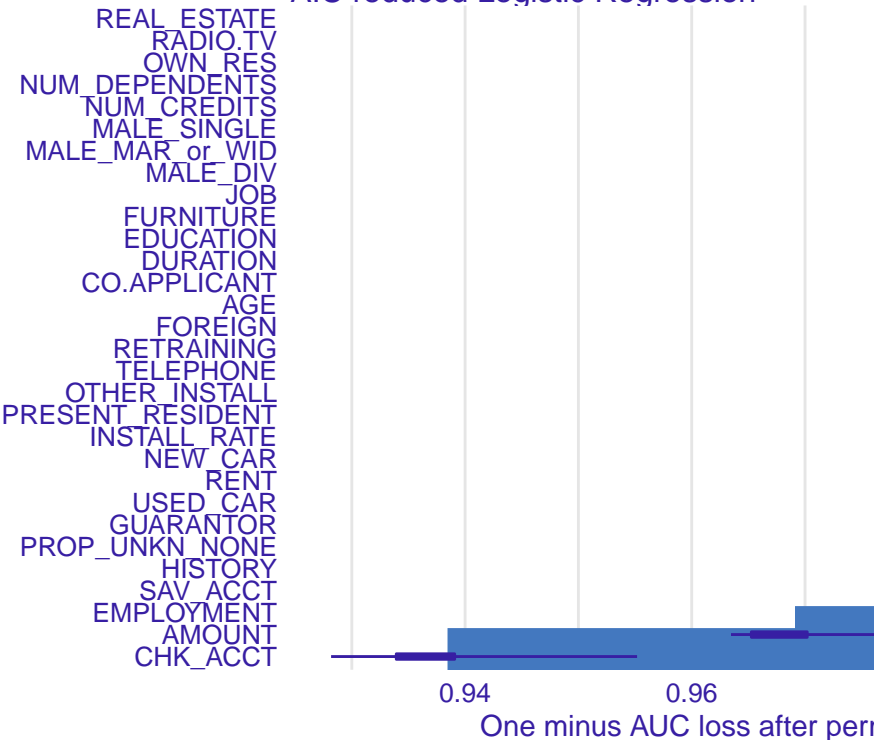
	Bad credit risk	Good credit risk
Bad credit risk	50	52
Good credit risk	27	121

##	Sensitivity	Specificity	Pos Pred Value
##	0.6493506	0.6994220	0.4901961
##	Neg Pred Value	Precision	Recall
##	0.8175676	0.4901961	0.6493506
##	F1	Prevalence	Detection Rate
##	0.5586592	0.3080000	0.2000000
##	Detection Prevalence	Balanced Accuracy	
##	0.4080000	0.6743863	

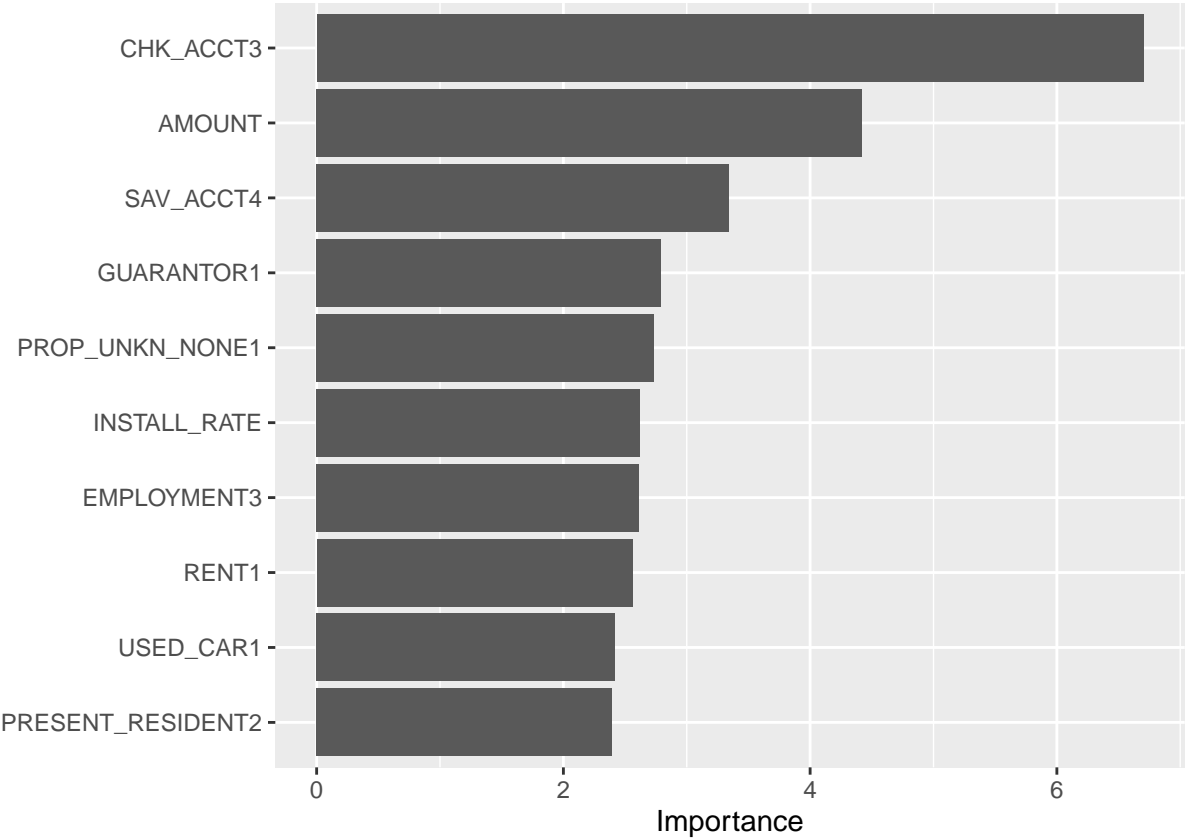
From this point we might think that the problem for the difficulty to predict the “Bad Credit” cases is not due to the models but rather the data itself. We might still want to perform other models to make sure of our intuition.

Feature Importance

created for the AIC reduced Logistic Regression
AIC reduced Logistic Regression



Variable importance for logistic regression



Listed above are the most important variables for the logarithmic regression we reduced. Here again, the **CHK_ACCT** variable differentiate itself from the others in term of importance in the model prediction.

3.a K-Nearest Neighbor (K=2) To perform a k-nearest neighbor method, we do not need to balance the data so we will use the unbalanced training set.

We first try to model it using a 2-NN (with Euclidean distance). Note that the model is fitting on the training set and the predictions are computed on the test set.

Table 12: Confusion Matrix of the 2-Nearest neighbor

	Bad credit risk	Good credit risk
Bad credit risk	21	45
Good credit risk	56	128

##	Sensitivity	Specificity	Pos Pred Value
##	0.2727273	0.7398844	0.3181818
##	Neg Pred Value	Precision	Recall
##	0.6956522	0.3181818	0.2727273
##	F1	Prevalence	Detection Rate
##	0.2937063	0.3080000	0.0840000
##	Detection Prevalence	Balanced Accuracy	
##	0.2640000	0.5063058	

The table is read as follow :

- We predicted 21 Bad credits and there were indeed 21 observed Bad credits. But the prediction misjudges 45 good credits by predicting them as bad credits.
- We predicted 128 Good credits as it was in fact a Good credits but 56 where predicted as Good while it was in fact Bad.

So again, this model also have difficulties to predict the “Bad Credit” cases.

The prediction is not perfect. We need to try to improve the prediction by changing K at that point. Therefore, we use K=3.

3.b K-Nearest Neighbor (K=3)

Table 13: Confusion Matrix of the 3-Nearest neighbor

	Bad credit risk	Good credit risk
Bad credit risk	58	70
Good credit risk	19	103

##	Sensitivity	Specificity	Pos Pred Value
##	0.1818182	0.8381503	0.3333333
##	Neg Pred Value	Precision	Recall
##	0.6971154	0.3333333	0.1818182
##	F1	Prevalence	Detection Rate
##	0.2352941	0.3080000	0.0560000
##	Detection Prevalence	Balanced Accuracy	
##	0.1680000	0.5099842	

The table is read as follow :

- We predicted 58 Bad credits and they were indeed observed Bad credits. But the prediction misjudges 70 good credits by predicting them as being bad credits.
- We predicted 103 Good credits as it was in fact a Good credits but 19 where predicted as Good while it was in fact Bad.

Again it seems not to have improved anything, the **F-measure** even seems to have decreased a little bit.

4. Linear Support Vector Machine The next model is the linear Support Vector Machine.

```
##
## Call:
## svm(formula = RESPONSE ~ ., data = German_Credit.tr.subs, kernel = "linear")
##
##
## Parameters:
##   SVM-Type:  C-classification
##   SVM-Kernel: linear
##       cost:  1
##
## Number of Support Vectors: 246
```

Table 14: Confusion Matrix of the Linear support vector machine

	Bad credit risk	Good credit risk
Bad credit risk	50	50
Good credit risk	27	123

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.6493506      0.7109827      0.5000000
##      Neg Pred Value      Precision      Recall
##      0.8200000      0.5000000      0.6493506
##      F1      Prevalence      Detection Rate
##      0.5649718      0.3080000      0.2000000
## Detection Prevalence      Balanced Accuracy
##      0.4000000      0.6801667
```

This model seems to have improved a little bit our ability to predict the “Bad Credit” cases. As half of the “Bad Credit” predicted by the model are correct.

Tunning the hyperparameters of Linear SVM We want to select the good hyperparameters for our linear SVM.

```
## Support Vector Machines with Linear Kernel
##
## 446 samples
## 30 predictor
## 2 classes: '0', '1'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 402, 400, 402, 401, 402, 402, ...
## Resampling results:
##
## Accuracy      Kappa
## 0.7264361      0.4530209
```



```
##
## Tuning parameter 'C' was held constant at a value of 1
We see that we have a good accuracy (0.72).
## Support Vector Machines with Linear Kernel
##
## 446 samples
## 30 predictor
## 2 classes: '0', '1'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 402, 400, 402, 401, 402, 402, ...
## Resampling results across tuning parameters:
##
## C      Accuracy  Kappa
## 1e-02  0.7264339  0.4532044
## 1e-01  0.7286056  0.4575791
## 1e+00  0.7264361  0.4530209
## 1e+01  0.7108278  0.4216992
## 1e+02  0.7130501  0.4261940
## 1e+03  0.7197672  0.4397558
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was C = 0.1.
```

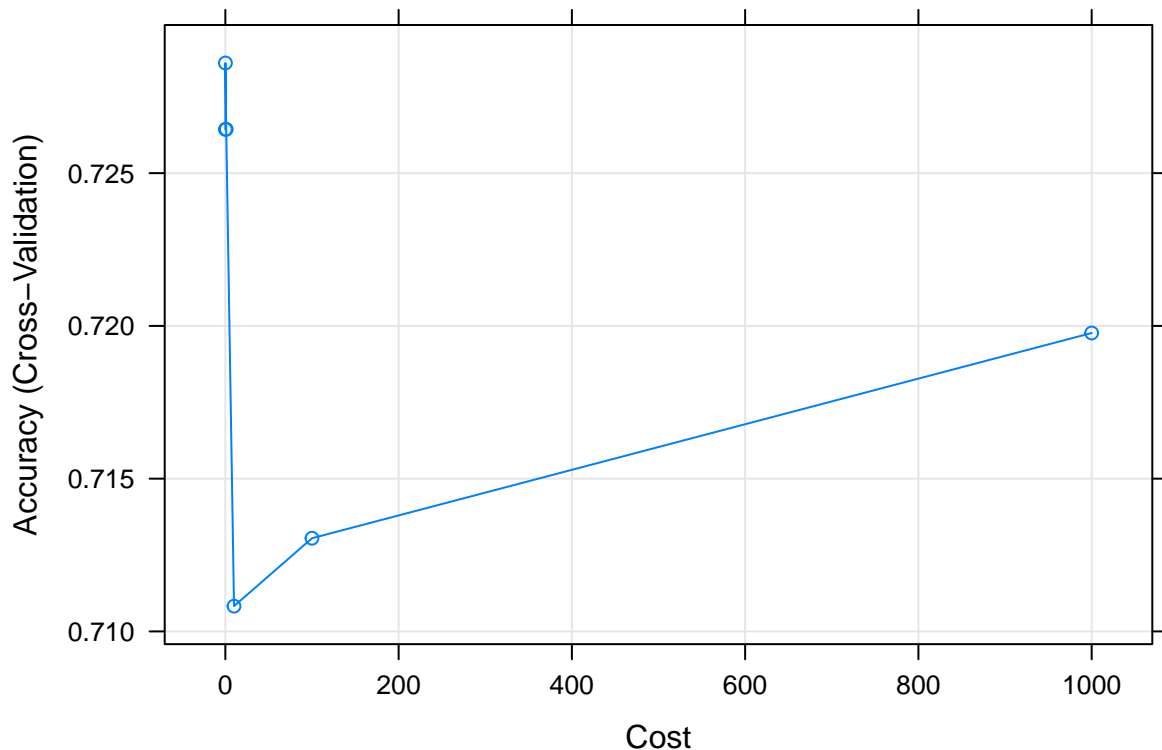


Table 15: Confusion Matrix of the Tuned linear support vector machine

	Bad credit risk	Good credit risk
Bad credit risk	49	49
Good credit risk	28	124

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.6363636      0.7167630      0.5000000
##      Neg Pred Value      Precision      Recall
##      0.8157895      0.5000000      0.6363636
##      F1      Prevalence      Detection Rate
##      0.5600000      0.3080000      0.1960000
## Detection Prevalence      Balanced Accuracy
##      0.3920000      0.6765633
```

Again, half of the “Bad Credit” predicted observations are indeed “Bad credit”.

The Linear support vector models are not too bad in the sense that they are better than the models we have seen so far.

5. Radial Basis Support Vector Machine

We try now with a radial basis kernel (the default).

```
##
## Call:
## svm(formula = RESPONSE ~ ., data = German_Credit.tr.subs, kernel = "radial")
##
##
## Parameters:
##      SVM-Type:  C-classification
##      SVM-Kernel: radial
##      cost:  1
##
## Number of Support Vectors:  334
```

Table 16: Confusion Matrix of the Radial base support vector machine

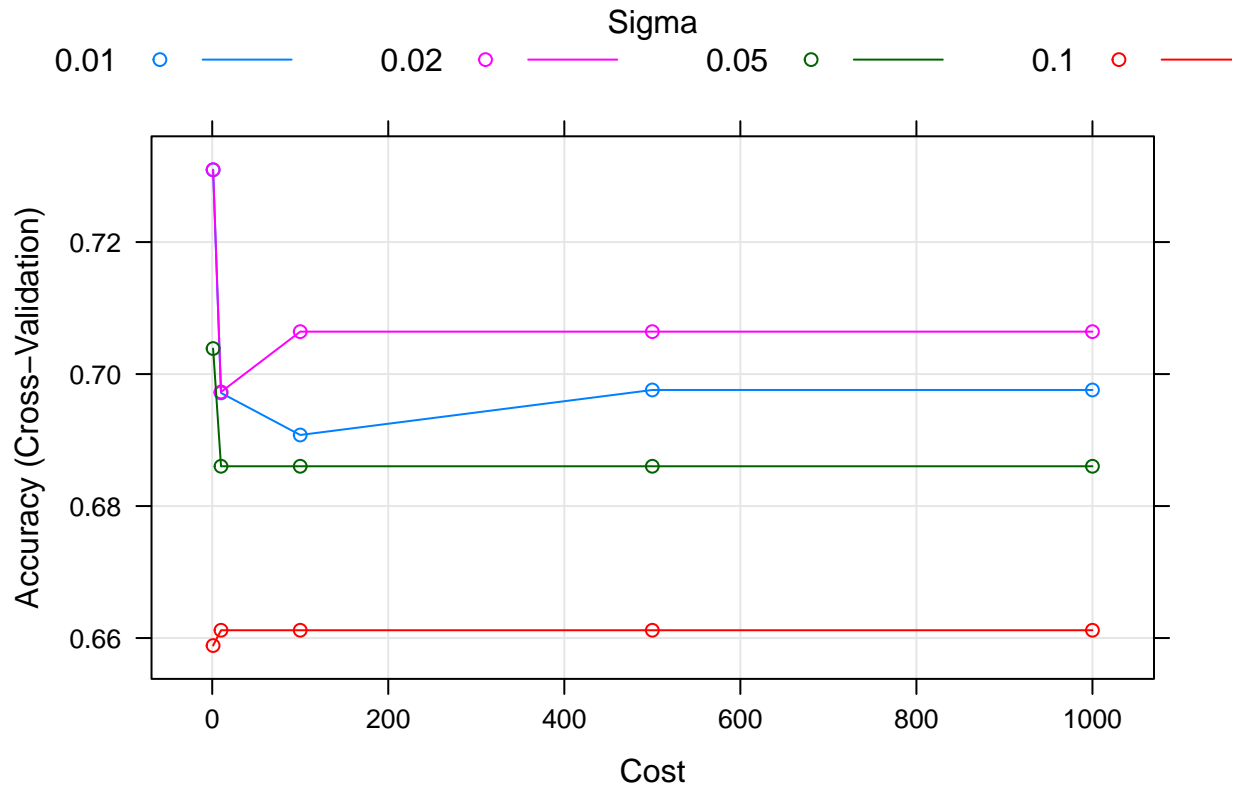
	Bad credit risk	Good credit risk
Bad credit risk	54	52
Good credit risk	23	121

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.7012987      0.6994220      0.5094340
##      Neg Pred Value      Precision      Recall
##      0.8402778      0.5094340      0.7012987
##      F1      Prevalence      Detection Rate
##      0.5901639      0.3080000      0.2160000
## Detection Prevalence      Balanced Accuracy
##      0.4240000      0.7003603
```

This model performance is very close to the linear support vector models. We need to infer more by looking at the tuned version.

Tunning the hyperparameters of Radial basis SVM

```
## Support Vector Machines with Radial Basis Function Kernel
##
## 446 samples
## 30 predictor
## 2 classes: '0', '1'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 402, 400, 402, 401, 402, 402, ...
## Resampling results across tuning parameters:
##
##  sigma  C      Accuracy  Kappa
##  0.01    1  0.7309289  0.4618150
##  0.01   10  0.6971476  0.3942416
##  0.01  100  0.6907708  0.3814209
##  0.01  500  0.6975889  0.3950572
##  0.01 1000  0.6975889  0.3950572
##  0.02    1  0.7309816  0.4620420
##  0.02   10  0.6972925  0.3946754
##  0.02  100  0.7064273  0.4127482
##  0.02  500  0.7064273  0.4127482
##  0.02 1000  0.7064273  0.4127482
##  0.05    1  0.7038647  0.4085756
##  0.05   10  0.6860299  0.3726705
##  0.05  100  0.6860299  0.3726705
##  0.05  500  0.6860299  0.3726705
##  0.05 1000  0.6860299  0.3726705
##  0.10    1  0.6588603  0.3190546
##  0.10   10  0.6611792  0.3234506
##  0.10  100  0.6611792  0.3234506
##  0.10  500  0.6611792  0.3234506
##  0.10 1000  0.6611792  0.3234506
##
## Accuracy was used to select the optimal model using the largest value.
## The final values used for the model were sigma = 0.02 and C = 1.
```



```
## sigma C
## 6 0.02 1
```

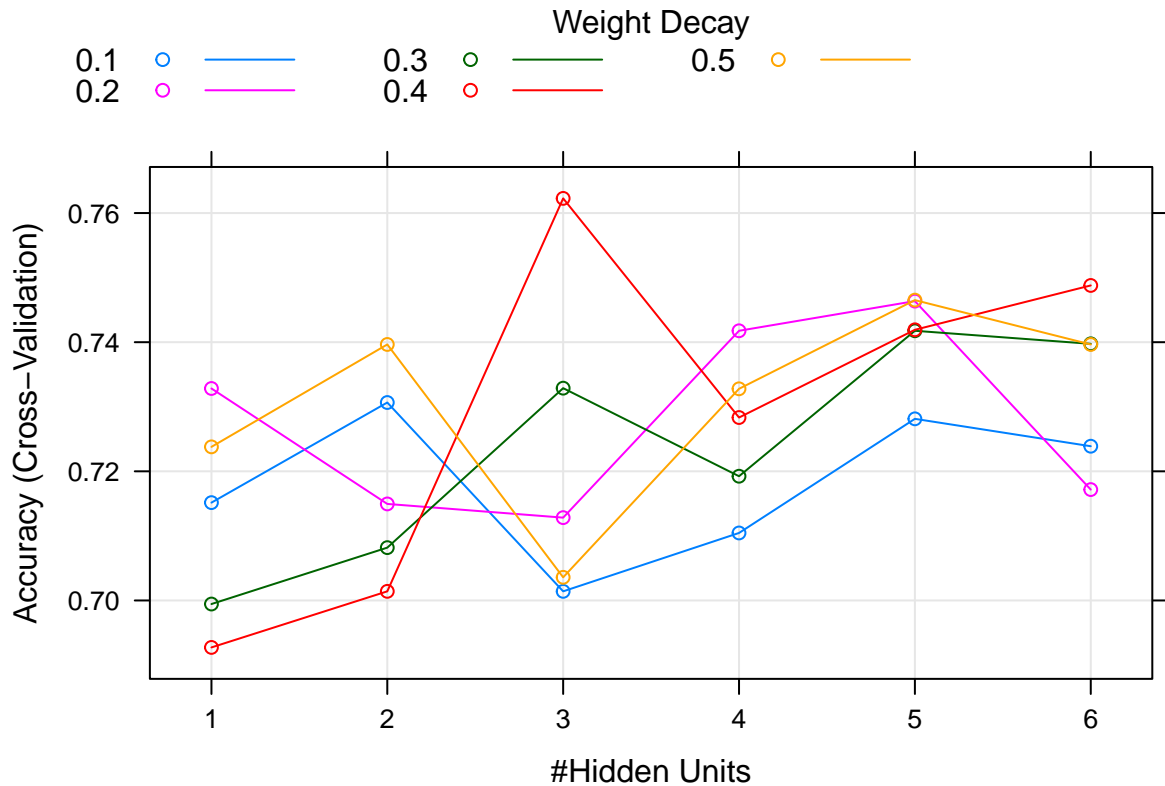
Table 17: Confusion Matrix of the Tuned radial base support vector machine

	Bad credit risk	Good credit risk
Bad credit risk	54	53
Good credit risk	23	120

```
## Sensitivity Specificity Pos Pred Value
## 0.7012987 0.6936416 0.5046729
## Neg Pred Value Precision Recall
## 0.8391608 0.5046729 0.7012987
## F1 Prevalence Detection Rate
## 0.5869565 0.3080000 0.2160000
## Detection Prevalence Balanced Accuracy
## 0.4280000 0.6974702
```

The model seems to be well balanced and it has good scores. The F-measure is quite high as well.

6. Neural Network - Simple hyperparameter tuning To select the good parameters, we build a search grid and fit the model with each possible value in the grid. This is brute force and time consuming. The best model is selected among all the possible choices.



The best Neural Networks parameters would be to choose 3 hidden layers, with a decay of 0.4.

Table 18: Confusion Matrix of the Hyperparameter tuned neural network 3 nodes

	Bad credit risk	Good credit risk
Bad credit risk	52	53
Good credit risk	25	120

```
##      Sensitivity      Specificity      Pos Pred Value
##      0.6753247      0.6936416      0.4952381
##      Neg Pred Value      Precision      Recall
##      0.8275862      0.4952381      0.6753247
##      F1      Prevalence      Detection Rate
##      0.5714286      0.3080000      0.2080000
## Detection Prevalence      Balanced Accuracy
##      0.4200000      0.6844831
```

We see that this Neural Network competes quite close to the support vector machines ones. Almost half of the “Bad credit” cases that it has predicted are correct.

7. Gradient Boosting The Gradient Boosting model accepts only numerical values so we have some transformation to do on our data in order to use it.

```
## ##### xgb.Booster
## raw: 31.2 Mb
## call:
##   xgb.train(params = xgb_params, data = xgb_train, nrounds = 5000,
##     verbose = 1)
```

```

## params (as set within xgb.train):
##   booster = "gbtree", eta = "0.01", max_depth = "8", gamma = "4", subsample = "0.75", colsample_bytree = "0.75"
## xgb.attributes:
##   niter
## callbacks:
##   cb.print.evaluation(period = print_every_n)
## # of features: 46
## niter: 5000
## nfeatures : 46

```

Here we have an accuracy of 68.4%. It is good but there is room for improvement.

Table 19: Confusion Matrix of the Gradient boosting

	Bad credit risk	Good credit risk
Bad credit risk	57	59
Good credit risk	20	114

```

##      Sensitivity      Specificity      Pos Pred Value
##      0.7402597      0.6589595      0.4913793
##      Neg Pred Value      Precision      Recall
##      0.8507463      0.4913793      0.7402597
##      F1      Prevalence      Detection Rate
##      0.5906736      0.3080000      0.2280000
## Detection Prevalence      Balanced Accuracy
##      0.4640000      0.6996096

```

Review of statistics

Once all the models were modeled we compared them according to their scores and metrics. Below we summarized all their accuracy into one table.

Table 20: Scores of the models (continued below)

	Big classification tree	Pruned classification tree	Autoprune classification tree	Logistic regression	AIC reduced Logistic regression	Linear support vector machine
Accuracy	0.644	0.564	0.584	0.704	0.684	0.692
Kappa	0.2945	0.2083	0.2251	0.3479	0.32	0.3328
Accuracy lower bound	0.5812	0.5001	0.5202	0.6432	0.6224	0.6307
Accuracy upper bound	0.7033	0.6264	0.6458	0.7599	0.7411	0.7486
Accuracy null	0.692	0.692	0.692	0.692	0.692	0.692
Accuracy P-value	0.9552	1	0.9999	0.369	0.6369	0.5308

	Big classification tree	Pruned classification tree	Autoprune classification tree	Logistic regression	AIC reduced Logistic regression	Linear support vector machine
Mcnemar P-value	1.158e-07	1.822e-14	3.352e-12	0.04813	0.00693	0.01217

	Tuned linear support vector machine	Radial base support vector machine	Tuned radial base support vector machine	Hyperparameter tuned neural network 3 nodes	Gradient Boosting
Accuracy	0.692	0.7	0.696	0.688	0.684
Kappa	0.3283	0.3628	0.3564	0.3352	0.35
Accuracy lower bound	0.6307	0.6391	0.6349	0.6266	0.6224
Accuracy upper bound	0.7486	0.7561	0.7524	0.7449	0.7411
Accuracy null	0.692	0.692	0.692	0.692	0.692
Accuracy P-value	0.5308	0.4219	0.4762	0.5847	0.6369
Mcnemar P-value	0.02265	0.001224	0.0008794	0.002235	1.909e-05

According to these two first tables, the best model would be the “Radial base linear support vector machine” as it has the highest accuracy level of 0.7 and the best kappa value of 0.3628.

The accuracy means that out of total number of observations, the model predicted correctly 70% of them. The Cohen’s Kappa Coefficient means that there is 36% of agreement, indicating that the raters agree in their classification for 36% of the cases.

We also remember that the model was almost better than the other models when it came to predict the “Bad credit” cases. Although the model remains quite poor at predicting them since only half of the predicted ones are correct.

Another table is done to compare the KNN because they were not performed on the balanced dataset.

Table 22: Scores of the KNN models

	2-Nearest neighbor	3-Nearest neighbor
Accuracy	0.596	0.636
Kappa	0.01313	0.02285
AccuracyLower	0.5323	0.573
AccuracyUpper	0.6574	0.6957
AccuracyNull	0.692	0.692
AccuracyPValue	0.9995	0.9752
McnemarPValue	0.3197	0.000365

Overall, we see that the worst model is the ‘Autoprune classification tree’. This is understandable because we pruned the model so much that we lost many observations on the way.

Conclusion

Recall, we computed several models. We first started with three versions of the classification tree, then we performed two logistic regression, two nearest neighbour, four support vector machines, one neural network and one gradient boosting model. Through all these models we noticed a common point which was their poor ability to predict the “Bad credit” cases. Knowing the purpose of this report, it is not really good as the banker might then misjudge the new applicant and refuse to give a credit while the applicant might be a good one. This will result in an opportunity loss for our client, the banker.

Since several models have been performed throughout this analysis, we came up with the conclusion that there might be a bias in the data itself. Indeed we might have good information and knowledge on the characteristics of a “good” applicant but the data could be improved and include more information on the “bad” applicant. This way, the models will then be able to be better trained.

Our recommendations/Suggestions

As we saw the models could be improved as the accuracies are not going over the 70%. We think that other variables describing better the ‘Bad’ credits could be added. For example, it would be interesting to know whether the applicant is under litigation for not paying back someone (‘acte de poursuite’ in French).

References

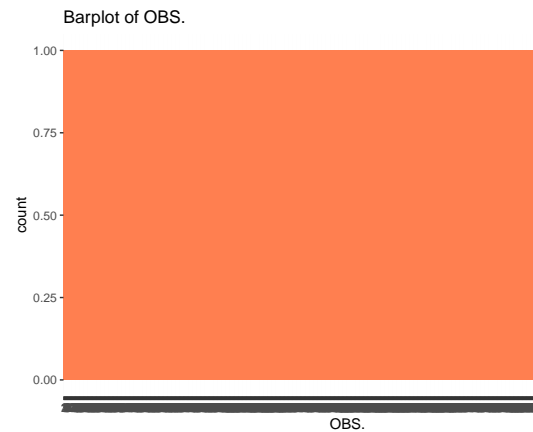
Annexes

Appendix A : Definitions of the attributes of the German Credit dataset

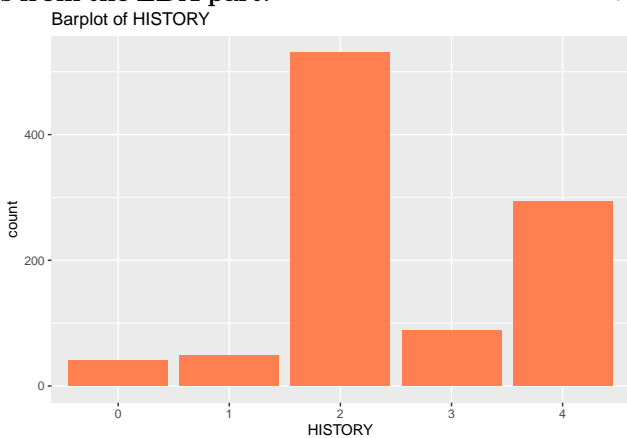
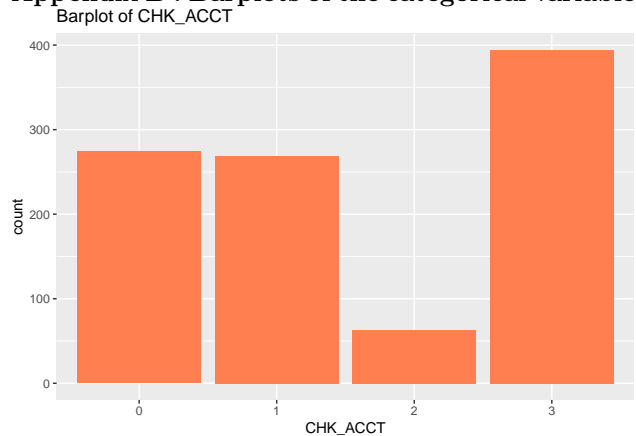
- 1) OBS# : Observation No.
- 2) CHK_ACCT : Checking account status
 - 0 : < 0 DM
 - 1 : $0 < \dots < 200$ DM
 - 2 : ≥ 200 DM
 - 3 : no checking account
- 3) DURATION : Duration of credit in months
- 4) HISTORY : Credit history
 - 0 : no credits taken
 - 1 : all credits at this bank paid back duly
 - 2 : existing credits paid back duly till now
 - 3 : delay in paying off in the past
 - 4 : critical account
- 5) NEW_CAR : Purpose of credit
 - car (new) 0 : No, 1 : Yes
- 6) USED_CAR : Purpose of credit
 - car (used) 0 : No, 1 : Yes
- 7) FURNITURE : Purpose of credit
 - furniture/equipment 0 : No, 1 : Yes
- 8) RADIO/TV : Purpose of credit
 - radio/television 0 : No, 1 : Yes
- 9) EDUCATION : Purpose of credit
 - education 0 : No, 1 : Yes

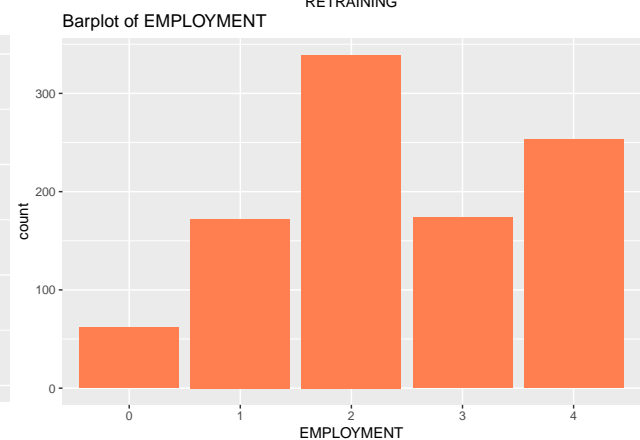
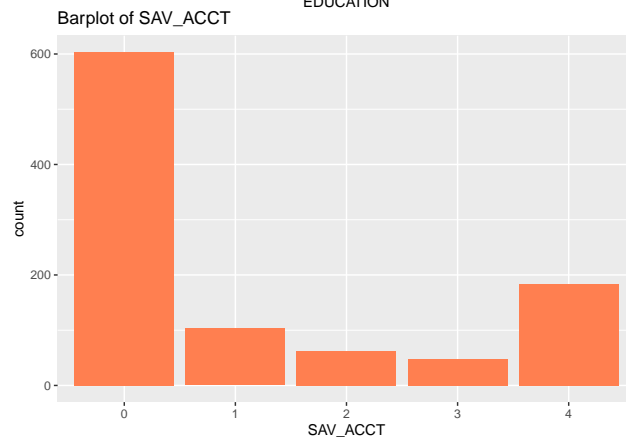
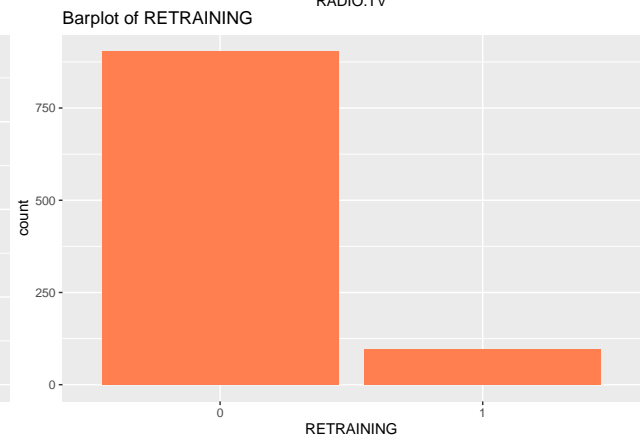
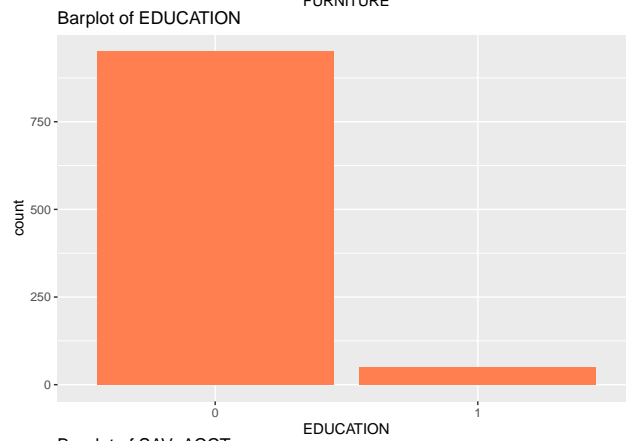
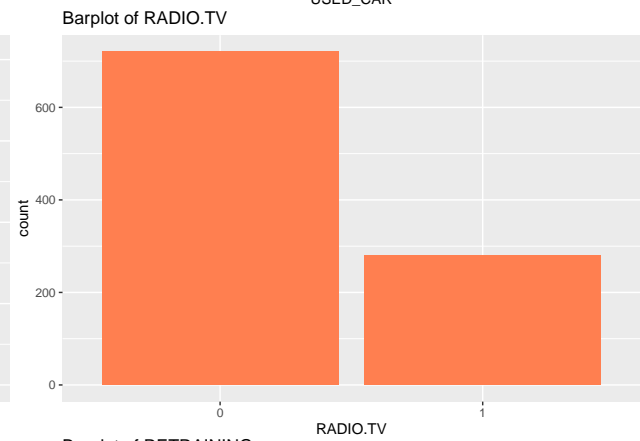
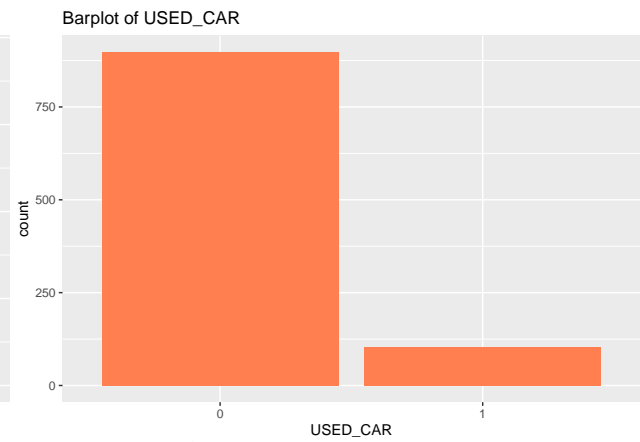
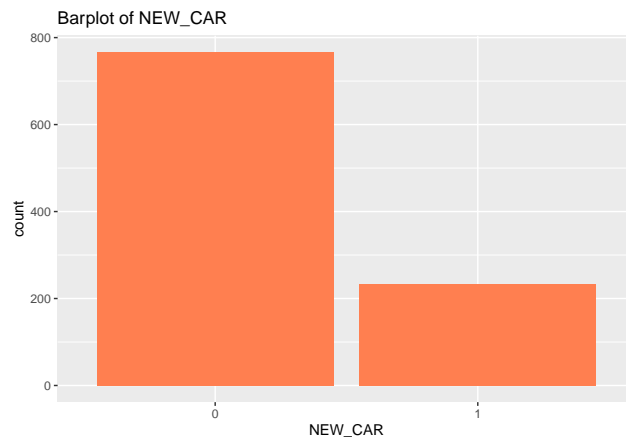
- 10) RETRAINING Purpose of credit
 - retraining 0 : No, 1 : Yes
- 11) AMOUNT : Credit amount
- 12) SAV_ACCT : Average balance in savings account
 - 0 : < 100 DM
 - 1 : 100 <= . . . < 500 DM
 - 2 : 500 <= . . . < 1000 DM
 - 3 : >= 1000 DM
 - 4 : unknown/no savings account
- 13) EMPLOYMENT : Present employment since
 - 0 : unemployed
 - 1 : < 1 year
 - 2 : 1 <= . . . < 4 years
 - 3 : 4 <= . . . < 7 years
 - 4 : >= 7 years
- 14) INSTALL_RATE : Installment rate as % of disposable income
- 15) MALE_DIV : Applicant is male and divorced
 - 0 : No, 1 : Yes
- 16) MALE_SINGLE : Applicant is male and single
 - 0 : No, 1 : Yes
- 17) MALE_MAR_WID : Applicant is male and married or a widower
 - 0 : No, 1 : Yes
- 18) CO-APPLICANT : Application has a co-applicant
 - 0 : No, 1 : Yes
- 19) GUARANTOR : Applicant has a guarantor
 - 0 : No, 1 : Yes
- 20) PRESENT_RESIDENT : Present resident since - years
 - 0 : <= 1 year
 - 1 : 1 < . . . <= 2 years
 - 2 : 2 < . . . <= 3 years
 - 3 : > 4 years
- 21) REAL_ESTATE : Applicant owns real estate
 - 0 : No, 1 : Yes
- 22) PROP_UNKN_NONE : Applicant owns no property (or unknown)
 - 0 : No, 1 : Yes
- 23) AGE : Age in years
- 24) OTHER_INSTALL : Applicant has other installment plan credit
 - 0 : No, 1 : Yes
- 25) RENT : Applicant rents
 - 0 : No, 1 : Yes

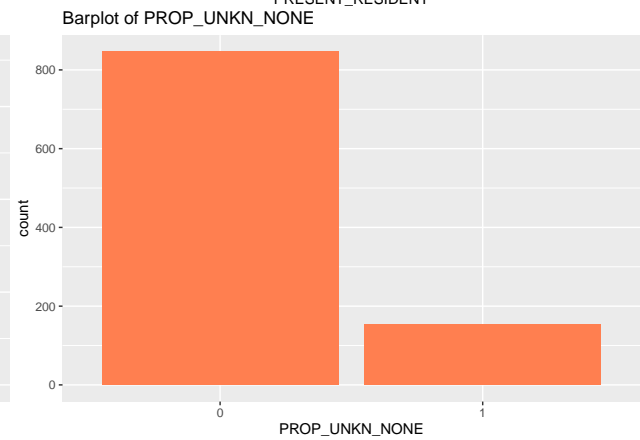
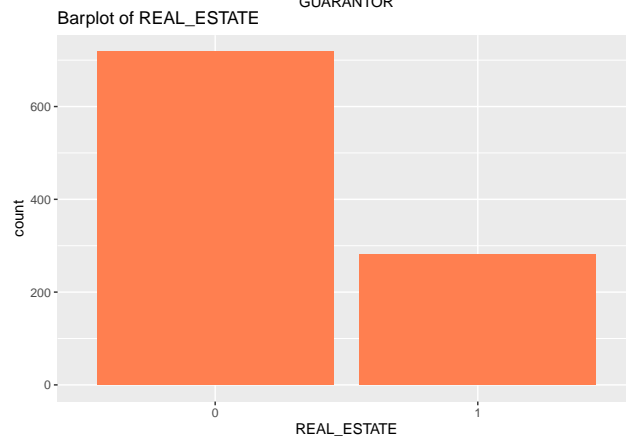
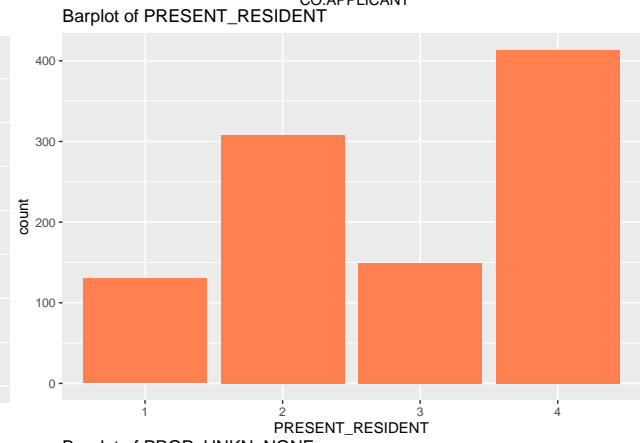
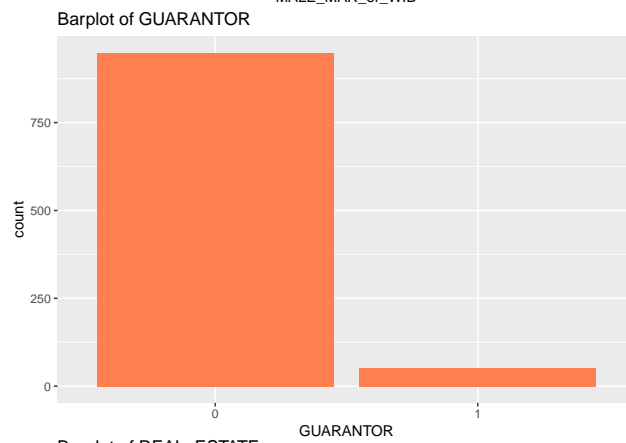
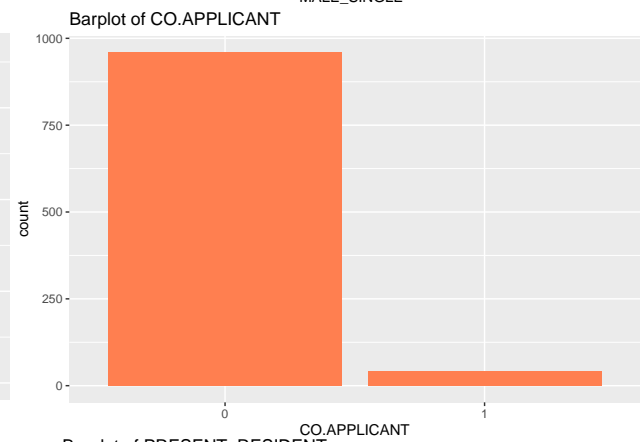
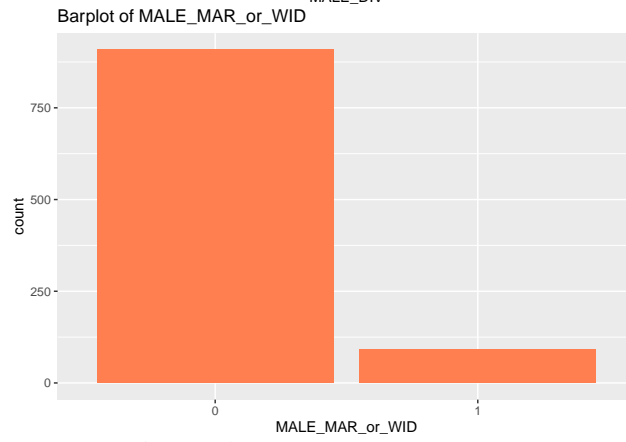
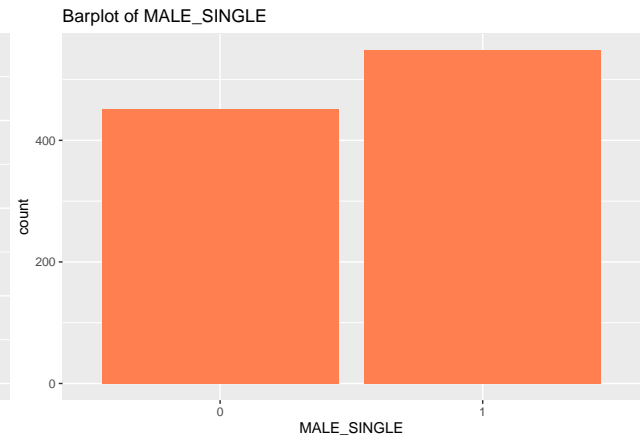
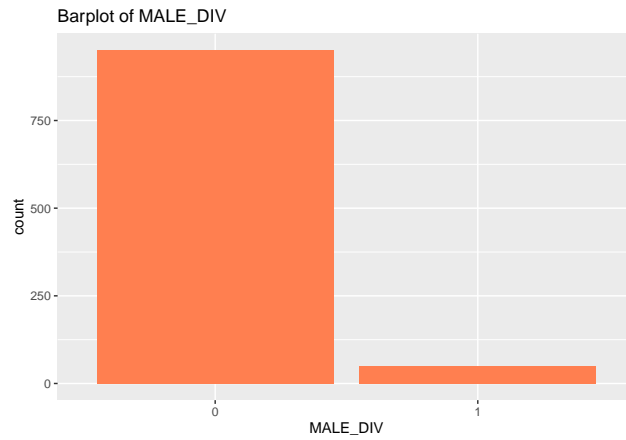
- 26) OWN_RES : Applicant owns residence
 - 0 : No, 1 : Yes
- 27) NUM_CREDITS : Number of existing credits at this bank
- 28) JOB : Nature of job
 - 0 : unemployed/unskilled non-resident
 - 1 : unskilled - resident
 - 2 : skilled employee/official
 - 3 : management/self-employed/
 - highly qualified employee/officer
- 29) NUM_DEPENDENTS : Number of people for whom liable to provide maintenance
- 30) TELEPHONE : Applicant has phone in his or her name
 - 0 : No, 1 : Yes
- 31) FOREIGN + Foreign worker
 - 0 : No, 1 : Yes

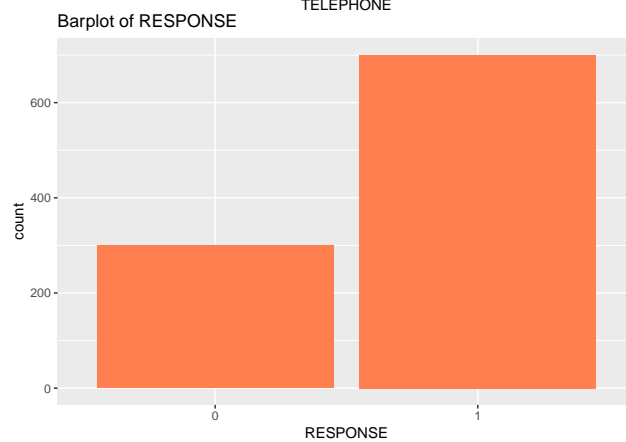
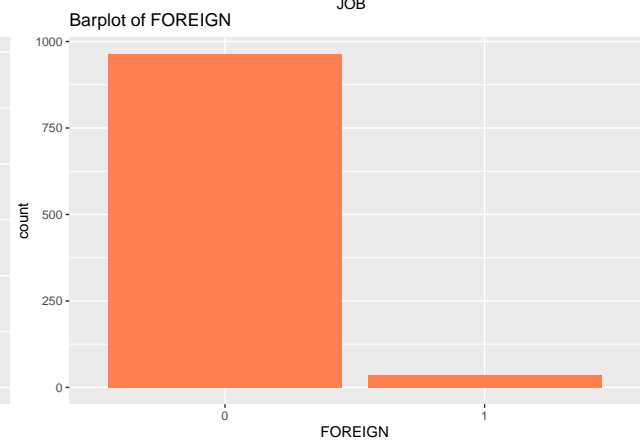
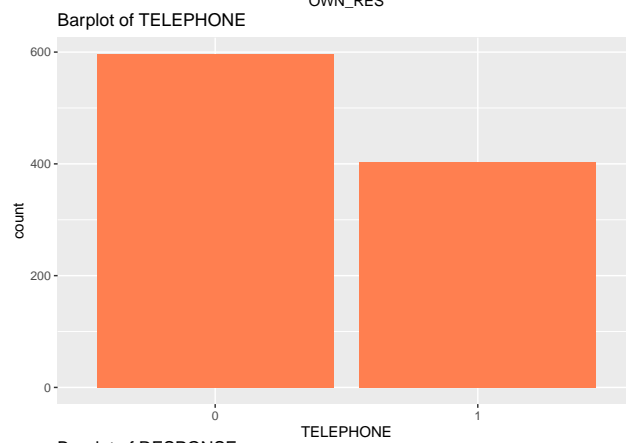
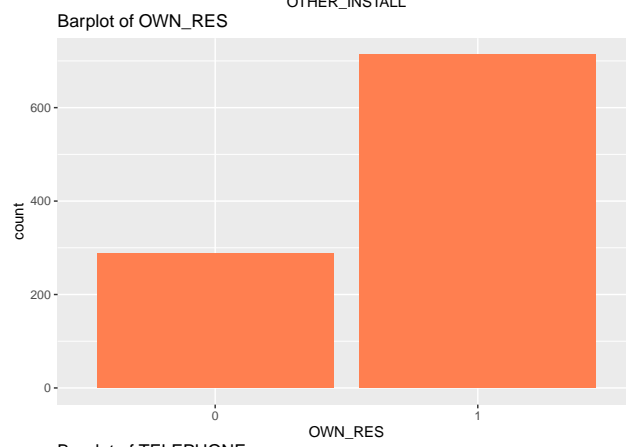
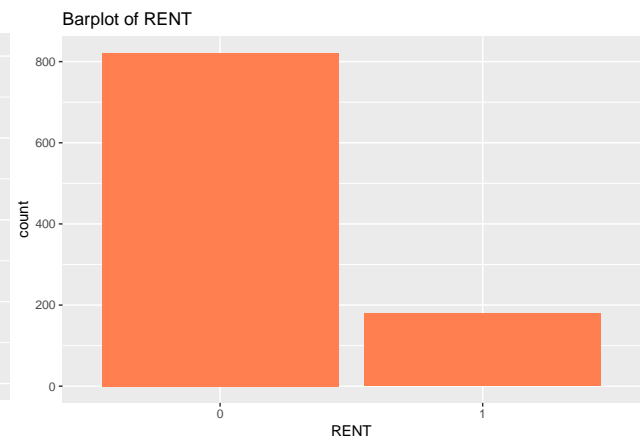
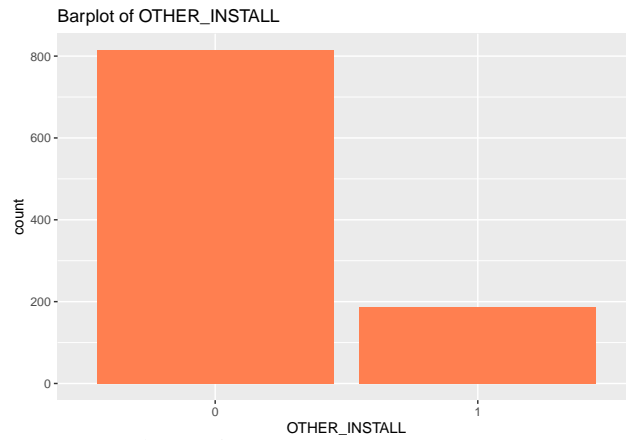


Appendix B : Barplots of the categorical variables from the EDA part.









Appendix C : General summary of the German Credit dataset

Data Frame Summary

Dimensions: 1000 x 32

Duplicates: 0

##

##	+	-----	+	Stats / Values	+	Freqs (% of Valid)	+	Graph
##	+	=====	+	=====	+	=====	+	=====
##		1		OBS.		1. 1		1 (0.1%)
##				[factor]		2. 2		1 (0.1%)
##						3. 3		1 (0.1%)
##						4. 4		1 (0.1%)
##						5. 5		1 (0.1%)
##						6. 6		1 (0.1%)
##						7. 7		1 (0.1%)
##						8. 8		1 (0.1%)
##						9. 9		1 (0.1%)
##						10. 10		1 (0.1%)
##						[990 others]		990 (99.0%)
##								IIIIIIIIIIIIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		2		CHK_ACCT		1. 0		274 (27.4%)
##				[factor]		2. 1		269 (26.9%)
##						3. 2		63 (6.3%)
##						4. 3		394 (39.4%)
##								IIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		3		DURATION		Mean (sd) : 20.9 (12.1)		33 distinct values
##				[numeric]		min < med < max:		:
##						4 < 18 < 72		:
##						IQR (CV) : 12 (0.6)		:
##								:
##								:
##	+	-----	+	-----	+	-----	+	-----
##		4		HISTORY		1. 0		40 (4.0%)
##				[factor]		2. 1		49 (4.9%)
##						3. 2		530 (53.0%)
##						4. 3		88 (8.8%)
##						5. 4		293 (29.3%)
##								IIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		5		NEW_CAR		1. 0		766 (76.6%)
##				[factor]		2. 1		234 (23.4%)
##								IIIIIIIIIIIIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		6		USED_CAR		1. 0		897 (89.7%)
##				[factor]		2. 1		103 (10.3%)
##								IIIIIIIIIIIIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		7		FURNITURE		1. 0		819 (81.9%)
##				[factor]		2. 1		181 (18.1%)
##								IIIIIIIIIIIIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		8		RADIO.TV		1. 0		720 (72.0%)
##				[factor]		2. 1		280 (28.0%)
##								IIIIIIIIIIIIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		9		EDUCATION		1. 0		950 (95.0%)
##				[factor]		2. 1		50 (5.0%)
##								IIIIIIIIIIIIIIIIIIII
##	+	-----	+	-----	+	-----	+	-----
##		10		RETRAINING		1. 0		903 (90.3%)
##								IIIIIIIIIIIIIIIIIIII

##				[factor]		2. 1		97 (9.7%)		I
##	+	-----	+		+		+		+	
##		11		AMOUNT		Mean (sd) : 3271.3 (2822.7)		921 distinct values		:
##				[numeric]		min < med < max:				: .
##						250 < 2319.5 < 18424				: :
##						IQR (CV) : 2606.8 (0.9)				: :
##										: : : .
##	+	-----	+		+		+		+	
##		12		SAV_ACCT		1. 0		603 (60.3%)		IIIIIIIIII
##				[factor]		2. 1		103 (10.3%)		II
##						3. 2		63 (6.3%)		I
##						4. 3		48 (4.8%)		
##						5. 4		183 (18.3%)		III
##	+	-----	+		+		+		+	
##		13		EMPLOYMENT		1. 0		62 (6.2%)		I
##				[factor]		2. 1		172 (17.2%)		III
##						3. 2		339 (33.9%)		IIIIII
##						4. 3		174 (17.4%)		III
##						5. 4		253 (25.3%)		IIII
##	+	-----	+		+		+		+	
##		14		INSTALL_RATE		Mean (sd) : 3 (1.1)		1 : 136 (13.6%)		II
##				[numeric]		min < med < max:		2 : 231 (23.1%)		IIII
##						1 < 3 < 4		3 : 157 (15.7%)		III
##						IQR (CV) : 2 (0.4)		4 : 476 (47.6%)		IIIIIIII
##	+	-----	+		+		+		+	
##		15		MALE_DIV		1. 0		950 (95.0%)		IIIIIIIIIIIIIIIIII
##				[factor]		2. 1		50 (5.0%)		I
##	+	-----	+		+		+		+	
##		16		MALE_SINGLE		1. 0		452 (45.2%)		IIIIIIII
##				[factor]		2. 1		548 (54.8%)		IIIIIIIIII
##	+	-----	+		+		+		+	
##		17		MALE_MAR_or_WID		1. 0		908 (90.8%)		IIIIIIIIIIIIIIIIII
##				[factor]		2. 1		92 (9.2%)		I
##	+	-----	+		+		+		+	
##		18		CO.APPLICANT		1. 0		959 (95.9%)		IIIIIIIIIIIIIIIIII
##				[factor]		2. 1		41 (4.1%)		
##	+	-----	+		+		+		+	
##		19		GUARANTOR		1. 0		948 (94.8%)		IIIIIIIIIIIIIIIIII
##				[factor]		2. 1		52 (5.2%)		I
##	+	-----	+		+		+		+	
##		20		PRESENT_RESIDENT		1. 1		130 (13.0%)		II
##				[factor]		2. 2		308 (30.8%)		IIIIII
##						3. 3		149 (14.9%)		II
##						4. 4		413 (41.3%)		IIIIIIII
##	+	-----	+		+		+		+	
##		21		REAL_ESTATE		1. 0		718 (71.8%)		IIIIIIIIIIIIIIIIII
##				[factor]		2. 1		282 (28.2%)		IIII
##	+	-----	+		+		+		+	
##		22		PROP_UNKN_NONE		1. 0		846 (84.6%)		IIIIIIIIIIIIIIIIII
##				[factor]		2. 1		154 (15.4%)		III
##	+	-----	+		+		+		+	
##		23		AGE		Mean (sd) : 35.5 (11.4)		53 distinct values		:
##				[numeric]		min < med < max:				: .
##						19 < 33 < 75				: : : :

##				IQR (CV) : 15 (0.3)				:	:	:	:	:
##								:	:	:	:	:
##	+	-----	+		+		+					
##		24		OTHER_INSTALL		1. 0		814	(81.4%)		IIIIIIIIIIIIIIIIII	
##				[factor]		2. 1		186	(18.6%)		III	
##	+	-----	+		+		+			+		
##		25		RENT		1. 0		821	(82.1%)		IIIIIIIIIIIIIIIIII	
##				[factor]		2. 1		179	(17.9%)		III	
##	+	-----	+		+		+			+		
##		26		OWN_RES		1. 0		287	(28.7%)		IIIII	
##				[factor]		2. 1		713	(71.3%)		IIIIIIIIIIIIIIIIII	
##	+	-----	+		+		+			+		
##		27		NUM_CREDITS		Mean (sd) : 1.4 (0.6)		1 :	633 (63.3%)		IIIIIIIIIIIIIIIIII	
##				[numeric]		min < med < max:		2 :	333 (33.3%)		IIIIIII	
##						1 < 1 < 4		3 :	28 (2.8%)			
##						IQR (CV) : 1 (0.4)		4 :	6 (0.6%)			
##	+	-----	+		+		+			+		
##		28		JOB		1. 0		22	(2.2%)			
##				[factor]		2. 1		200	(20.0%)		IIII	
##						3. 2		630	(63.0%)		IIIIIIIIIIIIIIIIII	
##						4. 3		148	(14.8%)		II	
##	+	-----	+		+		+			+		
##		29		NUM_DEPENDENTS		Min : 1		1 :	845 (84.5%)		IIIIIIIIIIIIIIIIII	
##				[numeric]		Mean : 1.2		2 :	155 (15.5%)		III	
##						Max : 2						
##	+	-----	+		+		+			+		
##		30		TELEPHONE		1. 0		596	(59.6%)		IIIIIIIIIIIIIIIIII	
##				[factor]		2. 1		404	(40.4%)		IIIIIIIIII	
##	+	-----	+		+		+			+		
##		31		FOREIGN		1. 0		963	(96.3%)		IIIIIIIIIIIIIIIIIIIIIIIIIIIIII	
##				[factor]		2. 1		37	(3.7%)			
##	+	-----	+		+		+			+		
##		32		RESPONSE		1. 0		300	(30.0%)		IIIIIII	
##				[factor]		2. 1		700	(70.0%)		IIIIIIIIIIIIIIIIIIII	
##	+	-----	+		+		+			+		