Final Project

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08/09/2020

# Dataset Info

1. For this project will be using the lending loan club dataset, located at <https://www.kaggle.com/wordsforthewise/lending-club>
2. Since this datasize is huge and due to comouting constraints, will using the data for 2018 only. Only approved loans dataset will be in scope for this project.
3. Effective dataset size if of 495,242 observations/loans

# About lending club

The Lending Club is a peer-to-peer lending service (it lends money to customers by matching lenders to borrowers), based in the United States. This company enables borrowers to create loan listings on its website by supplying details about themselves and the loans that they would like to request.

# Dataset Attributes

1. Dataset contains various attributes based on which the credit lending decision takes place, this includes Debt to income ratio, annual income, home ownership type (Rented,Mortgage, Owned), employment details. Dataset also contains geographical information like state and zip code. It also has issued loan details like funded Loan Amount, issued month and year, loan Term (36 or 60 months) and interest rate. Post loan has been issued, loan performance needs to be tracked, and this dataset also contains those details loan Status (Current, Paid Off, Charged Off, Delinquent), loan Grades and delinquency details.

# Research Objectives

1. Qualitative - Build a model which will indicate if the loan would ever be delinquent, the delinquency could be of 30, 60, 90 or 120 days.
2. Quantitative - Build a model which will provide the interest rate when the person applies for the loan.
3. Unsupervised - Identify correlation between various credit decisioning variables like fico, dti, annual income etc using PCA and K-Mean.

Please note that some of the research objective have changed than what were quoted in the project out line document in Week-5,  
a. Instead of loan amount, now predicting interest rate. b. For qualitative predicting only delinquency and not charge offs.

# Feature engineering

Load the whole dataset

lendingClubLoanData <- fread("data/Lending\_club\_dataset.csv", header = TRUE)

Create a origination year fild on the dataset, so that all loans which have originated in 2018 can be extracted.

nrow(lendingClubLoanData)

## [1] 2260701

lendingClubLoanData$orig\_year<-substr(lendingClubLoanData$issue\_d,5,8)

lendingClubLoanData\_2018 <- lendingClubLoanData %>%  
 filter(orig\_year == 2018)

lc\_ds\_size <- nrow(lendingClubLoanData\_2018)  
lc\_ds\_size

## [1] 495242

Dataset which will used for this analysis would comprise of 495242 observations.

Create file for all loans which originated in 2018

nrow(lendingClubLoanData\_2018)

## [1] 495242

write.csv(lendingClubLoanData\_2018, file = "data/lending\_club\_loan\_data\_2018\_final.csv", row.names=FALSE)

Load the final data set for analysis

final\_dataset <- fread("data/lending\_club\_loan\_data\_2018\_final.csv", header = TRUE)  
drops <- c("id","member\_id", "url", "desc")  
#final\_dataset[ , !(names(final\_dataset) %in% drops)]

List down all varibales in the dataset

names(final\_dataset)

## [1] "id"   
## [2] "member\_id"   
## [3] "loan\_amnt"   
## [4] "funded\_amnt"   
## [5] "funded\_amnt\_inv"   
## [6] "term"   
## [7] "int\_rate"   
## [8] "installment"   
## [9] "grade"   
## [10] "sub\_grade"   
## [11] "emp\_title"   
## [12] "emp\_length"   
## [13] "home\_ownership"   
## [14] "annual\_inc"   
## [15] "verification\_status"   
## [16] "issue\_d"   
## [17] "loan\_status"   
## [18] "pymnt\_plan"   
## [19] "url"   
## [20] "desc"   
## [21] "purpose"   
## [22] "title"   
## [23] "zip\_code"   
## [24] "addr\_state"   
## [25] "dti"   
## [26] "delinq\_2yrs"   
## [27] "earliest\_cr\_line"   
## [28] "fico\_range\_low"   
## [29] "fico\_range\_high"   
## [30] "inq\_last\_6mths"   
## [31] "mths\_since\_last\_delinq"   
## [32] "mths\_since\_last\_record"   
## [33] "open\_acc"   
## [34] "pub\_rec"   
## [35] "revol\_bal"   
## [36] "revol\_util"   
## [37] "total\_acc"   
## [38] "initial\_list\_status"   
## [39] "out\_prncp"   
## [40] "out\_prncp\_inv"   
## [41] "total\_pymnt"   
## [42] "total\_pymnt\_inv"   
## [43] "total\_rec\_prncp"   
## [44] "total\_rec\_int"   
## [45] "total\_rec\_late\_fee"   
## [46] "recoveries"   
## [47] "collection\_recovery\_fee"   
## [48] "last\_pymnt\_d"   
## [49] "last\_pymnt\_amnt"   
## [50] "next\_pymnt\_d"   
## [51] "last\_credit\_pull\_d"   
## [52] "last\_fico\_range\_high"   
## [53] "last\_fico\_range\_low"   
## [54] "collections\_12\_mths\_ex\_med"   
## [55] "mths\_since\_last\_major\_derog"   
## [56] "policy\_code"   
## [57] "application\_type"   
## [58] "annual\_inc\_joint"   
## [59] "dti\_joint"   
## [60] "verification\_status\_joint"   
## [61] "acc\_now\_delinq"   
## [62] "tot\_coll\_amt"   
## [63] "tot\_cur\_bal"   
## [64] "open\_acc\_6m"   
## [65] "open\_act\_il"   
## [66] "open\_il\_12m"   
## [67] "open\_il\_24m"   
## [68] "mths\_since\_rcnt\_il"   
## [69] "total\_bal\_il"   
## [70] "il\_util"   
## [71] "open\_rv\_12m"   
## [72] "open\_rv\_24m"   
## [73] "max\_bal\_bc"   
## [74] "all\_util"   
## [75] "total\_rev\_hi\_lim"   
## [76] "inq\_fi"   
## [77] "total\_cu\_tl"   
## [78] "inq\_last\_12m"   
## [79] "acc\_open\_past\_24mths"   
## [80] "avg\_cur\_bal"   
## [81] "bc\_open\_to\_buy"   
## [82] "bc\_util"   
## [83] "chargeoff\_within\_12\_mths"   
## [84] "delinq\_amnt"   
## [85] "mo\_sin\_old\_il\_acct"   
## [86] "mo\_sin\_old\_rev\_tl\_op"   
## [87] "mo\_sin\_rcnt\_rev\_tl\_op"   
## [88] "mo\_sin\_rcnt\_tl"   
## [89] "mort\_acc"   
## [90] "mths\_since\_recent\_bc"   
## [91] "mths\_since\_recent\_bc\_dlq"   
## [92] "mths\_since\_recent\_inq"   
## [93] "mths\_since\_recent\_revol\_delinq"   
## [94] "num\_accts\_ever\_120\_pd"   
## [95] "num\_actv\_bc\_tl"   
## [96] "num\_actv\_rev\_tl"   
## [97] "num\_bc\_sats"   
## [98] "num\_bc\_tl"   
## [99] "num\_il\_tl"   
## [100] "num\_op\_rev\_tl"   
## [101] "num\_rev\_accts"   
## [102] "num\_rev\_tl\_bal\_gt\_0"   
## [103] "num\_sats"   
## [104] "num\_tl\_120dpd\_2m"   
## [105] "num\_tl\_30dpd"   
## [106] "num\_tl\_90g\_dpd\_24m"   
## [107] "num\_tl\_op\_past\_12m"   
## [108] "pct\_tl\_nvr\_dlq"   
## [109] "percent\_bc\_gt\_75"   
## [110] "pub\_rec\_bankruptcies"   
## [111] "tax\_liens"   
## [112] "tot\_hi\_cred\_lim"   
## [113] "total\_bal\_ex\_mort"   
## [114] "total\_bc\_limit"   
## [115] "total\_il\_high\_credit\_limit"   
## [116] "revol\_bal\_joint"   
## [117] "sec\_app\_fico\_range\_low"   
## [118] "sec\_app\_fico\_range\_high"   
## [119] "sec\_app\_earliest\_cr\_line"   
## [120] "sec\_app\_inq\_last\_6mths"   
## [121] "sec\_app\_mort\_acc"   
## [122] "sec\_app\_open\_acc"   
## [123] "sec\_app\_revol\_util"   
## [124] "sec\_app\_open\_act\_il"   
## [125] "sec\_app\_num\_rev\_accts"   
## [126] "sec\_app\_chargeoff\_within\_12\_mths"   
## [127] "sec\_app\_collections\_12\_mths\_ex\_med"   
## [128] "sec\_app\_mths\_since\_last\_major\_derog"   
## [129] "hardship\_flag"   
## [130] "hardship\_type"   
## [131] "hardship\_reason"   
## [132] "hardship\_status"   
## [133] "deferral\_term"   
## [134] "hardship\_amount"   
## [135] "hardship\_start\_date"   
## [136] "hardship\_end\_date"   
## [137] "payment\_plan\_start\_date"   
## [138] "hardship\_length"   
## [139] "hardship\_dpd"   
## [140] "hardship\_loan\_status"   
## [141] "orig\_projected\_additional\_accrued\_interest"  
## [142] "hardship\_payoff\_balance\_amount"   
## [143] "hardship\_last\_payment\_amount"   
## [144] "disbursement\_method"   
## [145] "debt\_settlement\_flag"   
## [146] "debt\_settlement\_flag\_date"   
## [147] "settlement\_status"   
## [148] "settlement\_date"   
## [149] "settlement\_amount"   
## [150] "settlement\_percentage"   
## [151] "settlement\_term"   
## [152] "orig\_year"

Summary of all the varibales in the dataset

summary(final\_dataset)

## id member\_id loan\_amnt funded\_amnt   
## Min. : 70102325 Mode:logical Min. : 1000 Min. : 1000   
## 1st Qu.:131267288 NA's:495242 1st Qu.: 8000 1st Qu.: 8000   
## Median :136195162 Median :14000 Median :14000   
## Mean :136087208 Mean :16025 Mean :16025   
## 3rd Qu.:141042201 3rd Qu.:22000 3rd Qu.:22000   
## Max. :145647287 Max. :40000 Max. :40000   
##   
## funded\_amnt\_inv term int\_rate installment   
## Min. : 725 Length:495242 Min. : 5.31 Min. : 29.76   
## 1st Qu.: 8000 Class :character 1st Qu.: 8.46 1st Qu.: 254.56   
## Median :14000 Mode :character Median :11.80 Median : 386.82   
## Mean :16022 Mean :12.73 Mean : 466.61   
## 3rd Qu.:22000 3rd Qu.:16.01 3rd Qu.: 629.04   
## Max. :40000 Max. :30.99 Max. :1670.15   
##   
## grade sub\_grade emp\_title emp\_length   
## Length:495242 Length:495242 Length:495242 Length:495242   
## Class :character Class :character Class :character Class :character   
## Mode :character Mode :character Mode :character Mode :character   
##   
##   
##   
##   
## home\_ownership annual\_inc verification\_status issue\_d   
## Length:495242 Min. : 0 Length:495242 Length:495242   
## Class :character 1st Qu.: 46000 Class :character Class :character   
## Mode :character Median : 66000 Mode :character Mode :character   
## Mean : 80094   
## 3rd Qu.: 96000   
## Max. :9930475   
##   
## loan\_status pymnt\_plan url desc   
## Length:495242 Length:495242 Length:495242 Mode:logical   
## Class :character Class :character Class :character NA's:495242   
## Mode :character Mode :character Mode :character   
##   
##   
##   
##   
## purpose title zip\_code addr\_state   
## Length:495242 Length:495242 Length:495242 Length:495242   
## Class :character Class :character Class :character Class :character   
## Mode :character Mode :character Mode :character Mode :character   
##   
##   
##   
##   
## dti delinq\_2yrs earliest\_cr\_line fico\_range\_low   
## Min. : 0.00 Min. : 0.0000 Length:495242 Min. :660.0   
## 1st Qu.: 11.43 1st Qu.: 0.0000 Class :character 1st Qu.:680.0   
## Median : 17.71 Median : 0.0000 Mode :character Median :700.0   
## Mean : 19.67 Mean : 0.2293 Mean :706.4   
## 3rd Qu.: 25.03 3rd Qu.: 0.0000 3rd Qu.:725.0   
## Max. :999.00 Max. :58.0000 Max. :845.0   
## NA's :1132   
## fico\_range\_high inq\_last\_6mths mths\_since\_last\_delinq mths\_since\_last\_record  
## Min. :664.0 Min. :0.0000 Min. : 0.00 Min. : 1.0   
## 1st Qu.:684.0 1st Qu.:0.0000 1st Qu.: 19.00 1st Qu.: 69.0   
## Median :704.0 Median :0.0000 Median : 34.00 Median : 87.0   
## Mean :710.4 Mean :0.4422 Mean : 36.89 Mean : 83.3   
## 3rd Qu.:729.0 3rd Qu.:1.0000 3rd Qu.: 53.00 3rd Qu.:102.0   
## Max. :850.0 Max. :5.0000 Max. :226.00 Max. :127.0   
## NA's :276652 NA's :432258   
## open\_acc pub\_rec revol\_bal revol\_util   
## Min. : 0.00 Min. : 0.0000 Min. : 0 Min. : 0.00   
## 1st Qu.: 7.00 1st Qu.: 0.0000 1st Qu.: 5304 1st Qu.: 24.20   
## Median : 10.00 Median : 0.0000 Median : 10832 Median : 42.10   
## Mean : 11.49 Mean : 0.1345 Mean : 16271 Mean : 43.88   
## 3rd Qu.: 14.00 3rd Qu.: 0.0000 3rd Qu.: 19867 3rd Qu.: 62.30   
## Max. :101.00 Max. :52.0000 Max. :2358150 Max. :191.00   
## NA's :592   
## total\_acc initial\_list\_status out\_prncp out\_prncp\_inv   
## Min. : 2.00 Length:495242 Min. : 0 Min. : 0   
## 1st Qu.: 14.00 Class :character 1st Qu.: 4623 1st Qu.: 4622   
## Median : 21.00 Mode :character Median : 9742 Median : 9739   
## Mean : 22.62 Mean :12007 Mean :12005   
## 3rd Qu.: 29.00 3rd Qu.:17801 3rd Qu.:17801   
## Max. :160.00 Max. :40000 Max. :40000   
##   
## total\_pymnt total\_pymnt\_inv total\_rec\_prncp total\_rec\_int   
## Min. : 0 Min. : 0 Min. : 0 Min. : 0.0   
## 1st Qu.: 1758 1st Qu.: 1758 1st Qu.: 1115 1st Qu.: 401.6   
## Median : 3221 Median : 3221 Median : 2075 Median : 814.7   
## Mean : 4925 Mean : 4924 Mean : 3735 Mean : 1179.6   
## 3rd Qu.: 5909 3rd Qu.: 5908 3rd Qu.: 4000 3rd Qu.: 1575.2   
## Max. :51653 Max. :51653 Max. :40000 Max. :12795.0   
##   
## total\_rec\_late\_fee recoveries collection\_recovery\_fee  
## Min. : 0.0000 Min. : 0.00 Min. : 0.000   
## 1st Qu.: 0.0000 1st Qu.: 0.00 1st Qu.: 0.000   
## Median : 0.0000 Median : 0.00 Median : 0.000   
## Mean : 0.5128 Mean : 9.94 Mean : 1.748   
## 3rd Qu.: 0.0000 3rd Qu.: 0.00 3rd Qu.: 0.000   
## Max. :458.5700 Max. :33122.07 Max. :5961.973   
##   
## last\_pymnt\_d last\_pymnt\_amnt next\_pymnt\_d last\_credit\_pull\_d  
## Length:495242 Min. : 0.0 Length:495242 Length:495242   
## Class :character 1st Qu.: 270.7 Class :character Class :character   
## Mode :character Median : 436.9 Mode :character Mode :character   
## Mean : 1599.8   
## 3rd Qu.: 747.9   
## Max. :41353.7   
##   
## last\_fico\_range\_high last\_fico\_range\_low collections\_12\_mths\_ex\_med  
## Min. : 0.0 Min. : 0.0 Min. :0.00000   
## 1st Qu.:679.0 1st Qu.:675.0 1st Qu.:0.00000   
## Median :709.0 Median :705.0 Median :0.00000   
## Mean :709.4 Mean :703.7 Mean :0.01768   
## 3rd Qu.:744.0 3rd Qu.:740.0 3rd Qu.:0.00000   
## Max. :850.0 Max. :845.0 Max. :9.00000   
##   
## mths\_since\_last\_major\_derog policy\_code application\_type annual\_inc\_joint   
## Min. : 0.0 Min. :1 Length:495242 Min. : 5694   
## 1st Qu.: 29.0 1st Qu.:1 Class :character 1st Qu.: 85000   
## Median : 46.0 Median :1 Mode :character Median : 114000   
## Mean : 46.3 Mean :1 Mean : 128342   
## 3rd Qu.: 64.0 3rd Qu.:1 3rd Qu.: 152000   
## Max. :226.0 Max. :1 Max. :7874821   
## NA's :380409 NA's :426257   
## dti\_joint verification\_status\_joint acc\_now\_delinq   
## Min. : 0.0 Length:495242 Min. :0.00e+00   
## 1st Qu.:13.4 Class :character 1st Qu.:0.00e+00   
## Median :18.9 Mode :character Median :0.00e+00   
## Mean :19.4 Mean :5.25e-05   
## 3rd Qu.:25.0 3rd Qu.:0.00e+00   
## Max. :40.0 Max. :1.00e+00   
## NA's :426257   
## tot\_coll\_amt tot\_cur\_bal open\_acc\_6m open\_act\_il   
## Min. : 0 Min. : 0 Min. : 0.0000 Min. : 0.000   
## 1st Qu.: 0 1st Qu.: 26885 1st Qu.: 0.0000 1st Qu.: 1.000   
## Median : 0 Median : 74550 Median : 1.0000 Median : 2.000   
## Mean : 214 Mean : 143960 Mean : 0.8981 Mean : 2.701   
## 3rd Qu.: 0 3rd Qu.: 218044 3rd Qu.: 1.0000 3rd Qu.: 3.000   
## Max. :6214661 Max. :9971659 Max. :15.0000 Max. :56.000   
##   
## open\_il\_12m open\_il\_24m mths\_since\_rcnt\_il total\_bal\_il   
## Min. :0.0000 Min. : 0.000 Min. : 0.0 Min. : 0   
## 1st Qu.:0.0000 1st Qu.: 0.000 1st Qu.: 7.0 1st Qu.: 7851   
## Median :0.0000 Median : 1.000 Median : 13.0 Median : 22452   
## Mean :0.6729 Mean : 1.527 Mean : 21.1 Mean : 35324   
## 3rd Qu.:1.0000 3rd Qu.: 2.000 3rd Qu.: 25.0 3rd Qu.: 45845   
## Max. :8.0000 Max. :20.000 Max. :507.0 Max. :1837038   
## NA's :18410   
## il\_util open\_rv\_12m open\_rv\_24m max\_bal\_bc   
## Min. : 0 Min. : 0.000 Min. : 0.000 Min. : 0   
## 1st Qu.: 53 1st Qu.: 0.000 1st Qu.: 1.000 1st Qu.: 2183   
## Median : 71 Median : 1.000 Median : 2.000 Median : 4441   
## Mean : 68 Mean : 1.228 Mean : 2.624 Mean : 5863   
## 3rd Qu.: 85 3rd Qu.: 2.000 3rd Qu.: 4.000 3rd Qu.: 7772   
## Max. :1000 Max. :26.000 Max. :50.000 Max. :1170668   
## NA's :80824   
## all\_util total\_rev\_hi\_lim inq\_fi total\_cu\_tl   
## Min. : 0.00 Min. : 0 Min. : 0.000 Min. : 0.000   
## 1st Qu.: 40.00 1st Qu.: 16200 1st Qu.: 0.000 1st Qu.: 0.000   
## Median : 55.00 Median : 28700 Median : 1.000 Median : 0.000   
## Mean : 54.09 Mean : 38345 Mean : 1.087 Mean : 1.485   
## 3rd Qu.: 69.00 3rd Qu.: 48700 3rd Qu.: 2.000 3rd Qu.: 2.000   
## Max. :239.00 Max. :2087500 Max. :38.000 Max. :68.000   
## NA's :129   
## inq\_last\_12m acc\_open\_past\_24mths avg\_cur\_bal bc\_open\_to\_buy   
## Min. : 0.000 Min. : 0.000 Min. : 0 Min. : 0   
## 1st Qu.: 0.000 1st Qu.: 2.000 1st Qu.: 2904 1st Qu.: 2867   
## Median : 1.000 Median : 4.000 Median : 7033 Median : 8301   
## Mean : 1.937 Mean : 4.427 Mean : 13709 Mean : 15057   
## 3rd Qu.: 3.000 3rd Qu.: 6.000 3rd Qu.: 19031 3rd Qu.: 19694   
## Max. :67.000 Max. :54.000 Max. :623229 Max. :605996   
## NA's :40 NA's :6588   
## bc\_util chargeoff\_within\_12\_mths delinq\_amnt   
## Min. : 0.00 Min. :0.000000 Min. : 0.00   
## 1st Qu.: 25.95 1st Qu.:0.000000 1st Qu.: 0.00   
## Median : 48.80 Median :0.000000 Median : 0.00   
## Mean : 49.87 Mean :0.006823 Mean : 1.79   
## 3rd Qu.: 74.40 3rd Qu.:0.000000 3rd Qu.: 0.00   
## Max. :201.60 Max. :9.000000 Max. :65000.00   
## NA's :6803   
## mo\_sin\_old\_il\_acct mo\_sin\_old\_rev\_tl\_op mo\_sin\_rcnt\_rev\_tl\_op  
## Min. : 0 Min. : 1.0 Min. : 0.00   
## 1st Qu.: 85 1st Qu.:102.0 1st Qu.: 4.00   
## Median :129 Median :156.0 Median : 9.00   
## Mean :123 Mean :174.6 Mean : 15.13   
## 3rd Qu.:155 3rd Qu.:226.0 3rd Qu.: 19.00   
## Max. :848 Max. :826.0 Max. :502.00   
## NA's :18410   
## mo\_sin\_rcnt\_tl mort\_acc mths\_since\_recent\_bc  
## Min. : 0.000 Min. : 0.000 Min. : 0.00   
## 1st Qu.: 3.000 1st Qu.: 0.000 1st Qu.: 6.00   
## Median : 6.000 Median : 1.000 Median : 15.00   
## Mean : 8.719 Mean : 1.336 Mean : 25.55   
## 3rd Qu.: 11.000 3rd Qu.: 2.000 3rd Qu.: 30.00   
## Max. :382.000 Max. :87.000 Max. :661.00   
## NA's :6198   
## mths\_since\_recent\_bc\_dlq mths\_since\_recent\_inq mths\_since\_recent\_revol\_delinq  
## Min. : 0.0 Min. : 0.00 Min. : 0.0   
## 1st Qu.: 23.0 1st Qu.: 2.00 1st Qu.: 20.0   
## Median : 38.0 Median : 6.00 Median : 35.0   
## Mean : 40.5 Mean : 7.49 Mean : 37.8   
## 3rd Qu.: 57.0 3rd Qu.:11.00 3rd Qu.: 53.0   
## Max. :194.0 Max. :25.00 Max. :190.0   
## NA's :397132 NA's :61305 NA's :352552   
## num\_accts\_ever\_120\_pd num\_actv\_bc\_tl num\_actv\_rev\_tl num\_bc\_sats   
## Min. : 0.0000 Min. : 0.000 Min. : 0.000 Min. : 0.00   
## 1st Qu.: 0.0000 1st Qu.: 2.000 1st Qu.: 3.000 1st Qu.: 3.00   
## Median : 0.0000 Median : 3.000 Median : 5.000 Median : 4.00   
## Mean : 0.4679 Mean : 3.614 Mean : 5.362 Mean : 4.84   
## 3rd Qu.: 0.0000 3rd Qu.: 5.000 3rd Qu.: 7.000 3rd Qu.: 6.00   
## Max. :58.0000 Max. :50.000 Max. :72.000 Max. :69.00   
##   
## num\_bc\_tl num\_il\_tl num\_op\_rev\_tl num\_rev\_accts   
## Min. : 0.000 Min. : 0.000 Min. : 0.000 Min. : 2.00   
## 1st Qu.: 4.000 1st Qu.: 3.000 1st Qu.: 5.000 1st Qu.: 7.00   
## Median : 6.000 Median : 6.000 Median : 7.000 Median : 11.00   
## Mean : 7.093 Mean : 8.169 Mean : 8.163 Mean : 12.92   
## 3rd Qu.: 9.000 3rd Qu.: 11.000 3rd Qu.:10.000 3rd Qu.: 17.00   
## Max. :86.000 Max. :130.000 Max. :91.000 Max. :151.00   
##   
## num\_rev\_tl\_bal\_gt\_0 num\_sats num\_tl\_120dpd\_2m num\_tl\_30dpd   
## Min. : 0.000 Min. : 0.00 Min. :0 Min. :0.00e+00   
## 1st Qu.: 3.000 1st Qu.: 7.00 1st Qu.:0 1st Qu.:0.00e+00   
## Median : 5.000 Median : 10.00 Median :0 Median :0.00e+00   
## Mean : 5.325 Mean : 11.47 Mean :0 Mean :4.64e-05   
## 3rd Qu.: 7.000 3rd Qu.: 14.00 3rd Qu.:0 3rd Qu.:0.00e+00   
## Max. :65.000 Max. :101.00 Max. :0 Max. :1.00e+00   
## NA's :12404   
## num\_tl\_90g\_dpd\_24m num\_tl\_op\_past\_12m pct\_tl\_nvr\_dlq percent\_bc\_gt\_75  
## Min. : 0.00000 Min. : 0.00 Min. : 0.00 Min. : 0.00   
## 1st Qu.: 0.00000 1st Qu.: 1.00 1st Qu.: 92.30 1st Qu.: 0.00   
## Median : 0.00000 Median : 2.00 Median :100.00 Median : 25.00   
## Mean : 0.05993 Mean : 2.03 Mean : 94.58 Mean : 32.89   
## 3rd Qu.: 0.00000 3rd Qu.: 3.00 3rd Qu.:100.00 3rd Qu.: 57.10   
## Max. :58.00000 Max. :26.00 Max. :100.00 Max. :100.00   
## NA's :2 NA's :6596   
## pub\_rec\_bankruptcies tax\_liens tot\_hi\_cred\_lim total\_bal\_ex\_mort  
## Min. :0.0000 Min. : 0.00000 Min. : 0 Min. : 0   
## 1st Qu.:0.0000 1st Qu.: 0.00000 1st Qu.: 52059 1st Qu.: 19530   
## Median :0.0000 Median : 0.00000 Median : 116292 Median : 37556   
## Mean :0.1235 Mean : 0.01092 Mean : 184942 Mean : 51922   
## 3rd Qu.:0.0000 3rd Qu.: 0.00000 3rd Qu.: 269292 3rd Qu.: 66119   
## Max. :7.0000 Max. :52.00000 Max. :9999999 Max. :2622906   
##   
## total\_bc\_limit total\_il\_high\_credit\_limit revol\_bal\_joint   
## Min. : 0 Min. : 0 Min. : 0   
## 1st Qu.: 9800 1st Qu.: 14926 1st Qu.: 15477   
## Median : 19200 Median : 33754 Median : 27350   
## Mean : 26680 Mean : 45688 Mean : 34757   
## 3rd Qu.: 35200 3rd Qu.: 61914 3rd Qu.: 45215   
## Max. :1569000 Max. :2118996 Max. :1110019   
## NA's :426257   
## sec\_app\_fico\_range\_low sec\_app\_fico\_range\_high sec\_app\_earliest\_cr\_line  
## Min. :540.0 Min. :544.0 Length:495242   
## 1st Qu.:645.0 1st Qu.:649.0 Class :character   
## Median :670.0 Median :674.0 Mode :character   
## Mean :671.8 Mean :675.8   
## 3rd Qu.:700.0 3rd Qu.:704.0   
## Max. :845.0 Max. :850.0   
## NA's :426257 NA's :426257   
## sec\_app\_inq\_last\_6mths sec\_app\_mort\_acc sec\_app\_open\_acc sec\_app\_revol\_util  
## Min. :0.0 Min. : 0.0 Min. : 0.0 Min. : 0.0   
## 1st Qu.:0.0 1st Qu.: 0.0 1st Qu.: 7.0 1st Qu.: 38.3   
## Median :0.0 Median : 1.0 Median :10.0 Median : 59.1   
## Mean :0.6 Mean : 1.5 Mean :11.5 Mean : 57.1   
## 3rd Qu.:1.0 3rd Qu.: 2.0 3rd Qu.:15.0 3rd Qu.: 77.8   
## Max. :6.0 Max. :27.0 Max. :67.0 Max. :434.3   
## NA's :426257 NA's :426257 NA's :426257 NA's :427454   
## sec\_app\_open\_act\_il sec\_app\_num\_rev\_accts sec\_app\_chargeoff\_within\_12\_mths  
## Min. : 0 Min. : 0.0 Min. : 0   
## 1st Qu.: 1 1st Qu.: 7.0 1st Qu.: 0   
## Median : 2 Median : 11.0 Median : 0   
## Mean : 3 Mean : 12.5 Mean : 0   
## 3rd Qu.: 4 3rd Qu.: 17.0 3rd Qu.: 0   
## Max. :43 Max. :106.0 Max. :21   
## NA's :426257 NA's :426257 NA's :426257   
## sec\_app\_collections\_12\_mths\_ex\_med sec\_app\_mths\_since\_last\_major\_derog  
## Min. : 0.0 Min. : 0.0   
## 1st Qu.: 0.0 1st Qu.: 17.0   
## Median : 0.0 Median : 36.0   
## Mean : 0.1 Mean : 37.3   
## 3rd Qu.: 0.0 3rd Qu.: 57.0   
## Max. :23.0 Max. :185.0   
## NA's :426257 NA's :472865   
## hardship\_flag hardship\_type hardship\_reason hardship\_status   
## Length:495242 Length:495242 Length:495242 Length:495242   
## Class :character Class :character Class :character Class :character   
## Mode :character Mode :character Mode :character Mode :character   
##   
##   
##   
##   
## deferral\_term hardship\_amount hardship\_start\_date hardship\_end\_date   
## Min. :3 Min. : 6.0 Length:495242 Length:495242   
## 1st Qu.:3 1st Qu.: 87.4 Class :character Class :character   
## Median :3 Median :160.1 Mode :character Mode :character   
## Mean :3 Mean :196.1   
## 3rd Qu.:3 3rd Qu.:271.9   
## Max. :3 Max. :845.2   
## NA's :494874 NA's :494874   
## payment\_plan\_start\_date hardship\_length hardship\_dpd hardship\_loan\_status  
## Length:495242 Min. :3 Min. : 0.0 Length:495242   
## Class :character 1st Qu.:3 1st Qu.: 5.0 Class :character   
## Mode :character Median :3 Median :13.0 Mode :character   
## Mean :3 Mean :12.8   
## 3rd Qu.:3 3rd Qu.:20.0   
## Max. :3 Max. :29.0   
## NA's :494874 NA's :494874   
## orig\_projected\_additional\_accrued\_interest hardship\_payoff\_balance\_amount  
## Min. : 31.5 Min. : 424.1   
## 1st Qu.: 258.7 1st Qu.: 7966.5   
## Median : 479.8 Median :13323.6   
## Mean : 595.4 Mean :15633.3   
## 3rd Qu.: 819.9 3rd Qu.:22590.2   
## Max. :2535.7 Max. :40149.3   
## NA's :494921 NA's :494874   
## hardship\_last\_payment\_amount disbursement\_method debt\_settlement\_flag  
## Min. : 0.1 Length:495242 Length:495242   
## 1st Qu.: 50.9 Class :character Class :character   
## Median : 153.2 Mode :character Mode :character   
## Mean : 215.7   
## 3rd Qu.: 327.4   
## Max. :1159.6   
## NA's :494874   
## debt\_settlement\_flag\_date settlement\_status settlement\_date   
## Length:495242 Length:495242 Length:495242   
## Class :character Class :character Class :character   
## Mode :character Mode :character Mode :character   
##   
##   
##   
##   
## settlement\_amount settlement\_percentage settlement\_term orig\_year   
## Min. : 413.9 Min. :29.9 Min. : 1 Min. :2018   
## 1st Qu.: 3367.1 1st Qu.:45.0 1st Qu.:17 1st Qu.:2018   
## Median : 5626.1 Median :55.0 Median :18 Median :2018   
## Mean : 7145.7 Mean :54.6 Mean :18 Mean :2018   
## 3rd Qu.: 9761.5 3rd Qu.:65.0 3rd Qu.:24 3rd Qu.:2018   
## Max. :28503.0 Max. :80.0 Max. :24 Max. :2018   
## NA's :494762 NA's :494762 NA's :494762

## Variable Selection

1. Dataset contains lot of variables, some of these varibales are associated with secondary applicant, so excluding those variables. Some other varibales contian lot of NA values so dropped those variables

ds\_lc <- final\_dataset[,c("loan\_amnt",  
 "funded\_amnt",  
 "funded\_amnt\_inv",  
 "term",  
 "int\_rate",  
 "installment",  
 "grade",  
 "sub\_grade",  
 "home\_ownership",  
 "annual\_inc",  
 "loan\_status",  
 "dti",  
 "delinq\_2yrs",  
 "fico\_range\_low",  
 "fico\_range\_high",  
 "inq\_last\_6mths",  
 "mths\_since\_last\_delinq",  
 "mths\_since\_last\_record",  
 "open\_acc",  
 "pub\_rec",  
 "revol\_bal",  
 "revol\_util",  
 "total\_acc",  
 "out\_prncp",  
 "out\_prncp\_inv",  
 "total\_pymnt",  
 "total\_pymnt\_inv",  
 "total\_rec\_prncp",  
 "total\_rec\_int",  
 "total\_rec\_late\_fee",  
 "recoveries",  
 "collection\_recovery\_fee",  
 "last\_fico\_range\_high",  
 "last\_fico\_range\_low",  
 "mths\_since\_last\_major\_derog",  
 "acc\_now\_delinq",  
 "avg\_cur\_bal",  
 "inq\_last\_12m", "num\_tl\_30dpd", "num\_tl\_90g\_dpd\_24m", "tot\_hi\_cred\_lim", "num\_rev\_accts"  
 )]

## Clean up the datset

1. convert all categorical variables to factors
2. Remove the NA values
3. Convert variables to numeric or integer
4. Create a delinquent account flag, loan account becomes deliquent when loan status turns to either of the following (is\_acct\_delinquent = 1) a. Late (16-30 days) b. Late (31-120 days) c. Charged Off d. Default e. In Grace Period

Loan status with following is one which is not delinquent (is\_acct\_delinquent = 0)  
a. Current  
b. Fully Paid

nrow(ds\_lc)

## [1] 495242

ds\_lc <- na.omit(ds\_lc, cols = c("dti", "int\_rate"))  
nrow(ds\_lc)

## [1] 494110

levels(factor(ds\_lc$loan\_status))

## [1] "Charged Off" "Current" "Default"   
## [4] "Fully Paid" "In Grace Period" "Late (16-30 days)"   
## [7] "Late (31-120 days)"

levels(factor(ds\_lc$grade))

## [1] "A" "B" "C" "D" "E" "F" "G"

levels(factor(ds\_lc$sub\_grade))

## [1] "A1" "A2" "A3" "A4" "A5" "B1" "B2" "B3" "B4" "B5" "C1" "C2" "C3" "C4" "C5"  
## [16] "D1" "D2" "D3" "D4" "D5" "E1" "E2" "E3" "E4" "E5" "F1" "F2" "F3" "F4" "F5"  
## [31] "G1" "G2" "G3" "G4" "G5"

levels(factor(ds\_lc$home\_ownership))

## [1] "ANY" "MORTGAGE" "OWN" "RENT"

ds\_lc$term <- as.integer(as.factor(ds\_lc$term))   
ds\_lc$grade <- as.integer(as.factor(ds\_lc$grade))  
ds\_lc$sub\_grade <- as.integer(as.factor(ds\_lc$sub\_grade))  
ds\_lc$home\_ownership <- as.integer(as.factor(ds\_lc$home\_ownership))  
ds\_lc$int\_rate <- as.numeric(ds\_lc$int\_rate)  
ds\_lc$loan\_status <- as.integer(as.factor(ds\_lc$loan\_status))  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 1] <- 1  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 2] <- 0  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 3] <- 1  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 4] <- 0  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 5] <- 1  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 6] <- 0  
#ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 7] <- 1  
#ds\_lc$is\_acct\_delinquent <- factor(ds\_lc$is\_acct\_delinquent)  
#levels(factor(ds\_lc$is\_acct\_delinquent))  
#ds\_lc = subset(ds\_lc, select = -c(loan\_status))

cor(ds\_lc)

## loan\_amnt funded\_amnt funded\_amnt\_inv  
## loan\_amnt 1.000000000 1.000000000 0.999996431  
## funded\_amnt 1.000000000 1.000000000 0.999996431  
## funded\_amnt\_inv 0.999996431 0.999996431 1.000000000  
## term 0.382920212 0.382920212 0.383125468  
## int\_rate 0.003852733 0.003852733 0.003953011  
## installment 0.943022509 0.943022509 0.942953979  
## grade 0.007639237 0.007639237 0.007730099  
## sub\_grade 0.003261095 0.003261095 0.003355532  
## home\_ownership -0.156677785 -0.156677785 -0.156718890  
## annual\_inc 0.235938716 0.235938716 0.235942416  
## loan\_status -0.016390465 -0.016390465 -0.016388719  
## dti 0.046349677 0.046349677 0.046348146  
## delinq\_2yrs -0.017199481 -0.017199481 -0.017220019  
## fico\_range\_low 0.098274031 0.098274031 0.098349805  
## fico\_range\_high 0.098272857 0.098272857 0.098348632  
## inq\_last\_6mths -0.016122851 -0.016122851 -0.016150955  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 0.167820213 0.167820213 0.167804824  
## pub\_rec -0.043718920 -0.043718920 -0.043755256  
## revol\_bal 0.303135377 0.303135377 0.303138333  
## revol\_util NA NA NA  
## total\_acc 0.182344359 0.182344359 0.182336495  
## out\_prncp 0.833688171 0.833688171 0.833726070  
## out\_prncp\_inv 0.833696709 0.833696709 0.833739941  
## total\_pymnt 0.503599930 0.503599930 0.503532033  
## total\_pymnt\_inv 0.503657020 0.503657020 0.503593731  
## total\_rec\_prncp 0.394606358 0.394606358 0.394529897  
## total\_rec\_int 0.651241262 0.651241262 0.651258290  
## total\_rec\_late\_fee 0.049554213 0.049554213 0.049548150  
## recoveries 0.039263939 0.039263939 0.039277142  
## collection\_recovery\_fee 0.039122821 0.039122821 0.039135789  
## last\_fico\_range\_high 0.139337824 0.139337824 0.139370350  
## last\_fico\_range\_low 0.112018908 0.112018908 0.112043035  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 0.002585038 0.002585038 0.002587481  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 0.014312391 0.014312391 0.014294214  
## num\_tl\_30dpd 0.002281560 0.002281560 0.002283855  
## num\_tl\_90g\_dpd\_24m -0.019319259 -0.019319259 -0.019334430  
## tot\_hi\_cred\_lim 0.306986363 0.306986363 0.307018054  
## num\_rev\_accts 0.151574978 0.151574978 0.151552012  
## term int\_rate installment grade  
## loan\_amnt 0.382920212 0.003852733 0.943022509 0.007639237  
## funded\_amnt 0.382920212 0.003852733 0.943022509 0.007639237  
## funded\_amnt\_inv 0.383125468 0.003953011 0.942953979 0.007730099  
## term 1.000000000 0.315873119 0.126833134 0.317162573  
## int\_rate 0.315873119 1.000000000 0.045627846 0.970650942  
## installment 0.126833134 0.045627846 1.000000000 0.043225133  
## grade 0.317162573 0.970650942 0.043225133 1.000000000  
## sub\_grade 0.319772499 0.991921262 0.041078723 0.971497931  
## home\_ownership -0.105698102 0.076672572 -0.121842351 0.073167063  
## annual\_inc 0.038244945 -0.063022576 0.230372246 -0.061654515  
## loan\_status -0.012869648 0.066049488 -0.003936516 0.070778493  
## dti 0.042599609 0.108866984 0.052845661 0.104493955  
## delinq\_2yrs -0.018733536 0.104924407 0.002580986 0.105277093  
## fico\_range\_low 0.026621452 -0.444131200 0.031200628 -0.445972966  
## fico\_range\_high 0.026620931 -0.444125375 0.031200221 -0.445966261  
## inq\_last\_6mths 0.004523212 0.118095260 -0.002392947 0.116427626  
## mths\_since\_last\_delinq NA NA NA NA  
## mths\_since\_last\_record NA NA NA NA  
## open\_acc 0.065090967 -0.021399766 0.158881395 -0.021914670  
## pub\_rec 0.001024193 0.042710237 -0.037138644 0.048914936  
## revol\_bal 0.074986410 -0.021959008 0.294927862 -0.021542199  
## revol\_util NA NA NA NA  
## total\_acc 0.088376674 -0.044985807 0.160721339 -0.043563239  
## out\_prncp 0.400473074 0.022804997 0.755170398 0.015454447  
## out\_prncp\_inv 0.400625130 0.022877332 0.755132050 0.015522361  
## total\_pymnt 0.086325134 0.016828958 0.525196558 0.037658206  
## total\_pymnt\_inv 0.086475063 0.016900280 0.525211385 0.037722080  
## total\_rec\_prncp -0.004656810 -0.072107643 0.424086743 -0.052744615  
## total\_rec\_int 0.442989252 0.410399237 0.621183739 0.423245590  
## total\_rec\_late\_fee 0.010277979 0.049057407 0.059775068 0.050555783  
## recoveries 0.032448532 0.043509232 0.038725644 0.044924543  
## collection\_recovery\_fee 0.032263467 0.042321929 0.038341875 0.043776267  
## last\_fico\_range\_high 0.021666730 -0.405871937 0.087427902 -0.409761571  
## last\_fico\_range\_low 0.015103595 -0.343083135 0.068997809 -0.346999768  
## mths\_since\_last\_major\_derog NA NA NA NA  
## acc\_now\_delinq 0.004308905 0.003262334 0.001811403 0.003391450  
## avg\_cur\_bal NA NA NA NA  
## inq\_last\_12m 0.034148361 0.123783615 0.021788226 0.122993832  
## num\_tl\_30dpd 0.003879019 0.003342816 0.001693180 0.003411623  
## num\_tl\_90g\_dpd\_24m -0.009061182 0.053309127 -0.010692559 0.054599713  
## tot\_hi\_cred\_lim 0.106249415 -0.118911443 0.272687554 -0.116377823  
## num\_rev\_accts 0.044782512 -0.070099920 0.140900805 -0.067119423  
## sub\_grade home\_ownership annual\_inc  
## loan\_amnt 0.003261095 -0.156677785 0.2359387158  
## funded\_amnt 0.003261095 -0.156677785 0.2359387158  
## funded\_amnt\_inv 0.003355532 -0.156718890 0.2359424163  
## term 0.319772499 -0.105698102 0.0382449454  
## int\_rate 0.991921262 0.076672572 -0.0630225764  
## installment 0.041078723 -0.121842351 0.2303722461  
## grade 0.971497931 0.073167063 -0.0616545152  
## sub\_grade 1.000000000 0.080295606 -0.0671319853  
## home\_ownership 0.080295606 1.000000000 -0.1184635377  
## annual\_inc -0.067131985 -0.118463538 1.0000000000  
## loan\_status 0.073515991 -0.013121088 0.0009358584  
## dti 0.109993559 -0.051518077 -0.1052857082  
## delinq\_2yrs 0.108261874 -0.050270263 0.0413779496  
## fico\_range\_low -0.460446298 -0.095890360 0.0180188910  
## fico\_range\_high -0.460440587 -0.095892682 0.0180185365  
## inq\_last\_6mths 0.122450351 -0.022157249 0.0346032241  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc -0.023157065 -0.153695856 0.1435176618  
## pub\_rec 0.047855284 -0.010093267 -0.0122393305  
## revol\_bal -0.025138176 -0.161546851 0.2655227511  
## revol\_util NA NA NA  
## total\_acc -0.047576674 -0.238039827 0.1652009564  
## out\_prncp 0.011455899 -0.127512832 0.1901004364  
## out\_prncp\_inv 0.011526088 -0.127547895 0.1901050232  
## total\_pymnt 0.037166893 -0.089287524 0.1256627543  
## total\_pymnt\_inv 0.037233452 -0.089321251 0.1256825785  
## total\_rec\_prncp -0.055048499 -0.080790819 0.1116953873  
## total\_rec\_int 0.431305163 -0.067500837 0.1023674781  
## total\_rec\_late\_fee 0.052196916 -0.003540954 0.0161302822  
## recoveries 0.046097406 0.006369627 0.0020853917  
## collection\_recovery\_fee 0.044960357 0.006387752 0.0020665567  
## last\_fico\_range\_high -0.424990864 -0.089059154 0.0116669230  
## last\_fico\_range\_low -0.359534889 -0.085630068 0.0122406117  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 0.004319267 -0.002884071 0.0022103967  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 0.129298598 -0.118031996 0.0652556146  
## num\_tl\_30dpd 0.004345513 -0.002834661 0.0021593505  
## num\_tl\_90g\_dpd\_24m 0.055119728 -0.004363646 0.0078984880  
## tot\_hi\_cred\_lim -0.126109654 -0.515406238 0.3525239483  
## num\_rev\_accts -0.072150375 -0.137934044 0.1031635158  
## loan\_status dti delinq\_2yrs  
## loan\_amnt -0.0163904647 0.0463496769 -0.0171994812  
## funded\_amnt -0.0163904647 0.0463496769 -0.0171994812  
## funded\_amnt\_inv -0.0163887190 0.0463481460 -0.0172200190  
## term -0.0128696480 0.0425996090 -0.0187335359  
## int\_rate 0.0660494876 0.1088669839 0.1049244068  
## installment -0.0039365160 0.0528456611 0.0025809856  
## grade 0.0707784926 0.1044939546 0.1052770934  
## sub\_grade 0.0735159911 0.1099935589 0.1082618744  
## home\_ownership -0.0131210883 -0.0515180769 -0.0502702633  
## annual\_inc 0.0009358584 -0.1052857082 0.0413779496  
## loan\_status 1.0000000000 -0.0109872516 0.0102141488  
## dti -0.0109872516 1.0000000000 -0.0150975436  
## delinq\_2yrs 0.0102141488 -0.0150975436 1.0000000000  
## fico\_range\_low -0.0040314464 -0.0069413954 -0.1701543335  
## fico\_range\_high -0.0040321216 -0.0069444200 -0.1701510849  
## inq\_last\_6mths 0.0472363760 -0.0087823748 0.0123729038  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc -0.0041501266 0.1487021268 0.0288303802  
## pub\_rec 0.0161570330 -0.0071320523 -0.0411543703  
## revol\_bal -0.0242396970 0.1013595912 -0.0196930899  
## revol\_util NA NA NA  
## total\_acc 0.0284192530 0.1298543781 0.0998368294  
## out\_prncp -0.2071870633 0.0549809079 -0.0157018713  
## out\_prncp\_inv -0.2071438782 0.0549788886 -0.0157177821  
## total\_pymnt 0.3828427605 0.0093071615 -0.0005063478  
## total\_pymnt\_inv 0.3828231008 0.0093086295 -0.0005194844  
## total\_rec\_prncp 0.4185412745 -0.0083290007 -0.0069666975  
## total\_rec\_int -0.0382425937 0.0852225697 0.0292715207  
## total\_rec\_late\_fee 0.1247694431 -0.0038166645 0.0222086630  
## recoveries -0.0731974135 -0.0027747091 0.0027054680  
## collection\_recovery\_fee -0.0724438596 -0.0026845570 0.0028620101  
## last\_fico\_range\_high -0.0782368560 0.0036098758 -0.1345538219  
## last\_fico\_range\_low -0.0548607169 0.0078471314 -0.1040541545  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 0.0027540386 0.0001528656 0.0187593389  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 0.0594053230 0.0256614528 0.0265063066  
## num\_tl\_30dpd 0.0032050388 0.0001340608 0.0190237430  
## num\_tl\_90g\_dpd\_24m 0.0053381647 -0.0118091268 0.6613762046  
## tot\_hi\_cred\_lim 0.0119832679 0.0553516667 0.0551921414  
## num\_rev\_accts 0.0179007051 0.0822274175 0.0713271331  
## fico\_range\_low fico\_range\_high inq\_last\_6mths  
## loan\_amnt 0.098274031 0.098272857 -0.016122851  
## funded\_amnt 0.098274031 0.098272857 -0.016122851  
## funded\_amnt\_inv 0.098349805 0.098348632 -0.016150955  
## term 0.026621452 0.026620931 0.004523212  
## int\_rate -0.444131200 -0.444125375 0.118095260  
## installment 0.031200628 0.031200221 -0.002392947  
## grade -0.445972966 -0.445966261 0.116427626  
## sub\_grade -0.460446298 -0.460440587 0.122450351  
## home\_ownership -0.095890360 -0.095892682 -0.022157249  
## annual\_inc 0.018018891 0.018018537 0.034603224  
## loan\_status -0.004031446 -0.004032122 0.047236376  
## dti -0.006941395 -0.006944420 -0.008782375  
## delinq\_2yrs -0.170154333 -0.170151085 0.012372904  
## fico\_range\_low 1.000000000 0.999999871 -0.062192863  
## fico\_range\_high 0.999999871 1.000000000 -0.062194999  
## inq\_last\_6mths -0.062192863 -0.062194999 1.000000000  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 0.012021954 0.012020035 0.164187338  
## pub\_rec -0.184051967 -0.184048602 0.062155756  
## revol\_bal -0.041008215 -0.041008810 -0.016190588  
## revol\_util NA NA NA  
## total\_acc 0.034670400 0.034669192 0.156985413  
## out\_prncp 0.060329202 0.060328764 -0.035275313  
## out\_prncp\_inv 0.060386666 0.060386228 -0.035291464  
## total\_pymnt 0.056836538 0.056835391 0.018632101  
## total\_pymnt\_inv 0.056895890 0.056894744 0.018608717  
## total\_rec\_prncp 0.086714822 0.086713235 0.013425625  
## total\_rec\_int -0.120702734 -0.120700990 0.025836182  
## total\_rec\_late\_fee -0.016651086 -0.016649736 0.016956911  
## recoveries -0.004793327 -0.004793630 0.022502093  
## collection\_recovery\_fee -0.004420242 -0.004420554 0.022132159  
## last\_fico\_range\_high 0.554239033 0.554238275 -0.122643044  
## last\_fico\_range\_low 0.448696854 0.448696278 -0.108650483  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq -0.006627401 -0.006627230 0.006733042  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m -0.101708460 -0.101710646 0.462566380  
## num\_tl\_30dpd -0.006806362 -0.006806181 0.005246655  
## num\_tl\_90g\_dpd\_24m -0.101673474 -0.101671145 0.015905696  
## tot\_hi\_cred\_lim 0.154338775 0.154339115 0.042407648  
## num\_rev\_accts 0.028998546 0.028999704 0.161304719  
## mths\_since\_last\_delinq mths\_since\_last\_record  
## loan\_amnt NA NA  
## funded\_amnt NA NA  
## funded\_amnt\_inv NA NA  
## term NA NA  
## int\_rate NA NA  
## installment NA NA  
## grade NA NA  
## sub\_grade NA NA  
## home\_ownership NA NA  
## annual\_inc NA NA  
## loan\_status NA NA  
## dti NA NA  
## delinq\_2yrs NA NA  
## fico\_range\_low NA NA  
## fico\_range\_high NA NA  
## inq\_last\_6mths NA NA  
## mths\_since\_last\_delinq 1 NA  
## mths\_since\_last\_record NA 1  
## open\_acc NA NA  
## pub\_rec NA NA  
## revol\_bal NA NA  
## revol\_util NA NA  
## total\_acc NA NA  
## out\_prncp NA NA  
## out\_prncp\_inv NA NA  
## total\_pymnt NA NA  
## total\_pymnt\_inv NA NA  
## total\_rec\_prncp NA NA  
## total\_rec\_int NA NA  
## total\_rec\_late\_fee NA NA  
## recoveries NA NA  
## collection\_recovery\_fee NA NA  
## last\_fico\_range\_high NA NA  
## last\_fico\_range\_low NA NA  
## mths\_since\_last\_major\_derog NA NA  
## acc\_now\_delinq NA NA  
## avg\_cur\_bal NA NA  
## inq\_last\_12m NA NA  
## num\_tl\_30dpd NA NA  
## num\_tl\_90g\_dpd\_24m NA NA  
## tot\_hi\_cred\_lim NA NA  
## num\_rev\_accts NA NA  
## open\_acc pub\_rec revol\_bal revol\_util  
## loan\_amnt 0.167820213 -4.371892e-02 0.3031353773 NA  
## funded\_amnt 0.167820213 -4.371892e-02 0.3031353773 NA  
## funded\_amnt\_inv 0.167804824 -4.375526e-02 0.3031383327 NA  
## term 0.065090967 1.024193e-03 0.0749864102 NA  
## int\_rate -0.021399766 4.271024e-02 -0.0219590079 NA  
## installment 0.158881395 -3.713864e-02 0.2949278617 NA  
## grade -0.021914670 4.891494e-02 -0.0215421988 NA  
## sub\_grade -0.023157065 4.785528e-02 -0.0251381760 NA  
## home\_ownership -0.153695856 -1.009327e-02 -0.1615468511 NA  
## annual\_inc 0.143517662 -1.223933e-02 0.2655227511 NA  
## loan\_status -0.004150127 1.615703e-02 -0.0242396970 NA  
## dti 0.148702127 -7.132052e-03 0.1013595912 NA  
## delinq\_2yrs 0.028830380 -4.115437e-02 -0.0196930899 NA  
## fico\_range\_low 0.012021954 -1.840520e-01 -0.0410082150 NA  
## fico\_range\_high 0.012020035 -1.840486e-01 -0.0410088101 NA  
## inq\_last\_6mths 0.164187338 6.215576e-02 -0.0161905876 NA  
## mths\_since\_last\_delinq NA NA NA NA  
## mths\_since\_last\_record NA NA NA NA  
## open\_acc 1.000000000 9.374260e-03 0.2591593358 NA  
## pub\_rec 0.009374260 1.000000e+00 -0.0758159549 NA  
## revol\_bal 0.259159336 -7.581595e-02 1.0000000000 NA  
## revol\_util NA NA NA 1  
## total\_acc 0.746398102 2.547150e-03 0.2309505887 NA  
## out\_prncp 0.144114220 -4.697160e-02 0.2655340819 NA  
## out\_prncp\_inv 0.144104420 -4.699343e-02 0.2655370548 NA  
## total\_pymnt 0.083412824 -1.155224e-03 0.1369187052 NA  
## total\_pymnt\_inv 0.083413578 -1.187024e-03 0.1369401124 NA  
## total\_rec\_prncp 0.067731492 -4.015431e-03 0.1091035866 NA  
## total\_rec\_int 0.098613012 1.213911e-02 0.1706493186 NA  
## total\_rec\_late\_fee -0.010710187 -3.085977e-03 0.0055731399 NA  
## recoveries -0.003134903 4.709848e-03 -0.0008746645 NA  
## collection\_recovery\_fee -0.003200564 4.761926e-03 -0.0008297269 NA  
## last\_fico\_range\_high 0.024910200 -1.045679e-01 0.0265839257 NA  
## last\_fico\_range\_low 0.030089056 -8.231886e-02 0.0273805795 NA  
## mths\_since\_last\_major\_derog NA NA NA NA  
## acc\_now\_delinq 0.001458211 -3.616169e-04 0.0043697065 NA  
## avg\_cur\_bal NA NA NA NA  
## inq\_last\_12m 0.189774845 7.843465e-02 -0.0268563474 NA  
## num\_tl\_30dpd 0.001774289 -7.338182e-05 0.0029268879 NA  
## num\_tl\_90g\_dpd\_24m -0.001887868 -2.101857e-02 -0.0276327652 NA  
## tot\_hi\_cred\_lim 0.327264787 -6.110352e-02 0.4584005412 NA  
## num\_rev\_accts 0.720558787 2.948937e-02 0.2341479214 NA  
## total\_acc out\_prncp out\_prncp\_inv  
## loan\_amnt 0.182344359 0.8336881713 0.8336967093  
## funded\_amnt 0.182344359 0.8336881713 0.8336967093  
## funded\_amnt\_inv 0.182336495 0.8337260697 0.8337399408  
## term 0.088376674 0.4004730743 0.4006251297  
## int\_rate -0.044985807 0.0228049967 0.0228773323  
## installment 0.160721339 0.7551703979 0.7551320503  
## grade -0.043563239 0.0154544469 0.0155223608  
## sub\_grade -0.047576674 0.0114558993 0.0115260876  
## home\_ownership -0.238039827 -0.1275128322 -0.1275478946  
## annual\_inc 0.165200956 0.1901004364 0.1901050232  
## loan\_status 0.028419253 -0.2071870633 -0.2071438782  
## dti 0.129854378 0.0549809079 0.0549788886  
## delinq\_2yrs 0.099836829 -0.0157018713 -0.0157177821  
## fico\_range\_low 0.034670400 0.0603292016 0.0603866656  
## fico\_range\_high 0.034669192 0.0603287636 0.0603862275  
## inq\_last\_6mths 0.156985413 -0.0352753132 -0.0352914643  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 0.746398102 0.1441142201 0.1441044198  
## pub\_rec 0.002547150 -0.0469716001 -0.0469934286  
## revol\_bal 0.230950589 0.2655340819 0.2655370548  
## revol\_util NA NA NA  
## total\_acc 1.000000000 0.1368120534 0.1368129619  
## out\_prncp 0.136812053 1.0000000000 0.9999977116  
## out\_prncp\_inv 0.136812962 0.9999977116 1.0000000000  
## total\_pymnt 0.118083740 0.0046486205 0.0046603115  
## total\_pymnt\_inv 0.118087348 0.0047159266 0.0047301931  
## total\_rec\_prncp 0.106228851 -0.1186719933 -0.1186633906  
## total\_rec\_int 0.091122039 0.5852788190 0.5852947341  
## total\_rec\_late\_fee -0.006598512 0.0235820773 0.0235804478  
## recoveries -0.002183928 -0.0649772280 -0.0649658336  
## collection\_recovery\_fee -0.002120730 -0.0643082993 -0.0642970222  
## last\_fico\_range\_high 0.047273251 0.1600303205 0.1600492265  
## last\_fico\_range\_low 0.053348858 0.1537705394 0.1537809058  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 0.001601258 0.0011905812 0.0011923941  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 0.220514209 -0.0151437164 -0.0151504147  
## num\_tl\_30dpd 0.001994190 0.0007663134 0.0007680118  
## num\_tl\_90g\_dpd\_24m 0.055517446 -0.0166346840 -0.0166475560  
## tot\_hi\_cred\_lim 0.388567775 0.2439154976 0.2439442955  
## num\_rev\_accts 0.771322840 0.1131072098 0.1130959721  
## total\_pymnt total\_pymnt\_inv total\_rec\_prncp  
## loan\_amnt 0.5035999302 0.5036570201 3.946064e-01  
## funded\_amnt 0.5035999302 0.5036570201 3.946064e-01  
## funded\_amnt\_inv 0.5035320325 0.5035937311 3.945299e-01  
## term 0.0863251344 0.0864750628 -4.656810e-03  
## int\_rate 0.0168289582 0.0169002800 -7.210764e-02  
## installment 0.5251965581 0.5252113848 4.240867e-01  
## grade 0.0376582059 0.0377220799 -5.274461e-02  
## sub\_grade 0.0371668930 0.0372334524 -5.504850e-02  
## home\_ownership -0.0892875235 -0.0893212507 -8.079082e-02  
## annual\_inc 0.1256627543 0.1256825785 1.116954e-01  
## loan\_status 0.3828427605 0.3828231008 4.185413e-01  
## dti 0.0093071615 0.0093086295 -8.329001e-03  
## delinq\_2yrs -0.0005063478 -0.0005194844 -6.966698e-03  
## fico\_range\_low 0.0568365379 0.0568958904 8.671482e-02  
## fico\_range\_high 0.0568353914 0.0568947438 8.671324e-02  
## inq\_last\_6mths 0.0186321007 0.0186087168 1.342563e-02  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 0.0834128243 0.0834135778 6.773149e-02  
## pub\_rec -0.0011552240 -0.0011870244 -4.015431e-03  
## revol\_bal 0.1369187052 0.1369401124 1.091036e-01  
## revol\_util NA NA NA  
## total\_acc 0.1180837401 0.1180873481 1.062289e-01  
## out\_prncp 0.0046486205 0.0047159266 -1.186720e-01  
## out\_prncp\_inv 0.0046603115 0.0047301931 -1.186634e-01  
## total\_pymnt 1.0000000000 0.9999977379 9.796335e-01  
## total\_pymnt\_inv 0.9999977379 1.0000000000 9.796182e-01  
## total\_rec\_prncp 0.9796334868 0.9796182278 1.000000e+00  
## total\_rec\_int 0.3949109534 0.3949688282 2.055864e-01  
## total\_rec\_late\_fee 0.0406593060 0.0406586664 2.313606e-02  
## recoveries 0.0079373189 0.0079478183 -2.639359e-02  
## collection\_recovery\_fee 0.0080785014 0.0080888879 -2.608477e-02  
## last\_fico\_range\_high 0.0982162636 0.0982446138 1.260119e-01  
## last\_fico\_range\_low 0.0893757256 0.0893962591 1.128106e-01  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 0.0025415251 0.0025435166 -3.323112e-05  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 0.0466694780 0.0466548130 3.738382e-02  
## num\_tl\_30dpd 0.0023314647 0.0023333275 -8.733205e-05  
## num\_tl\_90g\_dpd\_24m -0.0066079789 -0.0066167025 -8.598754e-03  
## tot\_hi\_cred\_lim 0.1739818571 0.1740209404 1.583238e-01  
## num\_rev\_accts 0.0956047864 0.0955968217 8.796602e-02  
## total\_rec\_int total\_rec\_late\_fee recoveries  
## loan\_amnt 0.651241262 0.049554213 0.0392639388  
## funded\_amnt 0.651241262 0.049554213 0.0392639388  
## funded\_amnt\_inv 0.651258290 0.049548150 0.0392771416  
## term 0.442989252 0.010277979 0.0324485321  
## int\_rate 0.410399237 0.049057407 0.0435092320  
## installment 0.621183739 0.059775068 0.0387256437  
## grade 0.423245590 0.050555783 0.0449245427  
## sub\_grade 0.431305163 0.052196916 0.0460974063  
## home\_ownership -0.067500837 -0.003540954 0.0063696271  
## annual\_inc 0.102367478 0.016130282 0.0020853917  
## loan\_status -0.038242594 0.124769443 -0.0731974135  
## dti 0.085222570 -0.003816665 -0.0027747091  
## delinq\_2yrs 0.029271521 0.022208663 0.0027054680  
## fico\_range\_low -0.120702734 -0.016651086 -0.0047933270  
## fico\_range\_high -0.120700990 -0.016649736 -0.0047936304  
## inq\_last\_6mths 0.025836182 0.016956911 0.0225020928  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 0.098613012 -0.010710187 -0.0031349027  
## pub\_rec 0.012139110 -0.003085977 0.0047098483  
## revol\_bal 0.170649319 0.005573140 -0.0008746645  
## revol\_util NA NA NA  
## total\_acc 0.091122039 -0.006598512 -0.0021839278  
## out\_prncp 0.585278819 0.023582077 -0.0649772280  
## out\_prncp\_inv 0.585294734 0.023580448 -0.0649658336  
## total\_pymnt 0.394910953 0.040659306 0.0079373189  
## total\_pymnt\_inv 0.394968828 0.040658666 0.0079478183  
## total\_rec\_prncp 0.205586355 0.023136062 -0.0263935912  
## total\_rec\_int 1.000000000 0.085183551 -0.0108265011  
## total\_rec\_late\_fee 0.085183551 1.000000000 0.0191620433  
## recoveries -0.010826501 0.019162043 1.0000000000  
## collection\_recovery\_fee -0.010701043 0.019247306 0.9950056570  
## last\_fico\_range\_high -0.074905753 -0.096040528 -0.1393440923  
## last\_fico\_range\_low -0.052866463 -0.084289698 -0.1655039722  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 0.010252575 0.005826567 0.0141583980  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 0.054191849 0.020657188 0.0169163537  
## num\_tl\_30dpd 0.009304432 0.005447726 0.0150988682  
## num\_tl\_90g\_dpd\_24m 0.006796814 0.005458839 0.0024714283  
## tot\_hi\_cred\_lim 0.125699770 0.016736497 -0.0031025983  
## num\_rev\_accts 0.064444155 -0.011869097 -0.0002349269  
## collection\_recovery\_fee last\_fico\_range\_high  
## loan\_amnt 0.0391228212 0.139337824  
## funded\_amnt 0.0391228212 0.139337824  
## funded\_amnt\_inv 0.0391357888 0.139370350  
## term 0.0322634669 0.021666730  
## int\_rate 0.0423219292 -0.405871937  
## installment 0.0383418752 0.087427902  
## grade 0.0437762671 -0.409761571  
## sub\_grade 0.0449603574 -0.424990864  
## home\_ownership 0.0063877515 -0.089059154  
## annual\_inc 0.0020665567 0.011666923  
## loan\_status -0.0724438596 -0.078236856  
## dti -0.0026845570 0.003609876  
## delinq\_2yrs 0.0028620101 -0.134553822  
## fico\_range\_low -0.0044202421 0.554239033  
## fico\_range\_high -0.0044205541 0.554238275  
## inq\_last\_6mths 0.0221321591 -0.122643044  
## mths\_since\_last\_delinq NA NA  
## mths\_since\_last\_record NA NA  
## open\_acc -0.0032005637 0.024910200  
## pub\_rec 0.0047619264 -0.104567944  
## revol\_bal -0.0008297269 0.026583926  
## revol\_util NA NA  
## total\_acc -0.0021207302 0.047273251  
## out\_prncp -0.0643082993 0.160030320  
## out\_prncp\_inv -0.0642970222 0.160049227  
## total\_pymnt 0.0080785014 0.098216264  
## total\_pymnt\_inv 0.0080888879 0.098244614  
## total\_rec\_prncp -0.0260847663 0.126011907  
## total\_rec\_int -0.0107010427 -0.074905753  
## total\_rec\_late\_fee 0.0192473062 -0.096040528  
## recoveries 0.9950056570 -0.139344092  
## collection\_recovery\_fee 1.0000000000 -0.137493527  
## last\_fico\_range\_high -0.1374935265 1.000000000  
## last\_fico\_range\_low -0.1629165589 0.903453483  
## mths\_since\_last\_major\_derog NA NA  
## acc\_now\_delinq 0.0143597196 -0.007039362  
## avg\_cur\_bal NA NA  
## inq\_last\_12m 0.0164488731 -0.140877531  
## num\_tl\_30dpd 0.0153124488 -0.006502756  
## num\_tl\_90g\_dpd\_24m 0.0025185123 -0.076209291  
## tot\_hi\_cred\_lim -0.0030646041 0.113451659  
## num\_rev\_accts -0.0002601800 0.046356075  
## last\_fico\_range\_low mths\_since\_last\_major\_derog  
## loan\_amnt 0.112018908 NA  
## funded\_amnt 0.112018908 NA  
## funded\_amnt\_inv 0.112043035 NA  
## term 0.015103595 NA  
## int\_rate -0.343083135 NA  
## installment 0.068997809 NA  
## grade -0.346999768 NA  
## sub\_grade -0.359534889 NA  
## home\_ownership -0.085630068 NA  
## annual\_inc 0.012240612 NA  
## loan\_status -0.054860717 NA  
## dti 0.007847131 NA  
## delinq\_2yrs -0.104054155 NA  
## fico\_range\_low 0.448696854 NA  
## fico\_range\_high 0.448696278 NA  
## inq\_last\_6mths -0.108650483 NA  
## mths\_since\_last\_delinq NA NA  
## mths\_since\_last\_record NA NA  
## open\_acc 0.030089056 NA  
## pub\_rec -0.082318865 NA  
## revol\_bal 0.027380579 NA  
## revol\_util NA NA  
## total\_acc 0.053348858 NA  
## out\_prncp 0.153770539 NA  
## out\_prncp\_inv 0.153780906 NA  
## total\_pymnt 0.089375726 NA  
## total\_pymnt\_inv 0.089396259 NA  
## total\_rec\_prncp 0.112810597 NA  
## total\_rec\_int -0.052866463 NA  
## total\_rec\_late\_fee -0.084289698 NA  
## recoveries -0.165503972 NA  
## collection\_recovery\_fee -0.162916559 NA  
## last\_fico\_range\_high 0.903453483 NA  
## last\_fico\_range\_low 1.000000000 NA  
## mths\_since\_last\_major\_derog NA 1  
## acc\_now\_delinq -0.005444696 NA  
## avg\_cur\_bal NA NA  
## inq\_last\_12m -0.117767140 NA  
## num\_tl\_30dpd -0.005026549 NA  
## num\_tl\_90g\_dpd\_24m -0.059997743 NA  
## tot\_hi\_cred\_lim 0.104035423 NA  
## num\_rev\_accts 0.046084682 NA  
## acc\_now\_delinq avg\_cur\_bal inq\_last\_12m  
## loan\_amnt 2.585038e-03 NA 0.0143123912  
## funded\_amnt 2.585038e-03 NA 0.0143123912  
## funded\_amnt\_inv 2.587481e-03 NA 0.0142942144  
## term 4.308905e-03 NA 0.0341483606  
## int\_rate 3.262334e-03 NA 0.1237836153  
## installment 1.811403e-03 NA 0.0217882259  
## grade 3.391450e-03 NA 0.1229938317  
## sub\_grade 4.319267e-03 NA 0.1292985976  
## home\_ownership -2.884071e-03 NA -0.1180319955  
## annual\_inc 2.210397e-03 NA 0.0652556146  
## loan\_status 2.754039e-03 NA 0.0594053230  
## dti 1.528656e-04 NA 0.0256614528  
## delinq\_2yrs 1.875934e-02 NA 0.0265063066  
## fico\_range\_low -6.627401e-03 NA -0.1017084599  
## fico\_range\_high -6.627230e-03 NA -0.1017106463  
## inq\_last\_6mths 6.733042e-03 NA 0.4625663802  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 1.458211e-03 NA 0.1897748449  
## pub\_rec -3.616169e-04 NA 0.0784346472  
## revol\_bal 4.369707e-03 NA -0.0268563474  
## revol\_util NA NA NA  
## total\_acc 1.601258e-03 NA 0.2205142085  
## out\_prncp 1.190581e-03 NA -0.0151437164  
## out\_prncp\_inv 1.192394e-03 NA -0.0151504147  
## total\_pymnt 2.541525e-03 NA 0.0466694780  
## total\_pymnt\_inv 2.543517e-03 NA 0.0466548130  
## total\_rec\_prncp -3.323112e-05 NA 0.0373838167  
## total\_rec\_int 1.025258e-02 NA 0.0541918493  
## total\_rec\_late\_fee 5.826567e-03 NA 0.0206571882  
## recoveries 1.415840e-02 NA 0.0169163537  
## collection\_recovery\_fee 1.435972e-02 NA 0.0164488731  
## last\_fico\_range\_high -7.039362e-03 NA -0.1408775314  
## last\_fico\_range\_low -5.444696e-03 NA -0.1177671395  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 1.000000e+00 NA 0.0006622403  
## avg\_cur\_bal NA 1 NA  
## inq\_last\_12m 6.622403e-04 NA 1.0000000000  
## num\_tl\_30dpd 9.405371e-01 NA 0.0004295357  
## num\_tl\_90g\_dpd\_24m 6.921225e-03 NA 0.0172775975  
## tot\_hi\_cred\_lim 3.241562e-03 NA 0.1381390343  
## num\_rev\_accts 2.012808e-03 NA 0.1614614819  
## num\_tl\_30dpd num\_tl\_90g\_dpd\_24m tot\_hi\_cred\_lim  
## loan\_amnt 2.281560e-03 -0.019319259 0.306986363  
## funded\_amnt 2.281560e-03 -0.019319259 0.306986363  
## funded\_amnt\_inv 2.283855e-03 -0.019334430 0.307018054  
## term 3.879019e-03 -0.009061182 0.106249415  
## int\_rate 3.342816e-03 0.053309127 -0.118911443  
## installment 1.693180e-03 -0.010692559 0.272687554  
## grade 3.411623e-03 0.054599713 -0.116377823  
## sub\_grade 4.345513e-03 0.055119728 -0.126109654  
## home\_ownership -2.834661e-03 -0.004363646 -0.515406238  
## annual\_inc 2.159350e-03 0.007898488 0.352523948  
## loan\_status 3.205039e-03 0.005338165 0.011983268  
## dti 1.340608e-04 -0.011809127 0.055351667  
## delinq\_2yrs 1.902374e-02 0.661376205 0.055192141  
## fico\_range\_low -6.806362e-03 -0.101673474 0.154338775  
## fico\_range\_high -6.806181e-03 -0.101671145 0.154339115  
## inq\_last\_6mths 5.246655e-03 0.015905696 0.042407648  
## mths\_since\_last\_delinq NA NA NA  
## mths\_since\_last\_record NA NA NA  
## open\_acc 1.774289e-03 -0.001887868 0.327264787  
## pub\_rec -7.338182e-05 -0.021018570 -0.061103523  
## revol\_bal 2.926888e-03 -0.027632765 0.458400541  
## revol\_util NA NA NA  
## total\_acc 1.994190e-03 0.055517446 0.388567775  
## out\_prncp 7.663134e-04 -0.016634684 0.243915498  
## out\_prncp\_inv 7.680118e-04 -0.016647556 0.243944295  
## total\_pymnt 2.331465e-03 -0.006607979 0.173981857  
## total\_pymnt\_inv 2.333328e-03 -0.006616702 0.174020940  
## total\_rec\_prncp -8.733205e-05 -0.008598754 0.158323784  
## total\_rec\_int 9.304432e-03 0.006796814 0.125699770  
## total\_rec\_late\_fee 5.447726e-03 0.005458839 0.016736497  
## recoveries 1.509887e-02 0.002471428 -0.003102598  
## collection\_recovery\_fee 1.531245e-02 0.002518512 -0.003064604  
## last\_fico\_range\_high -6.502756e-03 -0.076209291 0.113451659  
## last\_fico\_range\_low -5.026549e-03 -0.059997743 0.104035423  
## mths\_since\_last\_major\_derog NA NA NA  
## acc\_now\_delinq 9.405371e-01 0.006921225 0.003241562  
## avg\_cur\_bal NA NA NA  
## inq\_last\_12m 4.295357e-04 0.017277598 0.138139034  
## num\_tl\_30dpd 1.000000e+00 0.005370969 0.003537508  
## num\_tl\_90g\_dpd\_24m 5.370969e-03 1.000000000 0.004441019  
## tot\_hi\_cred\_lim 3.537508e-03 0.004441019 1.000000000  
## num\_rev\_accts 2.206563e-03 0.024040048 0.218833601  
## num\_rev\_accts  
## loan\_amnt 0.1515749782  
## funded\_amnt 0.1515749782  
## funded\_amnt\_inv 0.1515520116  
## term 0.0447825122  
## int\_rate -0.0700999201  
## installment 0.1409008046  
## grade -0.0671194226  
## sub\_grade -0.0721503745  
## home\_ownership -0.1379340442  
## annual\_inc 0.1031635158  
## loan\_status 0.0179007051  
## dti 0.0822274175  
## delinq\_2yrs 0.0713271331  
## fico\_range\_low 0.0289985455  
## fico\_range\_high 0.0289997036  
## inq\_last\_6mths 0.1613047186  
## mths\_since\_last\_delinq NA  
## mths\_since\_last\_record NA  
## open\_acc 0.7205587870  
## pub\_rec 0.0294893720  
## revol\_bal 0.2341479214  
## revol\_util NA  
## total\_acc 0.7713228396  
## out\_prncp 0.1131072098  
## out\_prncp\_inv 0.1130959721  
## total\_pymnt 0.0956047864  
## total\_pymnt\_inv 0.0955968217  
## total\_rec\_prncp 0.0879660205  
## total\_rec\_int 0.0644441551  
## total\_rec\_late\_fee -0.0118690967  
## recoveries -0.0002349269  
## collection\_recovery\_fee -0.0002601800  
## last\_fico\_range\_high 0.0463560755  
## last\_fico\_range\_low 0.0460846818  
## mths\_since\_last\_major\_derog NA  
## acc\_now\_delinq 0.0020128077  
## avg\_cur\_bal NA  
## inq\_last\_12m 0.1614614819  
## num\_tl\_30dpd 0.0022065630  
## num\_tl\_90g\_dpd\_24m 0.0240400480  
## tot\_hi\_cred\_lim 0.2188336012  
## num\_rev\_accts 1.0000000000

Based on the above correlation matrix, following variables are highly collinear 1. loan\_amnt, funded\_amnt, funded\_amnt\_inv 2. int\_rate, grade, sub\_grade 3. fico\_range\_low, fico\_range\_high 4. last\_fico\_range\_high, last\_fico\_range\_low 5. total\_pymnt, total\_pymnt\_inv, total\_rec\_prncp

Dropping following varibales due to NA values mths\_since\_last\_delinq, mths\_since\_last\_record, mths\_since\_last\_major\_derog, avg\_cur\_bal

ds\_lc = subset(ds\_lc, select = -c(funded\_amnt, funded\_amnt\_inv, grade, sub\_grade, fico\_range\_low, last\_fico\_range\_low, total\_pymnt\_inv, total\_rec\_prncp, mths\_since\_last\_delinq, mths\_since\_last\_record, mths\_since\_last\_major\_derog, avg\_cur\_bal, revol\_util))

ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 1] <- 1  
ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 2] <- 0  
ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 3] <- 1  
ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 4] <- 0  
ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 5] <- 1  
ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 6] <- 0  
ds\_lc$is\_acct\_delinquent[ds\_lc$loan\_status == 7] <- 1  
ds\_lc$is\_acct\_delinquent <- factor(ds\_lc$is\_acct\_delinquent)  
levels(factor(ds\_lc$is\_acct\_delinquent))

## [1] "0" "1"

ds\_lc = subset(ds\_lc, select = -c(loan\_status))  
ds\_lc\_after\_correlation <- ds\_lc

Perform regular subset varibale selection test

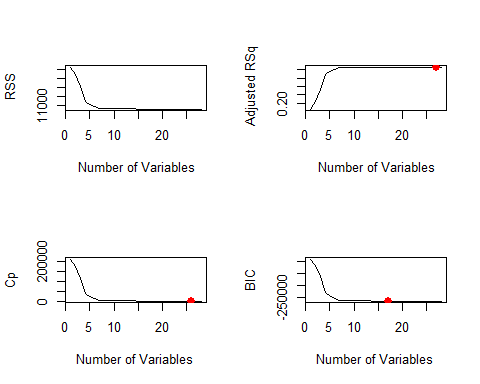
regular\_subset\_full <- regsubsets(is\_acct\_delinquent ~ ., ds\_lc, nvmax = 40)  
regular\_subset\_full\_summary <- summary(regular\_subset\_full)  
regular\_subset\_full\_summary

## Subset selection object  
## Call: regsubsets.formula(is\_acct\_delinquent ~ ., ds\_lc, nvmax = 40)  
## 28 Variables (and intercept)  
## Forced in Forced out  
## loan\_amnt FALSE FALSE  
## term FALSE FALSE  
## int\_rate FALSE FALSE  
## installment FALSE FALSE  
## home\_ownership FALSE FALSE  
## annual\_inc FALSE FALSE  
## dti FALSE FALSE  
## delinq\_2yrs FALSE FALSE  
## fico\_range\_high FALSE FALSE  
## inq\_last\_6mths FALSE FALSE  
## open\_acc FALSE FALSE  
## pub\_rec FALSE FALSE  
## revol\_bal FALSE FALSE  
## total\_acc FALSE FALSE  
## out\_prncp FALSE FALSE  
## out\_prncp\_inv FALSE FALSE  
## total\_pymnt FALSE FALSE  
## total\_rec\_int FALSE FALSE  
## total\_rec\_late\_fee FALSE FALSE  
## recoveries FALSE FALSE  
## collection\_recovery\_fee FALSE FALSE  
## last\_fico\_range\_high FALSE FALSE  
## acc\_now\_delinq FALSE FALSE  
## inq\_last\_12m FALSE FALSE  
## num\_tl\_30dpd FALSE FALSE  
## num\_tl\_90g\_dpd\_24m FALSE FALSE  
## tot\_hi\_cred\_lim FALSE FALSE  
## num\_rev\_accts FALSE FALSE  
## 1 subsets of each size up to 28  
## Selection Algorithm: exhaustive  
## loan\_amnt term int\_rate installment home\_ownership annual\_inc dti  
## 1 ( 1 ) " " " " " " " " " " " " " "  
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## 28 ( 1 ) "\*" "\*" "\*" "\*" "\*" "\*" "\*"  
## delinq\_2yrs fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal  
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## 28 ( 1 ) "\*" "\*" "\*" "\*" "\*" "\*"   
## total\_acc out\_prncp out\_prncp\_inv total\_pymnt total\_rec\_int  
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## total\_rec\_late\_fee recoveries collection\_recovery\_fee  
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## last\_fico\_range\_high acc\_now\_delinq inq\_last\_12m num\_tl\_30dpd  
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## 28 ( 1 ) "\*" "\*" "\*" "\*"   
## num\_tl\_90g\_dpd\_24m tot\_hi\_cred\_lim num\_rev\_accts  
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regular\_subset\_full\_summary$rsq

## [1] 0.1649569 0.2113047 0.2800062 0.3721668 0.3876568 0.4024289 0.4136643  
## [8] 0.4145148 0.4150604 0.4153697 0.4154948 0.4156485 0.4157870 0.4159196  
## [15] 0.4160709 0.4161246 0.4161593 0.4161740 0.4161873 0.4161973 0.4162080  
## [22] 0.4162178 0.4162256 0.4162328 0.4162372 0.4162396 0.4162410 0.4162413

par(mfrow =c(2,2))  
plot(regular\_subset\_full\_summary$rss ,xlab=" Number of Variables", ylab=" RSS", type="l")  
plot(regular\_subset\_full\_summary$adjr2 ,xlab =" Number of Variables", ylab=" Adjusted RSq",type="l")  
points (which.max(regular\_subset\_full\_summary$adjr2), regular\_subset\_full\_summary$adjr2[which.max(regular\_subset\_full\_summary$adjr2)], col ="red",cex =2, pch =20)  
plot(regular\_subset\_full\_summary$cp ,xlab =" Number of Variables ",ylab="Cp", type="l")  
points (which.min (regular\_subset\_full\_summary$cp ), regular\_subset\_full\_summary$cp [which.min (regular\_subset\_full\_summary$cp )], col ="red",cex =2, pch =20)  
plot(regular\_subset\_full\_summary$bic ,xlab=" Number of Variables ",ylab="BIC", type="l")  
points(which.min (regular\_subset\_full\_summary$bic), regular\_subset\_full\_summary$bic[which.min(regular\_subset\_full\_summary$bic )], col ="red",cex =2, pch =20)



Forward and backward subset selection test.

forward\_subset\_full <- regsubsets(is\_acct\_delinquent ~ ., ds\_lc, nvmax = 40, method="forward")  
summary(forward\_subset\_full)

## Subset selection object  
## Call: regsubsets.formula(is\_acct\_delinquent ~ ., ds\_lc, nvmax = 40,   
## method = "forward")  
## 28 Variables (and intercept)  
## Forced in Forced out  
## loan\_amnt FALSE FALSE  
## term FALSE FALSE  
## int\_rate FALSE FALSE  
## installment FALSE FALSE  
## home\_ownership FALSE FALSE  
## annual\_inc FALSE FALSE  
## dti FALSE FALSE  
## delinq\_2yrs FALSE FALSE  
## fico\_range\_high FALSE FALSE  
## inq\_last\_6mths FALSE FALSE  
## open\_acc FALSE FALSE  
## pub\_rec FALSE FALSE  
## revol\_bal FALSE FALSE  
## total\_acc FALSE FALSE  
## out\_prncp FALSE FALSE  
## out\_prncp\_inv FALSE FALSE  
## total\_pymnt FALSE FALSE  
## total\_rec\_int FALSE FALSE  
## total\_rec\_late\_fee FALSE FALSE  
## recoveries FALSE FALSE  
## collection\_recovery\_fee FALSE FALSE  
## last\_fico\_range\_high FALSE FALSE  
## acc\_now\_delinq FALSE FALSE  
## inq\_last\_12m FALSE FALSE  
## num\_tl\_30dpd FALSE FALSE  
## num\_tl\_90g\_dpd\_24m FALSE FALSE  
## tot\_hi\_cred\_lim FALSE FALSE  
## num\_rev\_accts FALSE FALSE  
## 1 subsets of each size up to 28  
## Selection Algorithm: forward  
## loan\_amnt term int\_rate installment home\_ownership annual\_inc dti  
## 1 ( 1 ) " " " " " " " " " " " " " "  
## 2 ( 1 ) " " " " " " " " " " " " " "  
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## delinq\_2yrs fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal  
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## total\_rec\_late\_fee recoveries collection\_recovery\_fee  
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## last\_fico\_range\_high acc\_now\_delinq inq\_last\_12m num\_tl\_30dpd  
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## num\_tl\_90g\_dpd\_24m tot\_hi\_cred\_lim num\_rev\_accts  
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backward\_subset\_full <- regsubsets(is\_acct\_delinquent ~ ., ds\_lc, nvmax = 40, method="backward")  
summary(backward\_subset\_full)

## Subset selection object  
## Call: regsubsets.formula(is\_acct\_delinquent ~ ., ds\_lc, nvmax = 40,   
## method = "backward")  
## 28 Variables (and intercept)  
## Forced in Forced out  
## loan\_amnt FALSE FALSE  
## term FALSE FALSE  
## int\_rate FALSE FALSE  
## installment FALSE FALSE  
## home\_ownership FALSE FALSE  
## annual\_inc FALSE FALSE  
## dti FALSE FALSE  
## delinq\_2yrs FALSE FALSE  
## fico\_range\_high FALSE FALSE  
## inq\_last\_6mths FALSE FALSE  
## open\_acc FALSE FALSE  
## pub\_rec FALSE FALSE  
## revol\_bal FALSE FALSE  
## total\_acc FALSE FALSE  
## out\_prncp FALSE FALSE  
## out\_prncp\_inv FALSE FALSE  
## total\_pymnt FALSE FALSE  
## total\_rec\_int FALSE FALSE  
## total\_rec\_late\_fee FALSE FALSE  
## recoveries FALSE FALSE  
## collection\_recovery\_fee FALSE FALSE  
## last\_fico\_range\_high FALSE FALSE  
## acc\_now\_delinq FALSE FALSE  
## inq\_last\_12m FALSE FALSE  
## num\_tl\_30dpd FALSE FALSE  
## num\_tl\_90g\_dpd\_24m FALSE FALSE  
## tot\_hi\_cred\_lim FALSE FALSE  
## num\_rev\_accts FALSE FALSE  
## 1 subsets of each size up to 28  
## Selection Algorithm: backward  
## loan\_amnt term int\_rate installment home\_ownership annual\_inc dti  
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## delinq\_2yrs fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal  
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## last\_fico\_range\_high acc\_now\_delinq inq\_last\_12m num\_tl\_30dpd  
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## num\_tl\_90g\_dpd\_24m tot\_hi\_cred\_lim num\_rev\_accts  
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ds\_lc = subset(ds\_lc, select = -c(out\_prncp\_inv,num\_tl\_30dpd,num\_tl\_90g\_dpd\_24m,num\_rev\_accts,acc\_now\_delinq, recoveries, collection\_recovery\_fee))

Check data types for all variables is int or numeric

str(ds\_lc)

## Classes 'data.table' and 'data.frame': 494110 obs. of 22 variables:  
## $ loan\_amnt : int 5000 15000 11200 25000 3000 17000 20000 19200 6500 10000 ...  
## $ term : int 1 1 2 2 1 2 1 2 1 2 ...  
## $ int\_rate : num 20.39 9.92 30.79 21.85 7.34 ...  
## $ installment : num 186.8 483.4 367.8 688.4 93.1 ...  
## $ home\_ownership : int 4 3 4 2 4 4 2 4 2 2 ...  
## $ annual\_inc : num 50000 196000 44000 65000 52000 52000 19000 36500 50000 80000 ...  
## $ dti : num 21.8 18.29 43.97 12.89 0.58 ...  
## $ delinq\_2yrs : int 1 0 1 1 0 0 0 3 0 0 ...  
## $ fico\_range\_high : int 669 704 669 669 764 674 799 679 709 664 ...  
## $ inq\_last\_6mths : int 0 0 2 1 0 0 1 0 0 1 ...  
## $ open\_acc : int 5 19 8 7 7 9 6 14 7 17 ...  
## $ pub\_rec : int 0 0 0 0 0 0 0 0 0 0 ...  
## $ revol\_bal : int 116 24243 1526 8657 141 15363 17144 13295 7871 10710 ...  
## $ total\_acc : int 18 53 14 16 30 14 9 18 16 23 ...  
## $ out\_prncp : num 3780 10878 10194 22189 0 ...  
## $ total\_pymnt : num 2044 5301 4008 7511 3012 ...  
## $ total\_rec\_int : num 824 1179.9 3001.4 4699.9 11.6 ...  
## $ total\_rec\_late\_fee : num 0 0 0 0 0 0 0 0 0 0 ...  
## $ last\_fico\_range\_high: int 609 694 629 669 764 634 799 559 714 634 ...  
## $ inq\_last\_12m : int 5 7 10 3 2 2 1 0 0 4 ...  
## $ tot\_hi\_cred\_lim : num 33430 605228 80367 101234 191216 ...  
## $ is\_acct\_delinquent : Factor w/ 2 levels "0","1": 1 1 1 1 1 1 1 1 1 1 ...  
## - attr(\*, ".internal.selfref")=<externalptr>

Summary for all variables in the dataset along with NA check.

summary(ds\_lc)

## loan\_amnt term int\_rate installment   
## Min. : 1000 Min. :1.000 Min. : 5.31 Min. : 29.76   
## 1st Qu.: 8000 1st Qu.:1.000 1st Qu.: 8.46 1st Qu.: 254.50   
## Median :14000 Median :1.000 Median :11.80 Median : 386.76   
## Mean :16017 Mean :1.304 Mean :12.73 Mean : 466.38   
## 3rd Qu.:22000 3rd Qu.:2.000 3rd Qu.:16.01 3rd Qu.: 628.67   
## Max. :40000 Max. :2.000 Max. :30.99 Max. :1670.15   
## home\_ownership annual\_inc dti delinq\_2yrs   
## Min. :1.00 Min. : 0 Min. : 0.00 Min. : 0.0000   
## 1st Qu.:2.00 1st Qu.: 46000 1st Qu.: 11.43 1st Qu.: 0.0000   
## Median :3.00 Median : 66000 Median : 17.71 Median : 0.0000   
## Mean :2.91 Mean : 80277 Mean : 19.67 Mean : 0.2295   
## 3rd Qu.:4.00 3rd Qu.: 96000 3rd Qu.: 25.03 3rd Qu.: 0.0000   
## Max. :4.00 Max. :9930475 Max. :999.00 Max. :58.0000   
## fico\_range\_high inq\_last\_6mths open\_acc pub\_rec   
## Min. :664.0 Min. :0.0000 Min. : 0.0 Min. : 0.0000   
## 1st Qu.:684.0 1st Qu.:0.0000 1st Qu.: 7.0 1st Qu.: 0.0000   
## Median :704.0 Median :0.0000 Median : 10.0 Median : 0.0000   
## Mean :710.4 Mean :0.4426 Mean : 11.5 Mean : 0.1346   
## 3rd Qu.:729.0 3rd Qu.:1.0000 3rd Qu.: 14.0 3rd Qu.: 0.0000   
## Max. :850.0 Max. :5.0000 Max. :101.0 Max. :52.0000   
## revol\_bal total\_acc out\_prncp total\_pymnt   
## Min. : 0 Min. : 2.00 Min. : 0 Min. : 0   
## 1st Qu.: 5306 1st Qu.: 14.00 1st Qu.: 4623 1st Qu.: 1757   
## Median : 10833 Median : 21.00 Median : 9736 Median : 3220   
## Mean : 16268 Mean : 22.64 Mean :12001 Mean : 4922   
## 3rd Qu.: 19865 3rd Qu.: 29.00 3rd Qu.:17788 3rd Qu.: 5902   
## Max. :2358150 Max. :160.00 Max. :40000 Max. :51653   
## total\_rec\_int total\_rec\_late\_fee last\_fico\_range\_high inq\_last\_12m   
## Min. : 0.0 Min. : 0.0000 Min. : 0.0 Min. : 0.000   
## 1st Qu.: 401.4 1st Qu.: 0.0000 1st Qu.:679.0 1st Qu.: 0.000   
## Median : 814.2 Median : 0.0000 Median :709.0 Median : 1.000   
## Mean : 1178.5 Mean : 0.5104 Mean :709.4 Mean : 1.938   
## 3rd Qu.: 1573.2 3rd Qu.: 0.0000 3rd Qu.:744.0 3rd Qu.: 3.000   
## Max. :12795.0 Max. :458.5700 Max. :850.0 Max. :67.000   
## tot\_hi\_cred\_lim is\_acct\_delinquent  
## Min. : 0 0:475138   
## 1st Qu.: 52075 1: 18972   
## Median : 116346   
## Mean : 184961   
## 3rd Qu.: 269331   
## Max. :9999999

Peak at initial set of records.

head(ds\_lc)

## loan\_amnt term int\_rate installment home\_ownership annual\_inc dti  
## 1: 5000 1 20.39 186.82 4 50000 21.80  
## 2: 15000 1 9.92 483.45 3 196000 18.29  
## 3: 11200 2 30.79 367.82 4 44000 43.97  
## 4: 25000 2 21.85 688.35 2 65000 12.89  
## 5: 3000 1 7.34 93.10 4 52000 0.58  
## 6: 17000 2 20.39 454.10 4 52000 15.65  
## delinq\_2yrs fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal  
## 1: 1 669 0 5 0 116  
## 2: 0 704 0 19 0 24243  
## 3: 1 669 2 8 0 1526  
## 4: 1 669 1 7 0 8657  
## 5: 0 764 0 7 0 141  
## 6: 0 674 0 9 0 15363  
## total\_acc out\_prncp total\_pymnt total\_rec\_int total\_rec\_late\_fee  
## 1: 18 3780.31 2043.690 824.00 0  
## 2: 53 10878.50 5301.420 1179.92 0  
## 3: 14 10193.73 4007.700 3001.43 0  
## 4: 16 22188.73 7511.160 4699.89 0  
## 5: 30 0.00 3011.577 11.58 0  
## 6: 14 15019.77 4956.590 2976.36 0  
## last\_fico\_range\_high inq\_last\_12m tot\_hi\_cred\_lim is\_acct\_delinquent  
## 1: 609 5 33430 0  
## 2: 694 7 605228 0  
## 3: 629 10 80367 0  
## 4: 669 3 101234 0  
## 5: 764 2 191216 0  
## 6: 634 2 32500 0

## Validation set

Identify whats right the subset distribution for training and test dataset

sample\_set<-sample(nrow(ds\_lc),nrow(ds\_lc)\*0.7)  
training\_dataset <- ds\_lc[sample\_set,]  
test\_dataset <- ds\_lc[-sample\_set,]  
regression\_model <- glm(is\_acct\_delinquent ~   
 loan\_amnt +  
 term +  
 int\_rate +  
 installment +  
 home\_ownership +  
 annual\_inc +  
 dti +  
 delinq\_2yrs +  
 fico\_range\_high +  
 inq\_last\_6mths +  
 open\_acc +  
 pub\_rec +  
 revol\_bal +  
 total\_acc +  
 out\_prncp +  
 total\_pymnt +  
 total\_rec\_int +  
 total\_rec\_late\_fee +  
 last\_fico\_range\_high +  
 inq\_last\_12m +  
 tot\_hi\_cred\_lim,   
 data = training\_dataset, family = "binomial")

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

probablity<-predict(regression\_model,test\_dataset,type="response")  
prediction<-ifelse(probablity > 0.5, 1, 0)  
validation\_error\_rate1 <- mean(prediction != test\_dataset$is\_acct\_delinquent)  
validation\_error\_rate1

## [1] 0.01904434

sample\_set<-sample(nrow(ds\_lc),nrow(ds\_lc)\*0.75)  
training\_dataset <- ds\_lc[sample\_set,]  
test\_dataset <- ds\_lc[-sample\_set,]  
regression\_model <- glm(is\_acct\_delinquent ~   
 loan\_amnt +  
 term +  
 int\_rate +  
 installment +  
 home\_ownership +  
 annual\_inc +  
 dti +  
 delinq\_2yrs +  
 fico\_range\_high +  
 inq\_last\_6mths +  
 open\_acc +  
 pub\_rec +  
 revol\_bal +  
 total\_acc +  
 out\_prncp +  
 total\_pymnt +  
 total\_rec\_int +  
 total\_rec\_late\_fee +  
 last\_fico\_range\_high +  
 inq\_last\_12m +  
 tot\_hi\_cred\_lim,   
 data = training\_dataset, family = "binomial")

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

probablity<-predict(regression\_model,test\_dataset,type="response")  
prediction<-ifelse(probablity > 0.5, 1, 0)  
validation\_error\_rate2 <- mean(prediction != test\_dataset$is\_acct\_delinquent)  
validation\_error\_rate2

## [1] 0.01921022

sample\_set<-sample(nrow(ds\_lc),nrow(ds\_lc)\*0.8)  
training\_dataset <- ds\_lc[sample\_set,]  
test\_dataset <- ds\_lc[-sample\_set,]  
regression\_model <- glm(is\_acct\_delinquent ~   
 loan\_amnt +  
 term +  
 int\_rate +  
 installment +  
 home\_ownership +  
 annual\_inc +  
 dti +  
 delinq\_2yrs +  
 fico\_range\_high +  
 inq\_last\_6mths +  
 open\_acc +  
 pub\_rec +  
 revol\_bal +  
 total\_acc +  
 out\_prncp +  
 total\_pymnt +  
 total\_rec\_int +  
 total\_rec\_late\_fee +  
 last\_fico\_range\_high +  
 inq\_last\_12m +  
 tot\_hi\_cred\_lim,   
 data = training\_dataset, family = "binomial")

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

probablity<-predict(regression\_model,test\_dataset,type="response")  
prediction<-ifelse(probablity > 0.5, 1, 0)  
validation\_error\_rate3 <- mean(prediction != test\_dataset$is\_acct\_delinquent)  
validation\_error\_rate3

## [1] 0.01868005

Following is the data split in training and test data ration along with validation error rate/misclassification

1. Tranining : Test -> 70 : 30, validation error rate 0.0190443. or 1.9044342%   
2. Tranining : Test -> 75 : 25, validation error rate 0.0192102. or 1.921022%   
3. Tranining : Test -> 80 : 20, validation error rate 0.0186801. or 1.8680051%

Validation error rate is different for different sample splits of taining and test dataset. This indicates that validation error rate varies by which observations are in the training/validation sets.

Partition the dataset based on results of above validation set approach.

data\_partition <- createDataPartition(y = ds\_lc$is\_acct\_delinquent, p = 0.75, list = FALSE)  
train\_dataset <- ds\_lc[data\_partition,]  
test\_dataset <- ds\_lc[-data\_partition,]

Number of observations in trianing and test dataset

nrow(train\_dataset)

## [1] 370583

nrow(test\_dataset)

## [1] 123527

## Logistic Regression

logistic\_regression <- glm(is\_acct\_delinquent ~   
 loan\_amnt +  
 term +  
 int\_rate +  
 installment +  
 home\_ownership +  
 annual\_inc +  
 dti +  
 delinq\_2yrs +  
 fico\_range\_high +  
 inq\_last\_6mths +  
 open\_acc +  
 pub\_rec +  
 revol\_bal +  
 total\_acc +  
 out\_prncp +  
 total\_pymnt +  
 total\_rec\_int +  
 total\_rec\_late\_fee +  
 last\_fico\_range\_high +  
 inq\_last\_12m +  
 tot\_hi\_cred\_lim   
 ,data = train\_dataset, family = binomial)

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

predictions <- predict(logistic\_regression, test\_dataset, type="response")  
predicted\_direction <- ifelse(predictions > 0.5, 1, 0)  
error\_rate\_lr <- mean(predicted\_direction != test\_dataset$is\_acct\_delinquent)  
error\_rate\_lr

## [1] 0.01939657

summary(logistic\_regression)

##   
## Call:  
## glm(formula = is\_acct\_delinquent ~ loan\_amnt + term + int\_rate +   
## installment + home\_ownership + annual\_inc + dti + delinq\_2yrs +   
## fico\_range\_high + inq\_last\_6mths + open\_acc + pub\_rec + revol\_bal +   
## total\_acc + out\_prncp + total\_pymnt + total\_rec\_int + total\_rec\_late\_fee +   
## last\_fico\_range\_high + inq\_last\_12m + tot\_hi\_cred\_lim, family = binomial,   
## data = train\_dataset)  
##   
## Deviance Residuals:   
## Min 1Q Median 3Q Max   
## -5.8434 -0.1700 -0.1096 -0.0653 7.4068   
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) 5.287e+00 3.745e-01 14.116 < 2e-16 \*\*\*  
## loan\_amnt 6.304e-03 6.369e-04 9.896 < 2e-16 \*\*\*  
## term 2.836e-01 6.199e-02 4.575 4.77e-06 \*\*\*  
## int\_rate 3.501e-02 3.954e-03 8.855 < 2e-16 \*\*\*  
## installment 3.063e-03 2.494e-04 12.285 < 2e-16 \*\*\*  
## home\_ownership 3.420e-02 1.662e-02 2.058 0.03956 \*   
## annual\_inc -2.711e-06 3.242e-07 -8.360 < 2e-16 \*\*\*  
## dti 8.080e-04 4.470e-04 1.808 0.07065 .   
## delinq\_2yrs -4.568e-02 1.575e-02 -2.900 0.00373 \*\*   
## fico\_range\_high 1.382e-02 4.979e-04 27.765 < 2e-16 \*\*\*  
## inq\_last\_6mths 3.712e-02 1.830e-02 2.028 0.04254 \*   
## open\_acc -2.368e-02 3.271e-03 -7.240 4.47e-13 \*\*\*  
## pub\_rec 1.998e-01 2.943e-02 6.787 1.14e-11 \*\*\*  
## revol\_bal -1.750e-06 8.207e-07 -2.132 0.03298 \*   
## total\_acc 1.756e-02 1.556e-03 11.284 < 2e-16 \*\*\*  
## out\_prncp -6.310e-03 6.370e-04 -9.906 < 2e-16 \*\*\*  
## total\_pymnt -6.523e-03 6.383e-04 -10.220 < 2e-16 \*\*\*  
## total\_rec\_int 6.286e-03 6.399e-04 9.823 < 2e-16 \*\*\*  
## total\_rec\_late\_fee 4.373e-02 1.208e-03 36.185 < 2e-16 \*\*\*  
## last\_fico\_range\_high -2.992e-02 2.559e-04 -116.929 < 2e-16 \*\*\*  
## inq\_last\_12m 3.658e-03 5.701e-03 0.642 0.52109   
## tot\_hi\_cred\_lim -4.004e-08 1.053e-07 -0.380 0.70383   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 120672 on 370582 degrees of freedom  
## Residual deviance: 51060 on 370561 degrees of freedom  
## AIC: 51104  
##   
## Number of Fisher Scoring iterations: 14

Following variables are statitically significant 1. loan\_amnt , term, int\_rate, installment, annual\_inc, fico\_range\_high, open\_acc, pub\_rec, total\_acc, out\_prncp, total\_pymnt, total\_rec\_int, total\_rec\_late\_fee, last\_fico\_range\_high. 2. Following are less significant delinq\_2yrs, home\_ownership, revol\_bal, inq\_last\_6mths

## LDA - Linear Discriminant analysis

lda\_model <- lda(is\_acct\_delinquent ~   
 loan\_amnt +  
 term +  
 int\_rate +  
 installment +  
 home\_ownership +  
 annual\_inc +  
 dti +  
 delinq\_2yrs +  
 fico\_range\_high +  
 inq\_last\_6mths +  
 open\_acc +  
 pub\_rec +  
 revol\_bal +  
 total\_acc +  
 out\_prncp +  
 total\_pymnt +  
 total\_rec\_int +  
 total\_rec\_late\_fee +  
 last\_fico\_range\_high +  
 inq\_last\_12m +  
 tot\_hi\_cred\_lim  
 ,data = train\_dataset)  
predictions <- predict(lda\_model, test\_dataset, type="response")  
confusion\_matrix <- table(predictions$class,   
 test\_dataset$is\_acct\_delinquent,   
 dnn = c("Predicted Status", "Observed Status"))  
confusion\_matrix

## Observed Status  
## Predicted Status 0 1  
## 0 118637 2533  
## 1 147 2210

error\_rate\_lda <- mean(predictions$class != test\_dataset$is\_acct\_delinquent)  
error\_rate\_lda

## [1] 0.02169566

lda\_model

## Call:  
## lda(is\_acct\_delinquent ~ loan\_amnt + term + int\_rate + installment +   
## home\_ownership + annual\_inc + dti + delinq\_2yrs + fico\_range\_high +   
## inq\_last\_6mths + open\_acc + pub\_rec + revol\_bal + total\_acc +   
## out\_prncp + total\_pymnt + total\_rec\_int + total\_rec\_late\_fee +   
## last\_fico\_range\_high + inq\_last\_12m + tot\_hi\_cred\_lim, data = train\_dataset)  
##   
## Prior probabilities of groups:  
## 0 1   
## 0.96160374 0.03839626   
##   
## Group means:  
## loan\_amnt term int\_rate installment home\_ownership annual\_inc dti  
## 0 15968.86 1.301843 12.59062 464.1567 2.904645 80360.59 19.64461  
## 1 17407.84 1.379928 16.08258 522.6086 3.057067 75473.63 20.29670  
## delinq\_2yrs fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal  
## 0 0.2271730 710.7269 0.4349692 11.51513 0.1341475 16317.1  
## 1 0.2764073 702.2274 0.6299810 10.95692 0.1605173 14352.2  
## total\_acc out\_prncp total\_pymnt total\_rec\_int total\_rec\_late\_fee  
## 0 22.65216 12166.254 4979.227 1176.297 0.3191504  
## 1 21.77841 8175.167 3325.927 1247.486 5.4479029  
## last\_fico\_range\_high inq\_last\_12m tot\_hi\_cred\_lim  
## 0 713.5734 1.912626 185747.3  
## 1 603.5727 2.503479 157559.4  
##   
## Coefficients of linear discriminants:  
## LD1  
## loan\_amnt 3.783664e-04  
## term 1.248940e-01  
## int\_rate 1.033248e-02  
## installment 6.765234e-04  
## home\_ownership 1.037697e-02  
## annual\_inc -3.593782e-07  
## dti 5.299934e-04  
## delinq\_2yrs -3.157674e-02  
## fico\_range\_high 8.773818e-03  
## inq\_last\_6mths 4.495268e-03  
## open\_acc -5.829063e-03  
## pub\_rec 2.258794e-02  
## revol\_bal -6.018502e-09  
## total\_acc 2.632893e-03  
## out\_prncp -3.832435e-04  
## total\_pymnt -3.976857e-04  
## total\_rec\_int 2.890081e-04  
## total\_rec\_late\_fee 3.770164e-02  
## last\_fico\_range\_high -1.325355e-02  
## inq\_last\_12m -1.273754e-03  
## tot\_hi\_cred\_lim -9.278842e-08

## QDA - Quadratic Discriminant Analysis

qda\_model <- qda(is\_acct\_delinquent ~   
 loan\_amnt +  
 term +  
 int\_rate +  
 installment +  
 home\_ownership +  
 annual\_inc +  
 dti +  
 delinq\_2yrs +  
 fico\_range\_high +  
 inq\_last\_6mths +  
 open\_acc +  
 pub\_rec +  
 revol\_bal +  
 total\_acc +  
 out\_prncp +  
 last\_fico\_range\_high +  
 inq\_last\_12m +  
 tot\_hi\_cred\_lim  
 ,data = train\_dataset)  
predictions <- predict(qda\_model, test\_dataset, type="response")  
confusion\_matrix <- table(predictions$class,   
 test\_dataset$is\_acct\_delinquent,   
 dnn = c("Predicted Status", "Observed Status"))  
confusion\_matrix

## Observed Status  
## Predicted Status 0 1  
## 0 114275 2077  
## 1 4509 2666

error\_rate\_qda <- mean(predictions$class != test\_dataset$is\_acct\_delinquent)  
error\_rate\_qda

## [1] 0.05331628

qda\_model

## Call:  
## qda(is\_acct\_delinquent ~ loan\_amnt + term + int\_rate + installment +   
## home\_ownership + annual\_inc + dti + delinq\_2yrs + fico\_range\_high +   
## inq\_last\_6mths + open\_acc + pub\_rec + revol\_bal + total\_acc +   
## out\_prncp + last\_fico\_range\_high + inq\_last\_12m + tot\_hi\_cred\_lim,   
## data = train\_dataset)  
##   
## Prior probabilities of groups:  
## 0 1   
## 0.96160374 0.03839626   
##   
## Group means:  
## loan\_amnt term int\_rate installment home\_ownership annual\_inc dti  
## 0 15968.86 1.301843 12.59062 464.1567 2.904645 80360.59 19.64461  
## 1 17407.84 1.379928 16.08258 522.6086 3.057067 75473.63 20.29670  
## delinq\_2yrs fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal  
## 0 0.2271730 710.7269 0.4349692 11.51513 0.1341475 16317.1  
## 1 0.2764073 702.2274 0.6299810 10.95692 0.1605173 14352.2  
## total\_acc out\_prncp last\_fico\_range\_high inq\_last\_12m tot\_hi\_cred\_lim  
## 0 22.65216 12166.254 713.5734 1.912626 185747.3  
## 1 21.77841 8175.167 603.5727 2.503479 157559.4

## KNN

train\_dataset\_matrix <- as.matrix(head(train\_dataset, 80000))  
test\_dataset\_matrix <- as.matrix(head(test\_dataset, 80000))  
train\_dataset\_mini <- head(train\_dataset, 80000)  
predictions <- knn(train\_dataset\_matrix, test\_dataset\_matrix, train\_dataset\_mini$is\_acct\_delinquent, 10)  
confusion\_matrix <- table(predictions,   
 train\_dataset\_mini$is\_acct\_delinquent,   
 dnn = c("Predicted Status", "Observed Status"))  
confusion\_matrix

## Observed Status  
## Predicted Status 0 1  
## 0 74158 5270  
## 1 543 29

error\_rate\_knn <- mean(predictions != train\_dataset\_mini$is\_acct\_delinquent)  
error\_rate\_knn

## [1] 0.0726625

## Tree

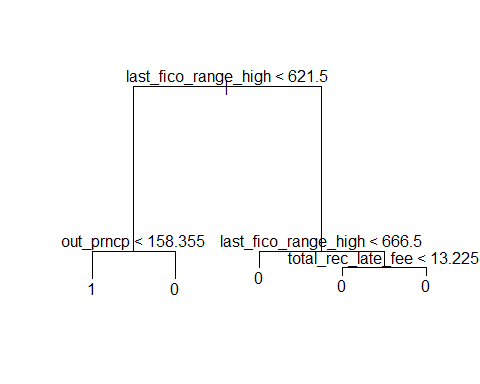
tree\_lc <- tree(is\_acct\_delinquent ~ .,train\_dataset)  
summary(tree\_lc)

##   
## Classification tree:  
## tree(formula = is\_acct\_delinquent ~ ., data = train\_dataset)  
## Variables actually used in tree construction:  
## [1] "last\_fico\_range\_high" "out\_prncp" "total\_rec\_late\_fee"   
## Number of terminal nodes: 5   
## Residual mean deviance: 0.1823 = 67560 / 370600   
## Misclassification error rate: 0.0248 = 9190 / 370583

tree\_lc

## node), split, n, deviance, yval, (yprob)  
## \* denotes terminal node  
##   
## 1) root 370583 120700 0 ( 0.961604 0.038396 )   
## 2) last\_fico\_range\_high < 621.5 16297 22540 1 ( 0.471191 0.528809 )   
## 4) out\_prncp < 158.355 5969 3266 1 ( 0.077902 0.922098 ) \*  
## 5) out\_prncp > 158.355 10328 12640 0 ( 0.698490 0.301510 ) \*  
## 3) last\_fico\_range\_high > 621.5 354286 57650 0 ( 0.984163 0.015837 )   
## 6) last\_fico\_range\_high < 666.5 40938 18900 0 ( 0.938590 0.061410 ) \*  
## 7) last\_fico\_range\_high > 666.5 313348 34760 0 ( 0.990116 0.009884 )   
## 14) total\_rec\_late\_fee < 13.225 311027 30450 0 ( 0.991509 0.008491 ) \*  
## 15) total\_rec\_late\_fee > 13.225 2321 2300 0 ( 0.803533 0.196467 ) \*

plot(tree\_lc)  
text(tree\_lc, pretty=0)



prediction <- predict(tree\_lc, test\_dataset, type="class")  
error\_rate\_tree <- mean(prediction != test\_dataset$is\_acct\_delinquent)  
error\_rate\_tree

## [1] 0.02543573

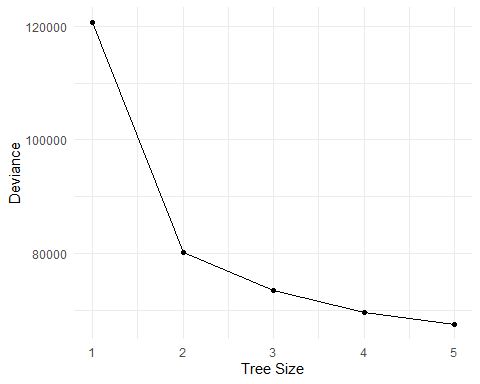
The prime indicator/factor for is loan account delinquent is last\_fico\_range\_high, out\_prncp and total\_rec\_late\_fee When last\_fico\_range\_high < 621.5 out\_prncp < 158.355 , then probablity of loan account becoming delinquent is high.

optimal\_tree <- cv.tree(tree\_lc, FUN = prune.tree)  
optimal\_tree

## $size  
## [1] 5 4 3 2 1  
##   
## $dev  
## [1] 67568.75 69576.84 73566.67 80192.41 120672.32  
##   
## $k  
## [1] -Inf 2012.395 3992.423 6627.537 40481.411  
##   
## $method  
## [1] "deviance"  
##   
## attr(,"class")  
## [1] "prune" "tree.sequence"

Optimal tree size is 4.

tree\_plot <- data.frame(x=optimal\_tree$size, y=optimal\_tree$dev)  
ggplot(tree\_plot, aes(x=x,y=y)) +   
 geom\_point() +   
 geom\_line() +   
 xlab("Tree Size") +   
 ylab("Deviance") +  
 theme\_minimal()



pruned\_tree <- prune.tree(tree\_lc, best = 5)  
optimal\_tree

## $size  
## [1] 5 4 3 2 1  
##   
## $dev  
## [1] 67568.75 69576.84 73566.67 80192.41 120672.32  
##   
## $k  
## [1] -Inf 2012.395 3992.423 6627.537 40481.411  
##   
## $method  
## [1] "deviance"  
##   
## attr(,"class")  
## [1] "prune" "tree.sequence"

#optimal\_tree <- cv.tree(tree\_lc, FUN = prune.tree)  
#optimal\_tree

summary(pruned\_tree)

##   
## Classification tree:  
## tree(formula = is\_acct\_delinquent ~ ., data = train\_dataset)  
## Variables actually used in tree construction:  
## [1] "last\_fico\_range\_high" "out\_prncp" "total\_rec\_late\_fee"   
## Number of terminal nodes: 5   
## Residual mean deviance: 0.1823 = 67560 / 370600   
## Misclassification error rate: 0.0248 = 9190 / 370583

summary(tree\_lc)

##   
## Classification tree:  
## tree(formula = is\_acct\_delinquent ~ ., data = train\_dataset)  
## Variables actually used in tree construction:  
## [1] "last\_fico\_range\_high" "out\_prncp" "total\_rec\_late\_fee"   
## Number of terminal nodes: 5   
## Residual mean deviance: 0.1823 = 67560 / 370600   
## Misclassification error rate: 0.0248 = 9190 / 370583

test\_error\_rate\_pruned <- mean(predict(pruned\_tree, test\_dataset, type = "class") != test\_dataset$is\_acct\_delinquent)  
test\_error\_rate\_pruned

## [1] 0.02543573

test\_error\_rate\_unpruned <- mean(prediction != test\_dataset$is\_acct\_delinquent)  
test\_error\_rate\_unpruned

## [1] 0.02543573

Test error rate of pruned tree is 0.0254357 and unpruned tree is 0.0254357.

Tree error rate is 0.0254357. Logistic regression error rate is 0.0193966. LDA error rate is 0.0216957. QDA error rate is 0.0533163. KNN error rate is 0.0726625.

# Predicting the Interest Rate

## Data Preparation, reset the training and test dataset, identify the interest mean for test dataset

Perform regular subset varibale selection test

ds\_lc <- ds\_lc\_after\_correlation  
regular\_subset\_full <- regsubsets(int\_rate ~ ., ds\_lc, nvmax = 40)  
regular\_subset\_full\_summary <- summary(regular\_subset\_full)  
regular\_subset\_full\_summary

## Subset selection object  
## Call: regsubsets.formula(int\_rate ~ ., ds\_lc, nvmax = 40)  
## 28 Variables (and intercept)  
## Forced in Forced out  
## loan\_amnt FALSE FALSE  
## term FALSE FALSE  
## installment FALSE FALSE  
## home\_ownership FALSE FALSE  
## annual\_inc FALSE FALSE  
## dti FALSE FALSE  
## delinq\_2yrs FALSE FALSE  
## fico\_range\_high FALSE FALSE  
## inq\_last\_6mths FALSE FALSE  
## open\_acc FALSE FALSE  
## pub\_rec FALSE FALSE  
## revol\_bal FALSE FALSE  
## total\_acc FALSE FALSE  
## out\_prncp FALSE FALSE  
## out\_prncp\_inv FALSE FALSE  
## total\_pymnt FALSE FALSE  
## total\_rec\_int FALSE FALSE  
## total\_rec\_late\_fee FALSE FALSE  
## recoveries FALSE FALSE  
## collection\_recovery\_fee FALSE FALSE  
## last\_fico\_range\_high FALSE FALSE  
## acc\_now\_delinq FALSE FALSE  
## inq\_last\_12m FALSE FALSE  
## num\_tl\_30dpd FALSE FALSE  
## num\_tl\_90g\_dpd\_24m FALSE FALSE  
## tot\_hi\_cred\_lim FALSE FALSE  
## num\_rev\_accts FALSE FALSE  
## is\_acct\_delinquent1 FALSE FALSE  
## 1 subsets of each size up to 28  
## Selection Algorithm: exhaustive  
## loan\_amnt term installment home\_ownership annual\_inc dti delinq\_2yrs  
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## fico\_range\_high inq\_last\_6mths open\_acc pub\_rec revol\_bal total\_acc  
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## out\_prncp out\_prncp\_inv total\_pymnt total\_rec\_int total\_rec\_late\_fee  
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## recoveries collection\_recovery\_fee last\_fico\_range\_high  
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## tot\_hi\_cred\_lim num\_rev\_accts is\_acct\_delinquent1  
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regular\_subset\_full\_summary$rsq

## [1] 0.1972473 0.3264305 0.4706522 0.5469314 0.5920637 0.6071163 0.6097479  
## [8] 0.6118065 0.6145510 0.6161798 0.6169453 0.6173691 0.6177940 0.6181047  
## [15] 0.6183851 0.6186869 0.6189722 0.6190940 0.6192078 0.6192787 0.6193367  
## [22] 0.6193688 0.6193889 0.6194045 0.6194099 0.6194111 0.6194112 0.6194112

ds\_lc = subset(ds\_lc, select = -c(open\_acc, revol\_bal, total\_pymnt, total\_rec\_late\_fee, recoveries, collection\_recovery\_fee, acc\_now\_delinq, num\_tl\_30dpd, total\_rec\_int, out\_prncp, out\_prncp\_inv))

train\_dataset\_subset <- sample(nrow(ds\_lc) \* 0.75)  
train\_dataset <- ds\_lc[train\_dataset\_subset, ]  
test\_dataset <- ds\_lc[-train\_dataset\_subset, ]  
nrow(train\_dataset)

## [1] 370582

nrow(test\_dataset)

## [1] 123528

test\_interest\_mean <- mean(test\_dataset$int\_rate)  
test\_interest\_mse <- mean((test\_dataset$int\_rate - test\_interest\_mean)^2)  
test\_interest\_mean

## [1] 12.55028

test\_interest\_mse

## [1] 25.85992

## Fit a linear model using least squares on the training set, and identify the test error obtained.

lm\_fit <- lm(int\_rate ~ . , data = train\_dataset)  
lm\_predictions <- predict(lm\_fit, test\_dataset)  
lm\_mse <- mean((lm\_predictions - test\_dataset$int\_rate)^2)  
lm\_mse

## [1] 10.04827

## Fit a ridge regression model and identify the test error obtained.

train\_ds\_matrix <- model.matrix(int\_rate ~ ., data = train\_dataset)  
test\_ds\_matrix <- model.matrix(int\_rate ~ ., data = test\_dataset)  
  
grid <- 10 ^ seq(4, -2, length = 100)  
  
ridge\_reg\_model <- cv.glmnet(train\_ds\_matrix, train\_dataset$int\_rate, alpha = 0, lambda = grid, thresh = 1e-12)  
ridge\_reg\_predictions <- predict(ridge\_reg\_model, test\_ds\_matrix, s = ridge\_reg\_model$lambda.min)  
ridge\_mse <- mean((test\_dataset$int\_rate - ridge\_reg\_predictions)^2)  
ridge\_mse

## [1] 10.06002

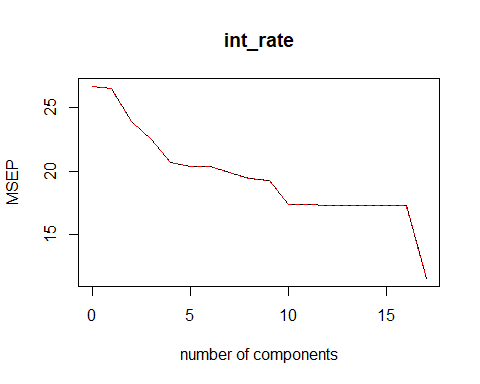
## Fit a Lasso model and identify the test error obtained.

lasso\_model <- cv.glmnet(train\_ds\_matrix, train\_dataset$int\_rate, alpha = 1, lambda = grid, thresh = 1e-12)  
lasso\_predictions <- predict(lasso\_model, test\_ds\_matrix, s = lasso\_model$lambda.min)  
lasso\_mse <- mean((test\_dataset$int\_rate - lasso\_predictions)^2)  
lasso\_rmse <- sqrt(mean((test\_dataset$int\_rate - lasso\_predictions)^2))  
lasso\_mse

## [1] 10.04519

## Fit a PCR model and identify the test error obtained.

pcr\_model <- pcr(int\_rate ~ . , data = train\_dataset, scale=T, validation="CV")  
validationplot(pcr\_model, val.type = "MSEP")

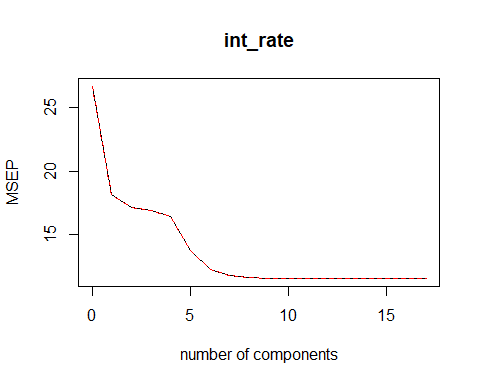


pcr\_predictions <- predict(pcr\_model, test\_dataset, ncomp = 15)  
pcr\_mse <- mean((test\_dataset$int\_rate - pcr\_predictions)^2)  
pcr\_rmse <- sqrt(mean((test\_dataset$int\_rate - pcr\_predictions)^2))  
pcr\_mse

## [1] 15.05007

## Fit a PLS model and identify the test error obtained.

pls\_model <- plsr(int\_rate ~ . , data = train\_dataset, scale=T, validation="CV")  
validationplot(pls\_model, val.type = "MSEP")



pls\_predictions <- predict(pls\_model, test\_dataset, ncomp = 15)  
pls\_mse <- mean((test\_dataset$int\_rate - pls\_predictions)^2)  
pls\_rmse <- sqrt(mean((test\_dataset$int\_rate - pls\_predictions)^2))  
pls\_mse

## [1] 10.04828

Compare R2 values for various models

lm\_test\_r2 <- (1 - (lm\_mse/test\_interest\_mse))  
ridge\_test\_r2 <- (1 - (ridge\_mse/test\_interest\_mse))  
lasso\_test\_r2 <- (1 - (lasso\_mse/test\_interest\_mse))  
pcr\_test\_r2 <- (1 - (pcr\_mse/test\_interest\_mse))  
pls\_test\_r2 <- (1 - (pls\_mse/test\_interest\_mse))  
  
cat("R square with linear model : ", lm\_test\_r2, "\n")

## R square with linear model : 0.6114345

cat("R square with ridge model : ", ridge\_test\_r2, "\n")

## R square with ridge model : 0.6109803

cat("R square with lasso model : ", lasso\_test\_r2, "\n")

## R square with lasso model : 0.6115538

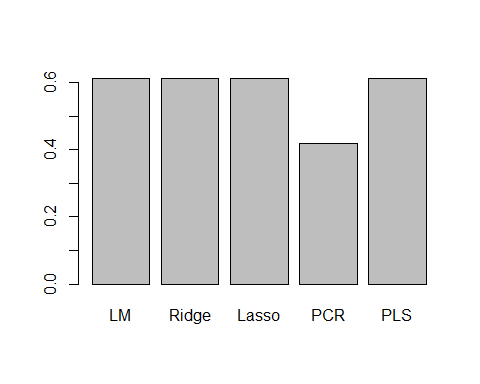
cat("R square with pcr : ", pcr\_test\_r2, "\n")

## R square with pcr : 0.4180156

cat("R square with pls : ", pls\_test\_r2, "\n")

## R square with pls : 0.6114344

barplot(c(lm\_test\_r2, ridge\_test\_r2, lasso\_test\_r2, pcr\_test\_r2, pls\_test\_r2),  
 names.arg = c("LM", "Ridge", "Lasso", "PCR", "PLS"))

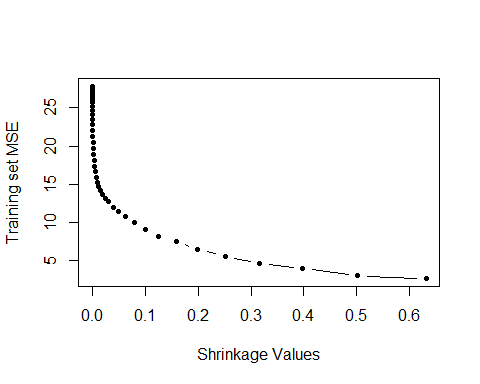


All models have R Square values near to 0.6. All models predict interest rate with high accuracy, pcr has lesser accuracy than others.

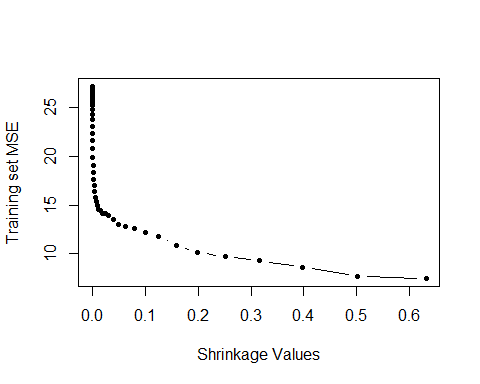
## Boosting

Changed the dataset size due to systme constraints

train\_dataset\_mini <- train\_dataset[1:1000,]  
test\_dataset\_mini <- test\_dataset[(1:1000),]  
  
pows <- seq(-10, -0.2, by = 0.1)  
lambdas <- 10^pows  
training\_errors <- rep(NA, length(lambdas))  
  
  
for (i in 1:length(lambdas)) {  
 boosting\_model <- gbm(int\_rate ~ . , data = train\_dataset\_mini, distribution = "gaussian",   
 n.trees = 1000, shrinkage = lambdas[i])  
   
 training\_predictions <- predict(boosting\_model, train\_dataset\_mini, n.trees = 1000)  
 training\_errors[i] <- mean((training\_predictions - train\_dataset\_mini$int\_rate)^2)  
}  
  
plot(lambdas, training\_errors, xlab = "Shrinkage Values", ylab = "Training set MSE", type = "b", pch = 20)



test\_errors <- rep(NA, length(lambdas))  
for (i in 1:length(lambdas)) {  
 boosting\_model <- gbm(int\_rate ~ . , data = train\_dataset\_mini, distribution = "gaussian",   
 n.trees = 1000, shrinkage = lambdas[i])  
   
 test\_predictions <- predict(boosting\_model, test\_dataset\_mini, n.trees = 1000)  
 test\_errors[i] <- mean((test\_predictions - test\_dataset\_mini$int\_rate)^2)  
}  
  
plot(lambdas, test\_errors, xlab = "Shrinkage Values", ylab = "Training set MSE", type = "b", pch = 20)



min(test\_errors)

## [1] 7.483292

min\_test\_err <- min(test\_errors)  
min\_test\_err\_at <- lambdas[which.min(test\_errors)]

Both regression approaches lm and lasso have higher MSE compared to that of boosting.

## Bagging

random\_forest\_model <- randomForest(int\_rate ~ . , data = train\_dataset\_mini, ntree = 500, mtry = ncol(train\_dataset\_mini)-1)  
random\_forest\_predictions <- predict(random\_forest\_model, test\_dataset\_mini)  
  
random\_forest\_test\_mse <- mean((random\_forest\_predictions - test\_dataset\_mini$int\_rate)^2)  
random\_forest\_test\_mse

## [1] 13.25701

Test MSE for bagging is 13.2570148 which is better than 7.4832922 which is best MSE from boosting

# Unspervised Learning - PCA

ds\_lc\_pca <- ds\_lc\_after\_correlation  
ds\_lc\_pca = subset(ds\_lc\_pca, select = -c(is\_acct\_delinquent,pub\_rec, total\_rec\_late\_fee, recoveries, collection\_recovery\_fee, acc\_now\_delinq,  
 num\_tl\_30dpd,num\_tl\_90g\_dpd\_24m))  
ds\_lc\_pca\_subset <- sample(nrow(ds\_lc), 1000)  
ds\_lc\_pca = ds\_lc\_pca[ds\_lc\_pca\_subset, ]  
str(ds\_lc\_pca)

## Classes 'data.table' and 'data.frame': 1000 obs. of 21 variables:  
## $ loan\_amnt : int 16800 40000 35000 5450 17000 9000 8000 27000 37000 20000 ...  
## $ term : int 2 1 1 1 1 1 1 2 1 1 ...  
## $ int\_rate : num 10.08 6.46 14.03 22.35 7.35 ...  
## $ installment : num 358 1225 1197 209 528 ...  
## $ home\_ownership : int 2 2 4 2 4 2 4 2 2 4 ...  
## $ annual\_inc : num 70000 72000 90000 70000 75000 63000 60000 125000 65000 109000 ...  
## $ dti : num 15.14 9.38 28.72 31.66 18.19 ...  
## $ delinq\_2yrs : int 0 0 0 1 0 0 0 0 0 3 ...  
## $ fico\_range\_high : int 764 754 704 709 724 774 699 684 759 674 ...  
## $ inq\_last\_6mths : int 0 0 2 1 0 0 0 0 1 0 ...  
## $ open\_acc : int 10 12 26 25 8 25 9 13 19 9 ...  
## $ revol\_bal : int 6126 33087 22258 19381 15757 12067 17187 12384 30993 520 ...  
## $ total\_acc : int 27 14 49 50 15 54 13 18 54 15 ...  
## $ out\_prncp : num 15473 35928 27572 4891 10830 ...  
## $ out\_prncp\_inv : num 15473 35928 27552 4891 10830 ...  
## $ total\_pymnt : num 2193 4887 10743 1039 7373 ...  
## $ total\_rec\_int : num 866 814 3315 480 1203 ...  
## $ last\_fico\_range\_high: int 754 699 704 679 684 789 689 729 749 644 ...  
## $ inq\_last\_12m : int 0 0 4 1 0 1 1 3 2 1 ...  
## $ tot\_hi\_cred\_lim : num 210577 411263 143200 346072 48164 ...  
## $ num\_rev\_accts : int 8 11 36 9 10 37 11 13 19 9 ...  
## - attr(\*, ".internal.selfref")=<externalptr>

pr.out <- prcomp (ds\_lc\_pca, scale =TRUE)  
names(pr.out)

## [1] "sdev" "rotation" "center" "scale" "x"

pr.out$center

## loan\_amnt term int\_rate   
## 15845.27500 1.29400 12.84468   
## installment home\_ownership annual\_inc   
## 465.32253 2.92000 82148.09735   
## dti delinq\_2yrs fico\_range\_high   
## 18.91436 0.24300 710.60100   
## inq\_last\_6mths open\_acc revol\_bal   
## 0.39700 11.61000 16711.85100   
## total\_acc out\_prncp out\_prncp\_inv   
## 22.42400 11871.73797 11869.92256   
## total\_pymnt total\_rec\_int last\_fico\_range\_high   
## 5002.13206 1201.61469 709.48500   
## inq\_last\_12m tot\_hi\_cred\_lim num\_rev\_accts   
## 1.80100 179734.06500 13.08400

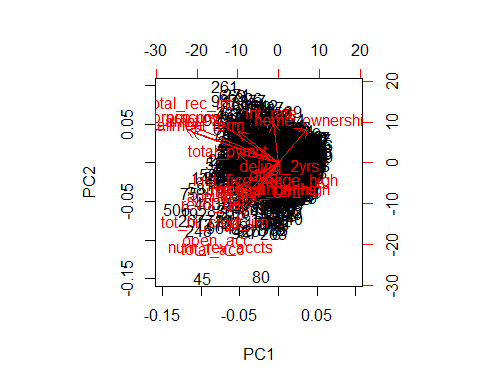
pr.out$scale

## loan\_amnt term int\_rate   
## 1.001715e+04 4.558199e-01 5.226016e+00   
## installment home\_ownership annual\_inc   
## 2.876985e+02 9.383392e-01 6.808805e+04   
## dti delinq\_2yrs fico\_range\_high   
## 1.262500e+01 7.915665e-01 3.721294e+01   
## inq\_last\_6mths open\_acc revol\_bal   
## 6.586538e-01 5.937268e+00 2.247028e+04   
## total\_acc out\_prncp out\_prncp\_inv   
## 1.162710e+01 9.270507e+03 9.269683e+03   
## total\_pymnt total\_rec\_int last\_fico\_range\_high   
## 5.576317e+03 1.136026e+03 5.154898e+01   
## inq\_last\_12m tot\_hi\_cred\_lim num\_rev\_accts   
## 2.155933e+00 1.867068e+05 7.915276e+00

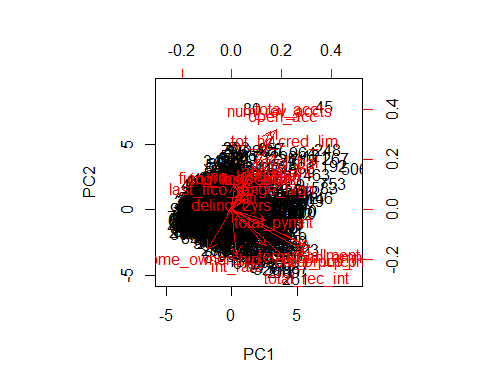
pr.out$rotation

## PC1 PC2 PC3 PC4  
## loan\_amnt -0.394465813 0.19110746 -0.09870499 0.004509554  
## term -0.169586844 0.18067548 0.09403278 -0.155898068  
## int\_rate -0.023748747 0.22889874 0.45963748 -0.019894863  
## installment -0.368870166 0.17837697 -0.06975950 0.044164271  
## home\_ownership 0.121619210 0.19854844 0.08390862 -0.131895655  
## annual\_inc -0.185309798 -0.15415446 -0.07355352 0.554133417  
## dti -0.069797429 -0.05139154 0.17783033 -0.402845774  
## delinq\_2yrs 0.001486556 -0.01715251 0.15535566 0.280728107  
## fico\_range\_high -0.013789323 -0.12413325 -0.48322556 -0.200956754  
## inq\_last\_6mths -0.049616070 -0.12225326 0.18751761 0.038380979  
## open\_acc -0.207773963 -0.36725572 0.20657466 -0.242332361  
## revol\_bal -0.223288514 -0.19061763 -0.03135348 0.166966286  
## total\_acc -0.223754310 -0.39926982 0.16477034 -0.180119578  
## out\_prncp -0.365196509 0.20962834 -0.08511054 -0.062989023  
## out\_prncp\_inv -0.365209356 0.20958999 -0.08510523 -0.063016531  
## total\_pymnt -0.170274851 0.05245716 -0.03080631 0.079623912  
## total\_rec\_int -0.300691805 0.27564465 0.14596656 -0.053925673  
## last\_fico\_range\_high -0.042918468 -0.08114876 -0.47907005 -0.259906399  
## inq\_last\_12m -0.086243859 -0.13113062 0.21324360 0.182241549  
## tot\_hi\_cred\_lim -0.214609115 -0.27457513 -0.14448261 0.281285466  
## num\_rev\_accts -0.194331640 -0.39209973 0.15811086 -0.223163398  
## PC5 PC6 PC7 PC8  
## loan\_amnt 1.568299e-01 -0.038684944 -0.03115670 -0.0408075892  
## term -3.316692e-01 0.280986169 0.24140819 -0.2047799921  
## int\_rate -1.672539e-01 -0.005382643 0.24641022 -0.0098887186  
## installment 2.607778e-01 -0.147931551 -0.06778477 0.0138850018  
## home\_ownership 3.284474e-01 -0.067686264 -0.40209221 0.2848090761  
## annual\_inc -3.742349e-02 0.004778112 -0.05988923 0.0961950238  
## dti -8.112948e-02 -0.304565923 0.36349235 0.1217788930  
## delinq\_2yrs -1.116137e-01 -0.126155467 -0.26277252 -0.6842147143  
## fico\_range\_high 3.583976e-02 0.221743364 0.12683401 -0.1409736957  
## inq\_last\_6mths 2.728005e-01 0.530257043 0.09698279 0.1732997705  
## open\_acc 4.871253e-02 -0.043514146 -0.14340182 0.0007616922  
## revol\_bal -1.482465e-01 -0.290008244 0.07714669 0.4345839169  
## total\_acc 5.916006e-05 -0.011930679 -0.12074643 -0.1461357119  
## out\_prncp -1.755227e-01 0.138713117 -0.23511468 0.0853416642  
## out\_prncp\_inv -1.756784e-01 0.138720914 -0.23501194 0.0853176231  
## total\_pymnt 5.809642e-01 -0.301920460 0.35140949 -0.2477069036  
## total\_rec\_int 2.959496e-02 0.006464123 0.12953091 -0.0966560075  
## last\_fico\_range\_high 4.875369e-02 0.087161075 0.09264631 -0.1455070151  
## inq\_last\_12m 2.826352e-01 0.476761390 0.17104112 0.0169078905  
## tot\_hi\_cred\_lim -2.382708e-01 -0.054022435 0.29738780 0.0733136314  
## num\_rev\_accts 4.415561e-02 -0.019363453 -0.25564700 -0.1026523320  
## PC9 PC10 PC11 PC12  
## loan\_amnt 0.008806248 -0.070491191 0.01027847 -0.139473446  
## term -0.422315628 0.335662079 0.12774490 -0.396670179  
## int\_rate -0.036245698 0.177273078 0.01052682 0.513419454  
## installment 0.136570874 -0.158915931 -0.01676597 0.059852761  
## home\_ownership -0.048839679 0.628246781 -0.02672620 -0.014071645  
## annual\_inc -0.075903738 0.321840404 -0.09683292 0.367042711  
## dti 0.563619755 0.163582632 -0.17410813 -0.076387161  
## delinq\_2yrs 0.428000347 0.274211591 0.11086594 -0.173984058  
## fico\_range\_high 0.070490834 0.253550475 -0.03948780 0.065852702  
## inq\_last\_6mths 0.331495261 -0.006346664 0.65776873 0.020295267  
## open\_acc -0.110192750 0.022084590 -0.06329800 0.090355822  
## revol\_bal -0.018499331 0.265509253 0.18409822 -0.355852486  
## total\_acc -0.113674661 -0.037232561 -0.01004437 0.113178393  
## out\_prncp 0.141225681 -0.076149419 -0.05971861 -0.017299092  
## out\_prncp\_inv 0.141140381 -0.076066607 -0.05971178 -0.017313189  
## total\_pymnt -0.213245791 0.025376718 0.12188302 -0.108519194  
## total\_rec\_int -0.111094105 0.029023439 0.03144502 0.263217808  
## last\_fico\_range\_high 0.080796554 0.263517456 0.01237452 0.311270429  
## inq\_last\_12m 0.102108288 0.075509958 -0.65603373 -0.224069652  
## tot\_hi\_cred\_lim 0.061536151 0.006502538 0.03324791 0.061878973  
## num\_rev\_accts -0.184178927 -0.022392846 0.06045110 0.007530041  
## PC13 PC14 PC15 PC16  
## loan\_amnt -0.078467375 0.051794454 0.042741702 -0.198362151  
## term -0.140468381 0.228627032 0.106905250 -0.073902625  
## int\_rate 0.201914105 -0.212722603 -0.081210473 -0.492125526  
## installment -0.002623489 -0.042369273 -0.013923968 -0.267554217  
## home\_ownership -0.141878537 -0.197150907 0.300520326 0.037811370  
## annual\_inc -0.302866815 0.477851284 -0.200228461 0.032133958  
## dti -0.260648721 0.277314964 -0.047352250 0.084512738  
## delinq\_2yrs 0.110741293 -0.104096546 -0.006681202 0.027805271  
## fico\_range\_high -0.324364623 -0.443177429 -0.457433359 -0.152966428  
## inq\_last\_6mths -0.036676954 0.074466904 0.013468259 0.025273132  
## open\_acc -0.082740564 -0.021826121 0.122435037 0.041005593  
## revol\_bal 0.450704089 -0.139025524 -0.306912385 -0.000935994  
## total\_acc -0.063514106 0.005778384 0.144514249 -0.018445297  
## out\_prncp 0.004267601 0.015408920 0.040300986 -0.036001650  
## out\_prncp\_inv 0.004254292 0.015414575 0.040246473 -0.036107536  
## total\_pymnt -0.030771063 0.051133060 0.048821356 -0.067008419  
## total\_rec\_int 0.064626343 -0.225792800 -0.189346669 0.767912097  
## last\_fico\_range\_high 0.571402533 0.291309041 0.250894202 0.032275418  
## inq\_last\_12m 0.238568591 -0.067368806 -0.006778284 0.014990019  
## tot\_hi\_cred\_lim -0.157501628 -0.421504555 0.580352174 0.041204631  
## num\_rev\_accts 0.085568386 -0.011131017 -0.257848606 -0.072367132  
## PC17 PC18 PC19 PC20  
## loan\_amnt -0.001252709 -2.264610e-05 -0.0816370348 8.295167e-01  
## term 0.013178533 -2.764376e-02 -0.2042882772 -1.415301e-01  
## int\_rate 0.013903038 3.675151e-03 0.1061513261 6.190869e-02  
## installment 0.011174348 1.370899e-03 -0.6617693613 -4.137718e-01  
## home\_ownership -0.126922740 -3.333469e-02 -0.0119976283 -6.073993e-04  
## annual\_inc 0.002003833 -2.189082e-02 0.0054931536 -3.463406e-03  
## dti -0.104201170 -8.130611e-02 0.0030537094 8.277638e-04  
## delinq\_2yrs 0.078376836 9.482218e-03 -0.0088260950 4.657468e-03  
## fico\_range\_high 0.060600082 9.910185e-02 0.0317223018 -1.341659e-02  
## inq\_last\_6mths 0.014037228 4.053501e-03 0.0001062685 4.617332e-04  
## open\_acc 0.804203854 -3.192218e-05 -0.0069359477 1.170405e-02  
## revol\_bal 0.054333827 1.817793e-01 0.0059151356 9.402961e-05  
## total\_acc -0.414149031 6.861166e-01 -0.0007036173 -7.829500e-03  
## out\_prncp 0.001473613 -2.712281e-03 0.3643166867 -1.825035e-01  
## out\_prncp\_inv 0.001386572 -2.841503e-03 0.3647433724 -1.819374e-01  
## total\_pymnt 0.016456330 -1.458095e-02 0.4668498468 -2.140703e-01  
## total\_rec\_int -0.038545917 1.320148e-03 -0.1167121022 5.555135e-02  
## last\_fico\_range\_high 0.010740888 -4.579167e-02 -0.0560042293 3.273764e-02  
## inq\_last\_12m -0.034444850 -1.383890e-02 -0.0107092587 -4.975758e-03  
## tot\_hi\_cred\_lim -0.108830996 -2.512512e-01 -0.0182742718 -9.214362e-04  
## num\_rev\_accts -0.355528982 -6.415971e-01 0.0111207829 -7.512467e-05  
## PC21  
## loan\_amnt -2.973263e-04  
## term 4.109704e-06  
## int\_rate -1.329229e-04  
## installment 4.012092e-04  
## home\_ownership 4.133337e-05  
## annual\_inc -2.448955e-05  
## dti -3.178243e-05  
## delinq\_2yrs 1.754884e-05  
## fico\_range\_high -4.600273e-05  
## inq\_last\_6mths 3.947363e-05  
## open\_acc 4.596496e-05  
## revol\_bal -2.684684e-05  
## total\_acc 2.999689e-05  
## out\_prncp -7.071321e-01  
## out\_prncp\_inv 7.070813e-01  
## total\_pymnt -3.768613e-05  
## total\_rec\_int 5.182154e-05  
## last\_fico\_range\_high -1.109102e-06  
## inq\_last\_12m 2.264823e-05  
## tot\_hi\_cred\_lim -4.400992e-05  
## num\_rev\_accts -1.038908e-04

biplot(pr.out)



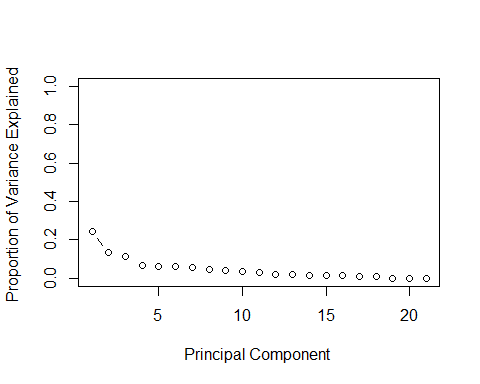
pr.out$rotation=-pr.out$rotation  
pr.out$x=-pr.out$x  
biplot (pr.out , scale =0)



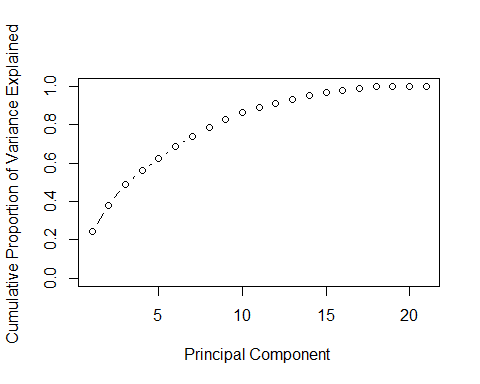
#pr.out$sdev  
pr.var =pr.out$sdev ^2  
pve=pr.var/sum(pr.var )  
pve

## [1] 2.461474e-01 1.340023e-01 1.115083e-01 6.853673e-02 6.314414e-02  
## [6] 6.155826e-02 5.466479e-02 4.825510e-02 3.892011e-02 3.571041e-02  
## [11] 2.910525e-02 2.184266e-02 2.033240e-02 1.742015e-02 1.503103e-02  
## [16] 1.285552e-02 1.169829e-02 7.654764e-03 1.270527e-03 3.416961e-04  
## [21] 8.271313e-08

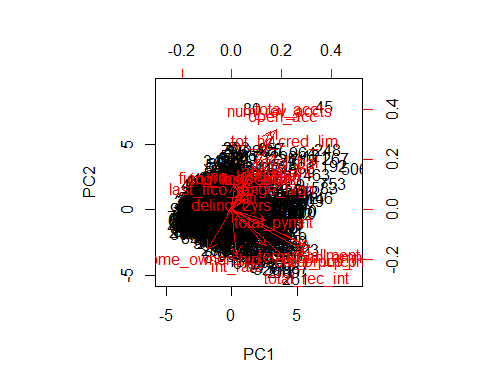
plot(pve , xlab="Principal Component ", ylab="Proportion of Variance Explained ", ylim=c(0,1) ,type="b")



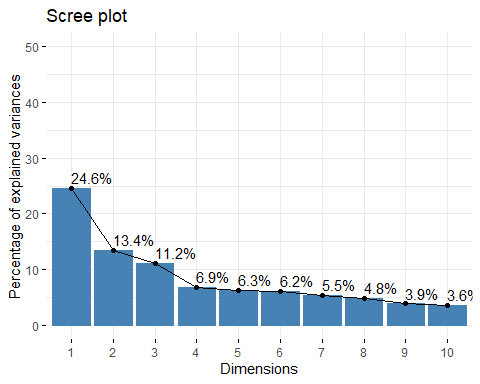
plot(cumsum (pve ), xlab="Principal Component ", ylab ="Cumulative Proportion of Variance Explained ", ylim=c(0,1) , type="b")



#autoplot(pr.out)  
biplot (pr.out , scale =0)



fviz\_eig(pr.out, addlabels = TRUE, ylim = c(0, 50))



pr.out

## Standard deviations (1, .., p=21):  
## [1] 2.273564615 1.677512763 1.530253116 1.199696352 1.151532455 1.136979950  
## [7] 1.071429240 1.006656376 0.904058847 0.865978415 0.781799394 0.677270904  
## [13] 0.653437403 0.604833165 0.561828825 0.519582391 0.495645152 0.400936454  
## [19] 0.163343426 0.084709017 0.001317944  
##   
## Rotation (n x k) = (21 x 21):  
## PC1 PC2 PC3 PC4  
## loan\_amnt 0.394465813 -0.19110746 0.09870499 -0.004509554  
## term 0.169586844 -0.18067548 -0.09403278 0.155898068  
## int\_rate 0.023748747 -0.22889874 -0.45963748 0.019894863  
## installment 0.368870166 -0.17837697 0.06975950 -0.044164271  
## home\_ownership -0.121619210 -0.19854844 -0.08390862 0.131895655  
## annual\_inc 0.185309798 0.15415446 0.07355352 -0.554133417  
## dti 0.069797429 0.05139154 -0.17783033 0.402845774  
## delinq\_2yrs -0.001486556 0.01715251 -0.15535566 -0.280728107  
## fico\_range\_high 0.013789323 0.12413325 0.48322556 0.200956754  
## inq\_last\_6mths 0.049616070 0.12225326 -0.18751761 -0.038380979  
## open\_acc 0.207773963 0.36725572 -0.20657466 0.242332361  
## revol\_bal 0.223288514 0.19061763 0.03135348 -0.166966286  
## total\_acc 0.223754310 0.39926982 -0.16477034 0.180119578  
## out\_prncp 0.365196509 -0.20962834 0.08511054 0.062989023  
## out\_prncp\_inv 0.365209356 -0.20958999 0.08510523 0.063016531  
## total\_pymnt 0.170274851 -0.05245716 0.03080631 -0.079623912  
## total\_rec\_int 0.300691805 -0.27564465 -0.14596656 0.053925673  
## last\_fico\_range\_high 0.042918468 0.08114876 0.47907005 0.259906399  
## inq\_last\_12m 0.086243859 0.13113062 -0.21324360 -0.182241549  
## tot\_hi\_cred\_lim 0.214609115 0.27457513 0.14448261 -0.281285466  
## num\_rev\_accts 0.194331640 0.39209973 -0.15811086 0.223163398  
## PC5 PC6 PC7 PC8  
## loan\_amnt -1.568299e-01 0.038684944 0.03115670 0.0408075892  
## term 3.316692e-01 -0.280986169 -0.24140819 0.2047799921  
## int\_rate 1.672539e-01 0.005382643 -0.24641022 0.0098887186  
## installment -2.607778e-01 0.147931551 0.06778477 -0.0138850018  
## home\_ownership -3.284474e-01 0.067686264 0.40209221 -0.2848090761  
## annual\_inc 3.742349e-02 -0.004778112 0.05988923 -0.0961950238  
## dti 8.112948e-02 0.304565923 -0.36349235 -0.1217788930  
## delinq\_2yrs 1.116137e-01 0.126155467 0.26277252 0.6842147143  
## fico\_range\_high -3.583976e-02 -0.221743364 -0.12683401 0.1409736957  
## inq\_last\_6mths -2.728005e-01 -0.530257043 -0.09698279 -0.1732997705  
## open\_acc -4.871253e-02 0.043514146 0.14340182 -0.0007616922  
## revol\_bal 1.482465e-01 0.290008244 -0.07714669 -0.4345839169  
## total\_acc -5.916006e-05 0.011930679 0.12074643 0.1461357119  
## out\_prncp 1.755227e-01 -0.138713117 0.23511468 -0.0853416642  
## out\_prncp\_inv 1.756784e-01 -0.138720914 0.23501194 -0.0853176231  
## total\_pymnt -5.809642e-01 0.301920460 -0.35140949 0.2477069036  
## total\_rec\_int -2.959496e-02 -0.006464123 -0.12953091 0.0966560075  
## last\_fico\_range\_high -4.875369e-02 -0.087161075 -0.09264631 0.1455070151  
## inq\_last\_12m -2.826352e-01 -0.476761390 -0.17104112 -0.0169078905  
## tot\_hi\_cred\_lim 2.382708e-01 0.054022435 -0.29738780 -0.0733136314  
## num\_rev\_accts -4.415561e-02 0.019363453 0.25564700 0.1026523320  
## PC9 PC10 PC11 PC12  
## loan\_amnt -0.008806248 0.070491191 -0.01027847 0.139473446  
## term 0.422315628 -0.335662079 -0.12774490 0.396670179  
## int\_rate 0.036245698 -0.177273078 -0.01052682 -0.513419454  
## installment -0.136570874 0.158915931 0.01676597 -0.059852761  
## home\_ownership 0.048839679 -0.628246781 0.02672620 0.014071645  
## annual\_inc 0.075903738 -0.321840404 0.09683292 -0.367042711  
## dti -0.563619755 -0.163582632 0.17410813 0.076387161  
## delinq\_2yrs -0.428000347 -0.274211591 -0.11086594 0.173984058  
## fico\_range\_high -0.070490834 -0.253550475 0.03948780 -0.065852702  
## inq\_last\_6mths -0.331495261 0.006346664 -0.65776873 -0.020295267  
## open\_acc 0.110192750 -0.022084590 0.06329800 -0.090355822  
## revol\_bal 0.018499331 -0.265509253 -0.18409822 0.355852486  
## total\_acc 0.113674661 0.037232561 0.01004437 -0.113178393  
## out\_prncp -0.141225681 0.076149419 0.05971861 0.017299092  
## out\_prncp\_inv -0.141140381 0.076066607 0.05971178 0.017313189  
## total\_pymnt 0.213245791 -0.025376718 -0.12188302 0.108519194  
## total\_rec\_int 0.111094105 -0.029023439 -0.03144502 -0.263217808  
## last\_fico\_range\_high -0.080796554 -0.263517456 -0.01237452 -0.311270429  
## inq\_last\_12m -0.102108288 -0.075509958 0.65603373 0.224069652  
## tot\_hi\_cred\_lim -0.061536151 -0.006502538 -0.03324791 -0.061878973  
## num\_rev\_accts 0.184178927 0.022392846 -0.06045110 -0.007530041  
## PC13 PC14 PC15 PC16  
## loan\_amnt 0.078467375 -0.051794454 -0.042741702 0.198362151  
## term 0.140468381 -0.228627032 -0.106905250 0.073902625  
## int\_rate -0.201914105 0.212722603 0.081210473 0.492125526  
## installment 0.002623489 0.042369273 0.013923968 0.267554217  
## home\_ownership 0.141878537 0.197150907 -0.300520326 -0.037811370  
## annual\_inc 0.302866815 -0.477851284 0.200228461 -0.032133958  
## dti 0.260648721 -0.277314964 0.047352250 -0.084512738  
## delinq\_2yrs -0.110741293 0.104096546 0.006681202 -0.027805271  
## fico\_range\_high 0.324364623 0.443177429 0.457433359 0.152966428  
## inq\_last\_6mths 0.036676954 -0.074466904 -0.013468259 -0.025273132  
## open\_acc 0.082740564 0.021826121 -0.122435037 -0.041005593  
## revol\_bal -0.450704089 0.139025524 0.306912385 0.000935994  
## total\_acc 0.063514106 -0.005778384 -0.144514249 0.018445297  
## out\_prncp -0.004267601 -0.015408920 -0.040300986 0.036001650  
## out\_prncp\_inv -0.004254292 -0.015414575 -0.040246473 0.036107536  
## total\_pymnt 0.030771063 -0.051133060 -0.048821356 0.067008419  
## total\_rec\_int -0.064626343 0.225792800 0.189346669 -0.767912097  
## last\_fico\_range\_high -0.571402533 -0.291309041 -0.250894202 -0.032275418  
## inq\_last\_12m -0.238568591 0.067368806 0.006778284 -0.014990019  
## tot\_hi\_cred\_lim 0.157501628 0.421504555 -0.580352174 -0.041204631  
## num\_rev\_accts -0.085568386 0.011131017 0.257848606 0.072367132  
## PC17 PC18 PC19 PC20  
## loan\_amnt 0.001252709 2.264610e-05 0.0816370348 -8.295167e-01  
## term -0.013178533 2.764376e-02 0.2042882772 1.415301e-01  
## int\_rate -0.013903038 -3.675151e-03 -0.1061513261 -6.190869e-02  
## installment -0.011174348 -1.370899e-03 0.6617693613 4.137718e-01  
## home\_ownership 0.126922740 3.333469e-02 0.0119976283 6.073993e-04  
## annual\_inc -0.002003833 2.189082e-02 -0.0054931536 3.463406e-03  
## dti 0.104201170 8.130611e-02 -0.0030537094 -8.277638e-04  
## delinq\_2yrs -0.078376836 -9.482218e-03 0.0088260950 -4.657468e-03  
## fico\_range\_high -0.060600082 -9.910185e-02 -0.0317223018 1.341659e-02  
## inq\_last\_6mths -0.014037228 -4.053501e-03 -0.0001062685 -4.617332e-04  
## open\_acc -0.804203854 3.192218e-05 0.0069359477 -1.170405e-02  
## revol\_bal -0.054333827 -1.817793e-01 -0.0059151356 -9.402961e-05  
## total\_acc 0.414149031 -6.861166e-01 0.0007036173 7.829500e-03  
## out\_prncp -0.001473613 2.712281e-03 -0.3643166867 1.825035e-01  
## out\_prncp\_inv -0.001386572 2.841503e-03 -0.3647433724 1.819374e-01  
## total\_pymnt -0.016456330 1.458095e-02 -0.4668498468 2.140703e-01  
## total\_rec\_int 0.038545917 -1.320148e-03 0.1167121022 -5.555135e-02  
## last\_fico\_range\_high -0.010740888 4.579167e-02 0.0560042293 -3.273764e-02  
## inq\_last\_12m 0.034444850 1.383890e-02 0.0107092587 4.975758e-03  
## tot\_hi\_cred\_lim 0.108830996 2.512512e-01 0.0182742718 9.214362e-04  
## num\_rev\_accts 0.355528982 6.415971e-01 -0.0111207829 7.512467e-05  
## PC21  
## loan\_amnt 2.973263e-04  
## term -4.109704e-06  
## int\_rate 1.329229e-04  
## installment -4.012092e-04  
## home\_ownership -4.133337e-05  
## annual\_inc 2.448955e-05  
## dti 3.178243e-05  
## delinq\_2yrs -1.754884e-05  
## fico\_range\_high 4.600273e-05  
## inq\_last\_6mths -3.947363e-05  
## open\_acc -4.596496e-05  
## revol\_bal 2.684684e-05  
## total\_acc -2.999689e-05  
## out\_prncp 7.071321e-01  
## out\_prncp\_inv -7.070813e-01  
## total\_pymnt 3.768613e-05  
## total\_rec\_int -5.182154e-05  
## last\_fico\_range\_high 1.109102e-06  
## inq\_last\_12m -2.264823e-05  
## tot\_hi\_cred\_lim 4.400992e-05  
## num\_rev\_accts 1.038908e-04

pr.out$rotation[1:21,1:5]

## PC1 PC2 PC3 PC4  
## loan\_amnt 0.394465813 -0.19110746 0.09870499 -0.004509554  
## term 0.169586844 -0.18067548 -0.09403278 0.155898068  
## int\_rate 0.023748747 -0.22889874 -0.45963748 0.019894863  
## installment 0.368870166 -0.17837697 0.06975950 -0.044164271  
## home\_ownership -0.121619210 -0.19854844 -0.08390862 0.131895655  
## annual\_inc 0.185309798 0.15415446 0.07355352 -0.554133417  
## dti 0.069797429 0.05139154 -0.17783033 0.402845774  
## delinq\_2yrs -0.001486556 0.01715251 -0.15535566 -0.280728107  
## fico\_range\_high 0.013789323 0.12413325 0.48322556 0.200956754  
## inq\_last\_6mths 0.049616070 0.12225326 -0.18751761 -0.038380979  
## open\_acc 0.207773963 0.36725572 -0.20657466 0.242332361  
## revol\_bal 0.223288514 0.19061763 0.03135348 -0.166966286  
## total\_acc 0.223754310 0.39926982 -0.16477034 0.180119578  
## out\_prncp 0.365196509 -0.20962834 0.08511054 0.062989023  
## out\_prncp\_inv 0.365209356 -0.20958999 0.08510523 0.063016531  
## total\_pymnt 0.170274851 -0.05245716 0.03080631 -0.079623912  
## total\_rec\_int 0.300691805 -0.27564465 -0.14596656 0.053925673  
## last\_fico\_range\_high 0.042918468 0.08114876 0.47907005 0.259906399  
## inq\_last\_12m 0.086243859 0.13113062 -0.21324360 -0.182241549  
## tot\_hi\_cred\_lim 0.214609115 0.27457513 0.14448261 -0.281285466  
## num\_rev\_accts 0.194331640 0.39209973 -0.15811086 0.223163398  
## PC5  
## loan\_amnt -1.568299e-01  
## term 3.316692e-01  
## int\_rate 1.672539e-01  
## installment -2.607778e-01  
## home\_ownership -3.284474e-01  
## annual\_inc 3.742349e-02  
## dti 8.112948e-02  
## delinq\_2yrs 1.116137e-01  
## fico\_range\_high -3.583976e-02  
## inq\_last\_6mths -2.728005e-01  
## open\_acc -4.871253e-02  
## revol\_bal 1.482465e-01  
## total\_acc -5.916006e-05  
## out\_prncp 1.755227e-01  
## out\_prncp\_inv 1.756784e-01  
## total\_pymnt -5.809642e-01  
## total\_rec\_int -2.959496e-02  
## last\_fico\_range\_high -4.875369e-02  
## inq\_last\_12m -2.826352e-01  
## tot\_hi\_cred\_lim 2.382708e-01  
## num\_rev\_accts -4.415561e-02

write.csv(pr.out$rotation[1:21,1:5], file = "data/pca\_output.csv", row.names=FALSE)

Based on the weights of variables across 5 components, here are the composition of variables across five components, in each of these componenets varibales listed below are correlated with each other

PC1 => total\_pymnt,num\_rev\_accts,term,open\_acc,total\_acc,annual\_inc,revol\_bal,tot\_hi\_cred\_lim,total\_rec\_int,out\_prncp,installment, loan\_amnt

PC2 => inq\_last\_6mths ,tot\_hi\_cred\_lim ,open\_acc,total\_acc ,num\_rev\_accts,total\_rec\_int ,int\_rate,out\_prncp ,out\_prncp\_inv,loan\_amnt,installment

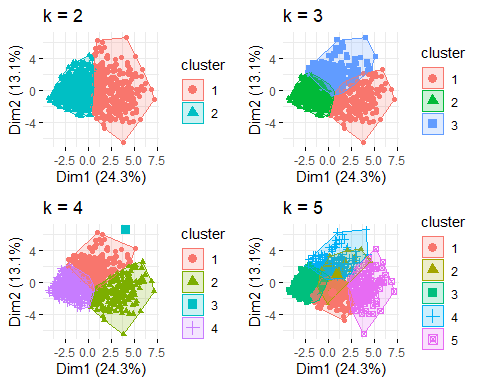
PC3 => total\_acc ,total\_rec\_int,delinq\_2yrs,dti,inq\_last\_12m,int\_rate,fico\_range\_high,last\_fico\_range\_high

PC4 => delinq\_2yrs,dti,revol\_bal ,inq\_last\_12m,inq\_last\_6mths ,total\_pymnt,fico\_range\_high

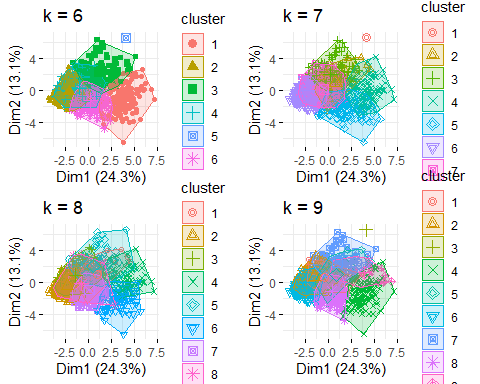
PC5 => annual\_inc,tot\_hi\_cred\_lim ,delinq\_2yrs,total\_acc ,total\_rec\_int ,num\_rev\_accts,total\_pymnt,fico\_range\_high,open\_acc,home\_ownership,last\_fico\_range\_high,dti

ds\_lc\_kmean <- ds\_lc\_after\_correlation  
ds\_lc\_kmean = subset(ds\_lc\_kmean, select = -c(is\_acct\_delinquent,pub\_rec, total\_rec\_late\_fee, recoveries, collection\_recovery\_fee, acc\_now\_delinq,  
 num\_tl\_30dpd,num\_tl\_90g\_dpd\_24m))  
ds\_lc\_kmean\_subset <- sample(nrow(ds\_lc\_kmean), 1000)  
ds\_lc\_kmean = ds\_lc\_kmean[ds\_lc\_kmean\_subset, ]  
ds\_lc\_kmean\_scaled <- as.data.frame(scale(ds\_lc\_kmean))

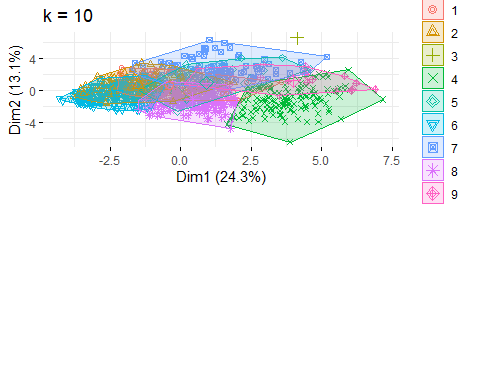
set.seed (12345)  
k2 <- kmeans(ds\_lc\_kmean\_scaled, centers = 2, nstart = 25)  
k3 <- kmeans(ds\_lc\_kmean\_scaled, centers = 3, nstart = 25)  
k4 <- kmeans(ds\_lc\_kmean\_scaled, centers = 4, nstart = 25)  
k5 <- kmeans(ds\_lc\_kmean\_scaled, centers = 5, nstart = 25)  
k6 <- kmeans(ds\_lc\_kmean\_scaled, centers = 6, nstart = 25)  
k7 <- kmeans(ds\_lc\_kmean\_scaled, centers = 7, nstart = 25)  
k8 <- kmeans(ds\_lc\_kmean\_scaled, centers = 8, nstart = 25)  
k9 <- kmeans(ds\_lc\_kmean\_scaled, centers = 9, nstart = 25)  
  
  
# plots to compare  
p2 <- fviz\_cluster(k2, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 2")  
p3 <- fviz\_cluster(k3, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 3")  
p4 <- fviz\_cluster(k4, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 4")  
p5 <- fviz\_cluster(k5, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 5")  
p6 <- fviz\_cluster(k6, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 6")  
p7 <- fviz\_cluster(k7, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 7")  
p8 <- fviz\_cluster(k8, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 8")  
p9 <- fviz\_cluster(k9, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 9")  
p10 <- fviz\_cluster(k9, geom = "point", data = ds\_lc\_kmean\_scaled, ggtheme = theme\_minimal()) + ggtitle("k = 10")  
  
  
grid.arrange(p2, p3, p4, p5, nrow = 2)



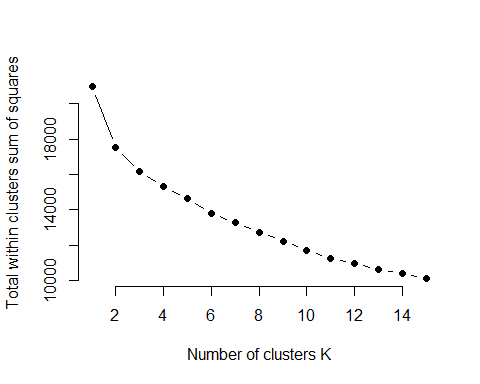
grid.arrange(p6, p7, p8, p9, nrow = 2)



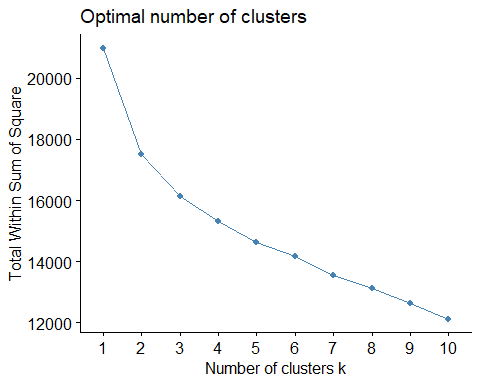
grid.arrange(p10, nrow = 2)



set.seed(1234)  
#Function to compute total within cluster sum of squares   
wss <- function(k) {  
 kmeans(ds\_lc\_kmean\_scaled, k, nstart = 25, iter.max = 10)$tot.withinss  
}  
  
#Compute and plot the within sum of squares (wss) for k = 1 to k = 10  
k.values <- 1:15  
  
#Extract wss for 2 - 10 clusters  
wss\_values <- map\_dbl(k.values, wss)  
  
plot(k.values, wss\_values,  
 type = "b", pch = 19, frame = FALSE,  
 xlab = "Number of clusters K",  
 ylab = "Total within clusters sum of squares")



set.seed(1234)  
fviz\_nbclust(ds\_lc\_kmean\_scaled, kmeans, method = "wss")



Based on the visualization 3 clusters seems to be better classification. 3 clusters have very less overlap compared to that of the 4 clusters.

ds\_lc\_kmean$cluster <- k3$cluster

ds\_lc\_kmean$category <- ""  
for(i in 1:nrow(ds\_lc\_kmean)){  
 if (ds\_lc\_kmean$cluster[i] == 1){  
 ds\_lc\_kmean$category[i] <- "Low"  
 }  
 else if (ds\_lc\_kmean$cluster[i] == 2){  
 ds\_lc\_kmean$category[i] <- "Medium"  
 }  
 else if (ds\_lc\_kmean$cluster[i] == 3){  
 ds\_lc\_kmean$category[i] <- "High"  
 }  
}  
  
low\_risk\_loans <- ds\_lc\_kmean %>%  
 filter(category == "Low")  
  
medium\_risk\_loans <- ds\_lc\_kmean %>%  
 filter(category == "Medium")  
  
high\_risk\_loans <- ds\_lc\_kmean %>%  
 filter(category == "High")

mean(low\_risk\_loans$int\_rate)

## [1] 14.04878

mean(medium\_risk\_loans$int\_rate)

## [1] 12.37679

mean(high\_risk\_loans$int\_rate)

## [1] 12.16153

mean(low\_risk\_loans$annual\_inc)

## [1] 108244

mean(medium\_risk\_loans$annual\_inc)

## [1] 61306.81

mean(high\_risk\_loans$annual\_inc)

## [1] 90406.98

mean(low\_risk\_loans$dti)

## [1] 21.15592

mean(medium\_risk\_loans$dti)

## [1] 17.23179

mean(high\_risk\_loans$dti)

## [1] 26.47302

mean(low\_risk\_loans$fico\_range\_high)

## [1] 712.7185

mean(medium\_risk\_loans$fico\_range\_high)

## [1] 709.4767

mean(high\_risk\_loans$fico\_range\_high)

## [1] 714.8266

mean(low\_risk\_loans$inq\_last\_6mths)

## [1] 0.3991597

mean(medium\_risk\_loans$inq\_last\_6mths)

## [1] 0.381323

mean(high\_risk\_loans$inq\_last\_6mths)

## [1] 0.6895161

mean(low\_risk\_loans$delinq\_2yrs)

## [1] 0.1806723

mean(medium\_risk\_loans$delinq\_2yrs)

## [1] 0.2081712

mean(high\_risk\_loans$delinq\_2yrs)

## [1] 0.141129