Final Draft

# Overview

### Abstract

The purpose of this report is to address the new regulations and to better understand the manufacturing process within ABC Beverage. We will examine all factors involved in the production process and will attempt to identify the factors that will help us properly predict the PH levels as well us understand the influence of the various factors on the overall process.

### Data used

This report is using the historical data collected from approximately 2572 samples which should be sufficient for the analysis.

### Brief overview of the process

We will first cleanup the data, by filling in or imputing the missing data, use various transformation methods in order to normalize the data to address issues such as outlier data points and other normalization related issues.

Next we will run various models in order to identify the factors that are important to reaching out goal and once we have those we will use various models in order to estimate the PH levels and come up with a best suiting method that we feel will be best to predict the data we are looking for.

We will include documented R code within the report so that it is easy to follow our research. Should you have any questions regarding the process or the code, feel free to reach out to our department.

# Data Exploration

We will get started by loading our historical data into a data frame and loading the necessary libraries.

library(missForest)  
library(corrgram)  
library(caret)  
library(psych)  
library(knitr)  
  
dfBevMod <- read.csv("https://github.com/ChristopheHunt/CUNY-DATA624/raw/master/data/StudentData.csv", header = TRUE)  
dfBevPred <- read.csv("https://raw.githubusercontent.com/ChristopheHunt/CUNY-DATA624/master/data/StudentEvaluation-%20TO%20PREDICT.csv", header =TRUE)

We will examine the training dataset we want to see how many predictor variables we are dealing with and if we are missing any data. We see several variables with missing data,

dim(dfBevMod)

## [1] 2571 33

It appears we have a total of 32 predictor variables and a target variable. Next we will check for any missing data.

colSums(is.na(dfBevMod))

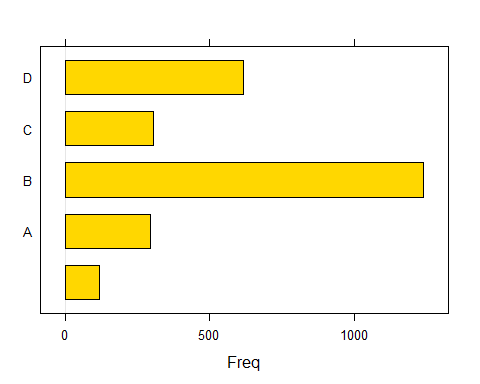
## Brand.Code Carb.Volume Fill.Ounces PC.Volume   
## 0 10 38 39   
## Carb.Pressure Carb.Temp PSC PSC.Fill   
## 27 26 33 23   
## PSC.CO2 Mnf.Flow Carb.Pressure1 Fill.Pressure   
## 39 2 32 22   
## Hyd.Pressure1 Hyd.Pressure2 Hyd.Pressure3 Hyd.Pressure4   
## 11 15 15 30   
## Filler.Level Filler.Speed Temperature Usage.cont   
## 20 57 14 5   
## Carb.Flow Density MFR Balling   
## 2 1 212 1   
## Pressure.Vacuum PH Oxygen.Filler Bowl.Setpoint   
## 0 4 12 2   
## Pressure.Setpoint Air.Pressurer Alch.Rel Carb.Rel   
## 12 0 9 10   
## Balling.Lvl   
## 1

We see many variables with NA’s – notably “MFR” has 212. Still, roughly 8% NA is workable, so we’ll choose to use imputation process to fill in the missing data.

Also, it appears that we have one categorical variable: Brand.Code

### Barchart

#Visualizing the single categorical variable  
barchart(dfBevMod[,1], col="Gold")



It appears that brand “B” occurs most frequently, followed by “D”

### Continuous and Discrete variables

Next we will review all the variables we are working with in order to better understand the data they are presenting us. We can see the mean, variation and other metrics within the following table for a quick detailed reference.

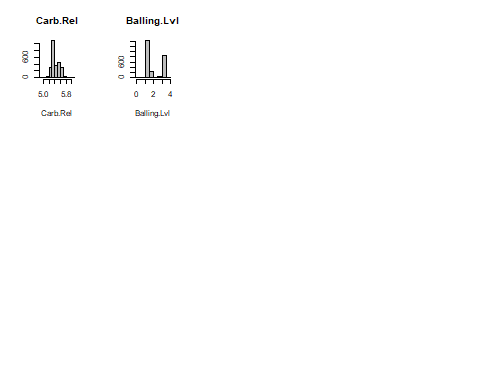
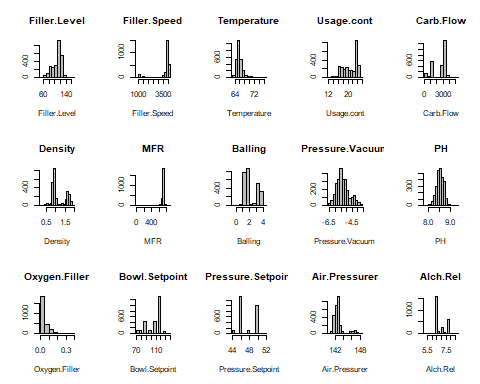
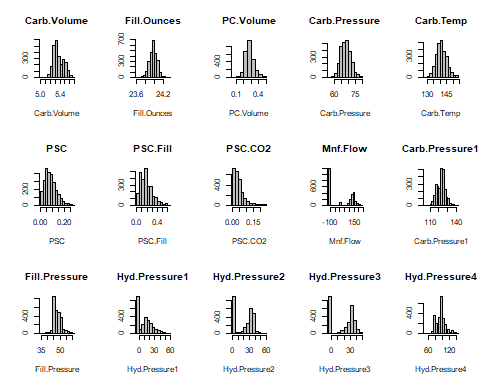
library(psych)  
library(knitr)  
table.desc <- describe(dfBevMod[,-1])  
table.prep <- as.matrix(table.desc)  
table.round <- round((table.prep), 2)  
kable(table.round)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | vars | n | mean | sd | median | trimmed | mad | min | max | range | skew | kurtosis | se |
| Carb.Volume | 1 | 2561 | 5.37 | 0.11 | 5.35 | 5.37 | 0.11 | 5.04 | 5.70 | 0.66 | 0.39 | -0.47 | 0.00 |
| Fill.Ounces | 2 | 2533 | 23.97 | 0.09 | 23.97 | 23.98 | 0.08 | 23.63 | 24.32 | 0.69 | -0.02 | 0.86 | 0.00 |
| PC.Volume | 3 | 2532 | 0.28 | 0.06 | 0.27 | 0.27 | 0.05 | 0.08 | 0.48 | 0.40 | 0.34 | 0.67 | 0.00 |
| Carb.Pressure | 4 | 2544 | 68.19 | 3.54 | 68.20 | 68.12 | 3.56 | 57.00 | 79.40 | 22.40 | 0.18 | -0.01 | 0.07 |
| Carb.Temp | 5 | 2545 | 141.09 | 4.04 | 140.80 | 140.99 | 3.85 | 128.60 | 154.00 | 25.40 | 0.25 | 0.24 | 0.08 |
| PSC | 6 | 2538 | 0.08 | 0.05 | 0.08 | 0.08 | 0.05 | 0.00 | 0.27 | 0.27 | 0.85 | 0.65 | 0.00 |
| PSC.Fill | 7 | 2548 | 0.20 | 0.12 | 0.18 | 0.18 | 0.12 | 0.00 | 0.62 | 0.62 | 0.93 | 0.77 | 0.00 |
| PSC.CO2 | 8 | 2532 | 0.06 | 0.04 | 0.04 | 0.05 | 0.03 | 0.00 | 0.24 | 0.24 | 1.73 | 3.73 | 0.00 |
| Mnf.Flow | 9 | 2569 | 24.57 | 119.48 | 65.20 | 21.07 | 169.02 | -100.20 | 229.40 | 329.60 | 0.00 | -1.87 | 2.36 |
| Carb.Pressure1 | 10 | 2539 | 122.59 | 4.74 | 123.20 | 122.54 | 4.45 | 105.60 | 140.20 | 34.60 | 0.05 | 0.14 | 0.09 |
| Fill.Pressure | 11 | 2549 | 47.92 | 3.18 | 46.40 | 47.71 | 2.37 | 34.60 | 60.40 | 25.80 | 0.55 | 1.41 | 0.06 |
| Hyd.Pressure1 | 12 | 2560 | 12.44 | 12.43 | 11.40 | 10.84 | 16.90 | -0.80 | 58.00 | 58.80 | 0.78 | -0.14 | 0.25 |
| Hyd.Pressure2 | 13 | 2556 | 20.96 | 16.39 | 28.60 | 21.05 | 13.34 | 0.00 | 59.40 | 59.40 | -0.30 | -1.56 | 0.32 |
| Hyd.Pressure3 | 14 | 2556 | 20.46 | 15.98 | 27.60 | 20.51 | 13.94 | -1.20 | 50.00 | 51.20 | -0.32 | -1.57 | 0.32 |
| Hyd.Pressure4 | 15 | 2541 | 96.29 | 13.12 | 96.00 | 95.45 | 11.86 | 52.00 | 142.00 | 90.00 | 0.55 | 0.63 | 0.26 |
| Filler.Level | 16 | 2551 | 109.25 | 15.70 | 118.40 | 111.04 | 9.19 | 55.80 | 161.20 | 105.40 | -0.85 | 0.05 | 0.31 |
| Filler.Speed | 17 | 2514 | 3687.20 | 770.82 | 3982.00 | 3919.99 | 47.44 | 998.00 | 4030.00 | 3032.00 | -2.87 | 6.71 | 15.37 |
| Temperature | 18 | 2557 | 65.97 | 1.38 | 65.60 | 65.80 | 0.89 | 63.60 | 76.20 | 12.60 | 2.39 | 10.16 | 0.03 |
| Usage.cont | 19 | 2566 | 20.99 | 2.98 | 21.79 | 21.25 | 3.19 | 12.08 | 25.90 | 13.82 | -0.54 | -1.02 | 0.06 |
| Carb.Flow | 20 | 2569 | 2468.35 | 1073.70 | 3028.00 | 2601.14 | 326.17 | 26.00 | 5104.00 | 5078.00 | -0.99 | -0.58 | 21.18 |
| Density | 21 | 2570 | 1.17 | 0.38 | 0.98 | 1.15 | 0.15 | 0.24 | 1.92 | 1.68 | 0.53 | -1.20 | 0.01 |
| MFR | 22 | 2359 | 704.05 | 73.90 | 724.00 | 718.16 | 15.42 | 31.40 | 868.60 | 837.20 | -5.09 | 30.46 | 1.52 |
| Balling | 23 | 2570 | 2.20 | 0.93 | 1.65 | 2.13 | 0.37 | -0.17 | 4.01 | 4.18 | 0.59 | -1.39 | 0.02 |
| Pressure.Vacuum | 24 | 2571 | -5.22 | 0.57 | -5.40 | -5.25 | 0.59 | -6.60 | -3.60 | 3.00 | 0.53 | -0.03 | 0.01 |
| PH | 25 | 2567 | 8.55 | 0.17 | 8.54 | 8.55 | 0.18 | 7.88 | 9.36 | 1.48 | -0.29 | 0.06 | 0.00 |
| Oxygen.Filler | 26 | 2559 | 0.05 | 0.05 | 0.03 | 0.04 | 0.02 | 0.00 | 0.40 | 0.40 | 2.66 | 11.09 | 0.00 |
| Bowl.Setpoint | 27 | 2569 | 109.33 | 15.30 | 120.00 | 111.35 | 0.00 | 70.00 | 140.00 | 70.00 | -0.97 | -0.06 | 0.30 |
| Pressure.Setpoint | 28 | 2559 | 47.62 | 2.04 | 46.00 | 47.60 | 0.00 | 44.00 | 52.00 | 8.00 | 0.20 | -1.60 | 0.04 |
| Air.Pressurer | 29 | 2571 | 142.83 | 1.21 | 142.60 | 142.58 | 0.59 | 140.80 | 148.20 | 7.40 | 2.25 | 4.73 | 0.02 |
| Alch.Rel | 30 | 2562 | 6.90 | 0.51 | 6.56 | 6.84 | 0.06 | 5.28 | 8.62 | 3.34 | 0.88 | -0.85 | 0.01 |
| Carb.Rel | 31 | 2561 | 5.44 | 0.13 | 5.40 | 5.43 | 0.12 | 4.96 | 6.06 | 1.10 | 0.50 | -0.29 | 0.00 |
| Balling.Lvl | 32 | 2570 | 2.05 | 0.87 | 1.48 | 1.98 | 0.21 | 0.00 | 3.66 | 3.66 | 0.59 | -1.49 | 0.02 |

### Nominal Variable Histogram

Next we will visually view each one of the factors, its easier to visually navigate through a large number of variables. We are interested to see how data is distributed for each one of the variables. Please refer to above table for more specific information.

dfBevModH <- dfBevMod[2:ncol(dfBevMod)] #removing factor var  
par(mfrow = c(3,5), cex = .5)  
for(i in colnames(dfBevModH)){  
hist(dfBevModH[,i], xlab = names(dfBevMod[i]),  
 main = names(dfBevModH[i]), col="grey", ylab="")  
}



We can see that Mnf.Flow and Hyd.Pressure 1,2,3 each have many values below 0 – possibly null-type entered values. Several variables are strongly skewed – some of which appear to have outliers.

Next we want to explore differences by Brand

BrandA <- dfBevMod[dfBevMod$Brand.Code == "A",]  
BAM <- colMeans(BrandA[,2:ncol(BrandA)], na.rm = TRUE)  
BrandB <- dfBevMod[dfBevMod$Brand.Code == "B",]  
BBM <- colMeans(BrandB[,2:ncol(BrandB)], na.rm = TRUE)  
BrandC <- dfBevMod[dfBevMod$Brand.Code == "C",]  
BCM <- colMeans(BrandC[,2:ncol(BrandC)], na.rm = TRUE)  
BrandD <- dfBevMod[dfBevMod$Brand.Code == "D",]  
BDM <- colMeans(BrandD[,2:ncol(BrandD)], na.rm = TRUE)  
BrandE <- dfBevMod[dfBevMod$Brand.Code == "",]  
BEM <- colMeans(BrandE[,2:ncol(BrandE)], na.rm = TRUE)  
  
combBrand <- cbind(BAM, BBM, BCM, BDM, BEM)  
combBrand

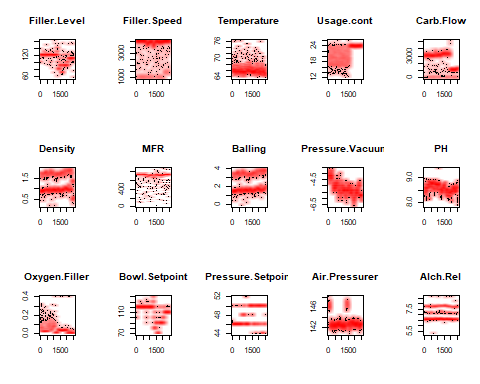
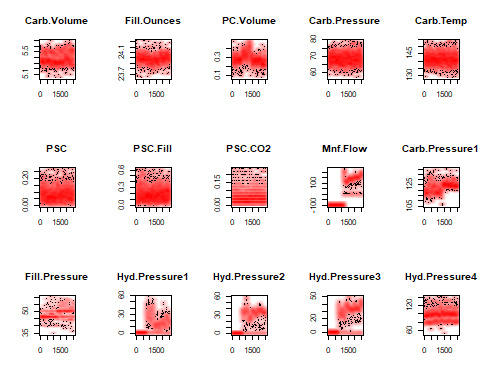
## BAM BBM BCM BDM  
## Carb.Volume 5.42568828 5.31248514 5.30019802 5.51044190  
## Fill.Ounces 23.98210526 23.97748705 23.98486667 23.95658456  
## PC.Volume 0.26877855 0.28239989 0.29019778 0.26174013  
## Carb.Pressure 69.28041237 67.19804719 66.92476821 70.69817579  
## Carb.Temp 141.22876712 141.11078431 141.05364238 141.13013115  
## PSC 0.07761672 0.08635948 0.08976821 0.08056579  
## PSC.Fill 0.19835052 0.19371847 0.21026490 0.19104918  
## PSC.CO2 0.05551724 0.05709360 0.06214765 0.05276316  
## Mnf.Flow 39.71467577 20.46176233 23.28092105 25.74666667  
## Carb.Pressure1 122.81862069 122.47500000 122.19401993 122.72363636  
## Fill.Pressure 48.22123288 48.17010561 48.22866667 46.96124795  
## Hyd.Pressure1 12.90238908 12.52469636 12.32828947 12.39671053  
## Hyd.Pressure2 21.15821918 21.10510949 19.16250000 21.97331137  
## Hyd.Pressure3 20.97465753 20.19253852 19.04671053 21.59011532  
## Hyd.Pressure4 101.28368794 100.05858421 102.54000000 83.45276873  
## Filler.Level 108.62671233 107.96156352 111.60198020 110.42262295  
## Filler.Speed 3582.07719298 3730.61943987 3673.66216216 3688.97674419  
## Temperature 66.06323024 65.89083536 66.71655629 65.46209150  
## Usage.cont 21.14034247 20.96623482 21.03657895 21.00653659  
## Carb.Flow 2387.35395189 2532.70056497 2311.53947368 2437.18048780  
## Density 1.57105802 0.90843296 0.92217105 1.68250407  
## MFR 704.98365759 705.63864818 704.02826087 703.97628319  
## Balling 3.19896928 1.51114216 1.63171053 3.48558699  
## Pressure.Vacuum -5.23890785 -5.15431800 -5.31052632 -5.26016260  
## PH 8.49740614 8.56678543 8.41368421 8.60250407  
## Oxygen.Filler 0.04147423 0.04783906 0.05160930 0.04495863  
## Bowl.Setpoint 109.11340206 107.76432607 111.61842105 110.88780488  
## Pressure.Setpoint 47.76219931 47.94269572 48.03367003 46.64600326  
## Air.Pressurer 142.73583618 142.95948345 142.76644737 142.69300813  
## Alch.Rel 7.13486301 6.55051095 6.56488449 7.69352846  
## Carb.Rel 5.51773973 5.36215385 5.35242525 5.60725203  
## Balling.Lvl 3.07706485 1.40611784 1.52059211 3.23206504  
## BEM  
## Carb.Volume 5.29086111  
## Fill.Ounces 23.99712644  
## PC.Volume 0.28882759  
## Carb.Pressure 66.26050420  
## Carb.Temp 140.51794872  
## PSC 0.09037607  
## PSC.Fill 0.18931034  
## PSC.CO2 0.05593220  
## Mnf.Flow 27.15333333  
## Carb.Pressure1 123.46050420  
## Fill.Pressure 48.78290598  
## Hyd.Pressure1 10.89000000  
## Hyd.Pressure2 18.43666667  
## Hyd.Pressure3 19.78666667  
## Hyd.Pressure4 95.98275862  
## Filler.Level 112.15084746  
## Filler.Speed 3517.82905983  
## Temperature 67.22689076  
## Usage.cont 20.72933333  
## Carb.Flow 2557.43333333  
## Density 0.96866667  
## MFR 685.10280374  
## Balling 1.67083333  
## Pressure.Vacuum -5.33333333  
## PH 8.48883333  
## Oxygen.Filler 0.04730084  
## Bowl.Setpoint 112.16666667  
## Pressure.Setpoint 47.79831933  
## Air.Pressurer 142.67166667  
## Alch.Rel 6.64151261  
## Carb.Rel 5.34423729  
## Balling.Lvl 1.46873950

Notable differences exist among brands by Hyd.Pressure4, Density, Balling, and Balling.Lvl

### Density Plot

Next we will use density plots to better understand the data and look for any abnormalities.

par(mfrow = c(3,5), cex = .5)  
for (i in colnames(dfBevModH)) {  
 smoothScatter(dfBevModH[,i], main = names(dfBevModH[i]), ylab = "",   
 xlab = "", colramp = colorRampPalette(c("white", "red")))  
 }

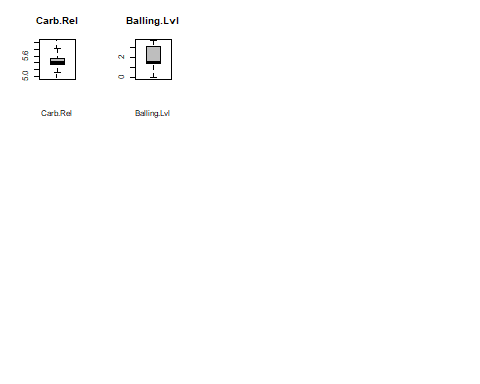
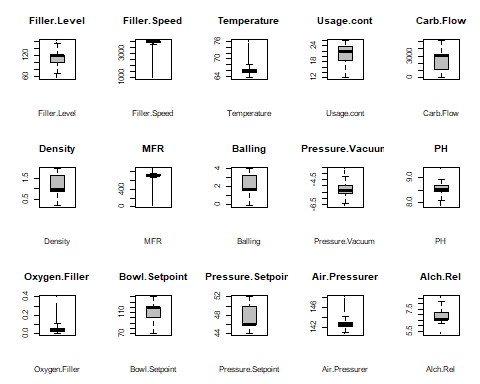
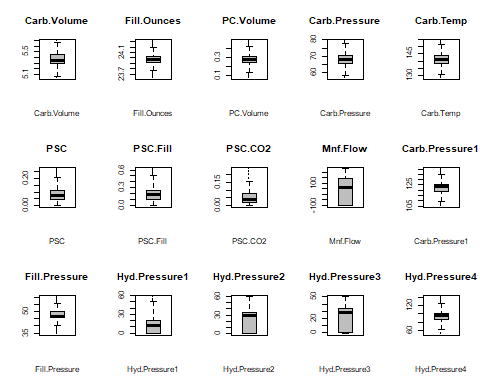


The odd data in Mnf.Flow appears to be related to similarly zero-out data in Hyd.Pressure1, Hyd.Press2, and Hyd.Pressure3. Several other variables have dichotomous patterns in data behavior, including “Carb.Pressure1”, “Filler.Level”, “Usage.cont”, “Carb.Flow”, and “Oxygen.Filler”. This leaves two options; we can alter these gaps by possibly inputing new values in, or we can use algorithms that can easily handle quick pattern shifts, such as forests and MARS.

### BoxPlots

Next we want to take a look at any outliers within our variables. Boxplots provide a quick and effective way of view the data and look for any skew or outliers

par(mfrow = c(3,5), cex = .5)  
for(i in colnames(dfBevModH)){  
boxplot(dfBevModH[,i], xlab = names(dfBevModH[i]),  
 main = names(dfBevModH[i]), col="grey", ylab="")  
}



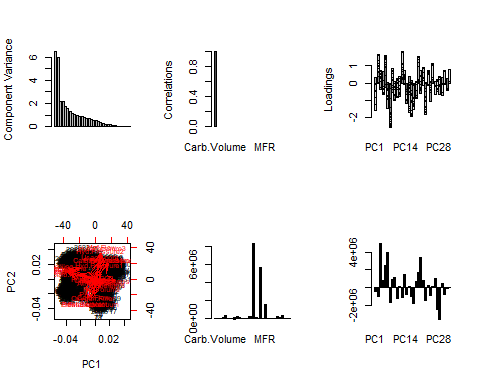
Again, several variables with large skews and outliers are present we will need to use transformation techniques later on to handle this issue.

### Principle Component Analysis

Since we are dealing with 32 predictor variables and not all of them can be relevant to our study, we will need a way to filter through the variables to reduce the number of variables we are working with. This can be done with PCA

PCA <- function(X) {  
 Xpca <- prcomp(na.omit(X), center = T, scale. = T)   
 M <- as.matrix(na.omit(X)); R <- as.matrix(Xpca$rotation); score <- M %\*% R  
 print(list("Importance of Components" = summary(Xpca)$importance[ ,1:5],   
 "Rotation (Variable Loadings)" = Xpca$rotation[ ,1:5],  
 "Correlation between X and PC" = cor(na.omit(X), score)[ ,1:5]))  
 par(mfrow=c(2,3))  
 barplot(Xpca$sdev^2, ylab = "Component Variance")  
 barplot(cor(cbind(X)), ylab = "Correlations")  
 barplot(Xpca$rotation, ylab = "Loadings")   
 biplot(Xpca); barplot(M); barplot(score)  
}  
PCA(dfBevModH)

## $`Importance of Components`  
## PC1 PC2 PC3 PC4 PC5  
## Standard deviation 2.540088 2.449148 1.477634 1.47603 1.310421  
## Proportion of Variance 0.201630 0.187450 0.068230 0.06808 0.053660  
## Cumulative Proportion 0.201630 0.389070 0.457310 0.52539 0.579050  
##   
## $`Rotation (Variable Loadings)`  
## PC1 PC2 PC3 PC4  
## Carb.Volume -0.320871550 0.126525924 -0.063988169 0.0689976465  
## Fill.Ounces 0.033313610 -0.010524814 0.073850141 0.2358285280  
## PC.Volume 0.072479708 -0.108552900 -0.069562774 -0.3956296184  
## Carb.Pressure -0.208006297 0.060068377 -0.068128144 0.1465200114  
## Carb.Temp -0.033305138 -0.006187462 -0.040764654 0.1184540029  
## PSC 0.034729843 -0.007932387 0.007672846 0.0166335686  
## PSC.Fill 0.005088232 -0.025583769 -0.008017467 0.0803836356  
## PSC.CO2 0.029539988 0.013537129 -0.010869845 0.1017169746  
## Mnf.Flow 0.080644367 0.358177152 0.044915507 0.0252965168  
## Carb.Pressure1 0.037910196 0.212302734 0.028684308 0.1765112631  
## Fill.Pressure 0.162738779 0.217724987 -0.208305845 0.0873750286  
## Hyd.Pressure1 0.040714287 0.156202166 0.028117601 -0.4998183585  
## Hyd.Pressure2 0.057453860 0.313403614 0.076107892 -0.3208825682  
## Hyd.Pressure3 0.071682634 0.348252038 0.032135037 -0.2278539437  
## Hyd.Pressure4 0.268513018 -0.023674824 -0.168038357 -0.0027778884  
## Filler.Level -0.098309141 -0.276213319 0.109275148 -0.2476992005  
## Filler.Speed -0.036355308 0.001197480 0.619301867 0.0628275426  
## Temperature 0.105282829 -0.066203240 -0.105105120 0.0321416038  
## Usage.cont 0.053341657 0.248028048 0.106147980 0.1153232541  
## Carb.Flow -0.019747290 -0.192400631 -0.190052445 0.0123151046  
## Density -0.355713158 0.107013359 -0.067887877 -0.0009745302  
## MFR -0.040893045 -0.001083672 0.620594464 0.0666977237  
## Balling -0.354342525 0.141148693 -0.040775757 -0.0141207975  
## Pressure.Vacuum -0.046505652 -0.268137181 0.018936117 0.2043414157  
## PH -0.115017697 -0.166446153 -0.043839565 -0.1546589220  
## Oxygen.Filler -0.017291886 -0.210617922 -0.096839733 -0.0417513911  
## Bowl.Setpoint -0.103923455 -0.273585690 0.086519475 -0.2471199864  
## Pressure.Setpoint 0.181047509 0.208820308 -0.105820469 0.0562644751  
## Air.Pressurer 0.031569404 -0.035033996 -0.071242723 0.2609739989  
## Alch.Rel -0.364650212 0.099430202 -0.076928665 -0.0194895814  
## Carb.Rel -0.352557712 0.079691885 -0.073882285 -0.0418290381  
## Balling.Lvl -0.361905544 0.108856318 -0.069790925 0.0073156499  
## PC5  
## Carb.Volume -0.1289819052  
## Fill.Ounces -0.1229858345  
## PC.Volume 0.1598460185  
## Carb.Pressure 0.5485412373  
## Carb.Temp 0.6879491706  
## PSC -0.0797130932  
## PSC.Fill -0.1062661776  
## PSC.CO2 -0.0212550379  
## Mnf.Flow -0.0159976226  
## Carb.Pressure1 -0.0290714575  
## Fill.Pressure 0.0003314597  
## Hyd.Pressure1 0.0951143049  
## Hyd.Pressure2 0.0947102915  
## Hyd.Pressure3 0.0851266883  
## Hyd.Pressure4 -0.0064600449  
## Filler.Level -0.0659270082  
## Filler.Speed 0.1239047672  
## Temperature 0.1020654842  
## Usage.cont -0.1185660052  
## Carb.Flow 0.1730300450  
## Density -0.0203213313  
## MFR 0.1118598210  
## Balling -0.0496622835  
## Pressure.Vacuum -0.0377417295  
## PH 0.0428191812  
## Oxygen.Filler 0.0913810644  
## Bowl.Setpoint -0.0734787536  
## Pressure.Setpoint 0.0479371223  
## Air.Pressurer 0.0998622820  
## Alch.Rel -0.0372397655  
## Carb.Rel -0.0243017040  
## Balling.Lvl -0.0570128001  
##   
## $`Correlation between X and PC`  
## PC1 PC2 PC3 PC4  
## Carb.Volume 0.002672235 0.111348522 0.063613298 -0.011847085  
## Fill.Ounces 0.040529153 0.087715367 0.097669459 0.059771410  
## PC.Volume -0.180340769 -0.271489773 -0.199880836 -0.115598261  
## Carb.Pressure -0.066204190 0.025722112 0.036530429 0.061413374  
## Carb.Temp -0.069518362 -0.039493236 -0.003344882 0.074340078  
## PSC 0.040662924 0.037176123 0.018514307 0.006021336  
## PSC.Fill -0.021548310 -0.028862504 -0.023591759 0.007699516  
## PSC.CO2 0.035580707 0.022245482 0.003727000 0.020391565  
## Mnf.Flow 0.723291814 0.693451292 0.295235376 -0.147391760  
## Carb.Pressure1 0.375637900 0.371884050 0.168815533 0.006765179  
## Fill.Pressure 0.498230248 0.300422256 -0.075514622 -0.207326749  
## Hyd.Pressure1 0.275073293 0.247417853 0.076691158 -0.437731705  
## Hyd.Pressure2 0.487809573 0.485370725 0.238650794 -0.300196428  
## Hyd.Pressure3 0.580859072 0.545232467 0.225502363 -0.280195784  
## Hyd.Pressure4 0.296714868 0.029386412 -0.206499978 -0.204162315  
## Filler.Level -0.389979312 -0.217909690 0.031229026 -0.134337700  
## Filler.Speed -0.470607794 0.059325780 0.832380594 0.798933852  
## Temperature -0.032400811 -0.131025575 -0.131935567 0.013501453  
## Usage.cont 0.515662927 0.567466858 0.306198713 -0.105542769  
## Carb.Flow -0.728865476 -0.966223188 -0.604417233 0.368469211  
## Density -0.117230400 -0.008474646 0.016244812 0.022657754  
## MFR -0.455045229 0.066334864 0.812095962 0.771973495  
## Balling -0.017953566 0.121197295 0.097470770 -0.026074148  
## Pressure.Vacuum -0.457986670 -0.407097197 -0.119183474 0.240746451  
## PH -0.345239874 -0.323918002 -0.164411012 -0.017197343  
## Oxygen.Filler -0.424027239 -0.467026196 -0.247762941 0.093078019  
## Bowl.Setpoint -0.373730212 -0.214155886 0.007211244 -0.163635722  
## Pressure.Setpoint 0.411830072 0.282182390 0.035998404 -0.095125936  
## Air.Pressurer -0.075890499 -0.120293496 -0.078403739 0.157033933  
## Alch.Rel -0.102425243 0.006988524 0.003604029 -0.018809036  
## Carb.Rel -0.108413466 0.008531971 0.019415972 -0.047949293  
## Balling.Lvl -0.060110506 0.060109493 0.043885246 -0.025858266  
## PC5  
## Carb.Volume -0.093658221  
## Fill.Ounces -0.100673596  
## PC.Volume 0.233542757  
## Carb.Pressure 0.011754537  
## Carb.Temp 0.072779034  
## PSC -0.036486635  
## PSC.Fill 0.008941563  
## PSC.CO2 -0.014123789  
## Mnf.Flow -0.460810554  
## Carb.Pressure1 -0.260300884  
## Fill.Pressure -0.238063463  
## Hyd.Pressure1 -0.154832629  
## Hyd.Pressure2 -0.275314801  
## Hyd.Pressure3 -0.323771761  
## Hyd.Pressure4 -0.090604320  
## Filler.Level 0.028038837  
## Filler.Speed 0.247282208  
## Temperature 0.103770602  
## Usage.cont -0.454543589  
## Carb.Flow 0.950568080  
## Density 0.034322442  
## MFR 0.224469906  
## Balling -0.084814051  
## Pressure.Vacuum 0.277242437  
## PH 0.211975600  
## Oxygen.Filler 0.354347799  
## Bowl.Setpoint 0.012366381  
## Pressure.Setpoint -0.169959804  
## Air.Pressurer 0.125926876  
## Alch.Rel 0.005207278  
## Carb.Rel -0.012596007  
## Balling.Lvl -0.050934875

 First two components account for most of the variance, although Mnf.Flow is highly prioritized, so I’m concerned that it may be a function of the null-like values.

# Data Transformation

Since Brand Code is a categorical variable, we will have to transform it to a binary so that models can use the data.

#df\_imputed$Brand.Code = NULL  
dfBevMod$Brand.Code[dfBevMod$Brand.Code == ""] <- NA  
dfBevMod$Brand.Code <- droplevels(dfBevMod$Brand.Code)  
  
dfBevPred$Brand.Code[dfBevPred$Brand.Code == ""] <- NA  
dfBevPred$Brand.Code <- droplevels(dfBevPred$Brand.Code)  
  
#Recode categorical factor  
dfBevMod$A <- ifelse(dfBevMod$Brand.Code == "A", 1, 0)  
dfBevMod$B <- ifelse(dfBevMod$Brand.Code == "B", 1, 0)  
dfBevMod$C <- ifelse(dfBevMod$Brand.Code == "C", 1, 0)  
dfBevMod$D <- ifelse(dfBevMod$Brand.Code == "D", 1, 0)  
dfBevMod$Brand.Code <- NULL  
  
dfBevPred$A <- ifelse(dfBevPred$Brand.Code == "A", 1, 0)  
dfBevPred$B <- ifelse(dfBevPred$Brand.Code == "B", 1, 0)  
dfBevPred$C <- ifelse(dfBevPred$Brand.Code == "C", 1, 0)  
dfBevPred$D <- ifelse(dfBevPred$Brand.Code == "D", 1, 0)  
dfBevPred$Brand.Code <- NULL

### Imputation

Next we will use the missForest library to impute the missing variable of the predictor variables. The library will use the best method in filling in the missing data.

Please note: We need to perform this step in order to have a complete dataset. Most models will not run on a data set with missing data. This is a common step in data science and filling in the data does not compromise the final results

#dfImpMod = missForest(dfBevMod)  
#dfImpMod$OOBerror #error rate looks good?  
#dfModImp <- dfImpMod$ximp  
  
#dfImpPred <- missForest(dfBevPred)  
#dfPredImp <- dfImpPred$ximp  
#dfPredImp$PH <- NA #redadding PH  
  
#write.csv(dfModImp, "TrainImputeData.csv")  
#write.csv(dfPredImp, "PredictImputeData.csv")  
  
#Stored current imputation results on github to quicken knitr iterations  
dfModImp <- read.csv("https://raw.githubusercontent.com/ChristopheHunt/CUNY-DATA624/master/data/TrainImputeData.csv")  
dfPredImp <- read.csv("https://raw.githubusercontent.com/ChristopheHunt/CUNY-DATA624/master/data/PredictImputeData.csv")

### Preprocessing

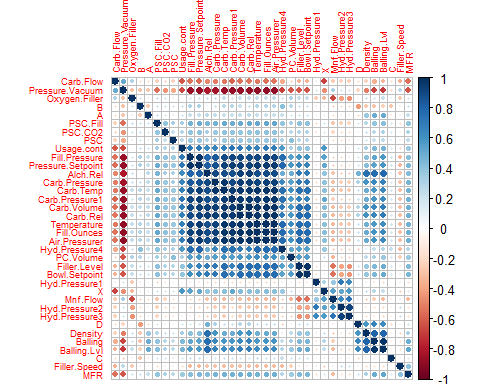
Next we will preprocess the data using various methods, this step will handle the issues of outliers and will get the data in the final stage where it can be used with the predictive models. Due to the different types of model inputs (some preprocess, other’s dont), we will be creating a range of preprocessed variables

dfModImpX <- dfModImp[,!(names(dfModImp) == "PH")]  
dfModImpY <- dfModImp[, names(dfModImp) == "PH"]  
  
dfPredImpX <- dfPredImp[,!(names(dfPredImp) == "PH")]  
dfPredImpY <- dfPredImp[, names(dfPredImp) == "PH"]  
  
#Spatial Sign outlier processing  
dfModImpSsX <- spatialSign(dfModImpX)  
dfPredImpSsX <- spatialSign(dfPredImpX)  
  
#BoxCox Only  
transModB <- preProcess(dfModImpSsX, method = "BoxCox") #transformed all 22 variables  
dfModBX <- predict(transModB, dfModImpSsX)  
  
transPredB <- preProcess(dfPredImpSsX, method = "BoxCox") #transformed 23 variables (should we use the Modeling model from above, instead of predicting model?)  
dfPredBX <- predict(transPredB, dfPredImpSsX)  
  
#BoxCox, Centering, and Scaling  
transModBCS <- preProcess(dfModImpSsX, method = c("BoxCox", "center", "scale")) #22 BC, 35 centered, 35 scaled  
dfModBCSX <- predict(transModBCS, dfModImpSsX)  
  
transPredBCS <- preProcess(dfPredImpSsX, method = c("BoxCox", "center", "scale")) #23 BC, 35 centered, 35 scaled  
dfPredBCSX <- predict(transPredBCS, dfPredImpSsX)  
  
#BoxCox, Centering, Scaling, and PCA  
transModBCSP <- preProcess(dfModImpSsX, method = c("BoxCox", "center", "scale", "pca")) #22 BC, 35 centered, 35 scaled  
dfModBCSPX <- predict(transModBCSP, dfModImpSsX)  
  
transPredBCSP <- preProcess(dfPredImpSsX, method = c("BoxCox", "center", "scale", "pca")) #23 BC, 35 centered, 35 scaled  
dfPredBCSPX <- predict(transPredBCSP, dfPredImpSsX)

Next we will attempt to reduce the number of predictor variables. We will review the correlation between the variables and find the highly correlated ones that can be reduced.

The dark blue and dark red dots indicate a string correlation, normally models do not improve if we feed them highly correlated data, therefore identifying and removing the highly correlated data will help us reduce processing speed and improve accuracy.

#corrgram(dfModBCSX, order=TRUE,  
# upper.panel=panel.cor, main="Correlation Matrix")  
library(corrplot)  
#install.packages("corrplot")  
correlations <- cor(dfModBCSX)  
corrplot(correlations, order = "hclust", tl.cex = 0.55)



We can see several very highly correlated variables. We will reduce our dataset and remove pairs that have correlation above 0.75.

hc = findCorrelation(correlations, cutoff=0.75)  
length(hc) #18 vars

## [1] 16

#Reducing  
dfModBCSRX = dfModBCSX[,-c(hc)] #Box-Cox, Center, Scale  
dfPredBCSRX = dfPredBCSX[,-c(hc)]  
  
dfModBRX = dfModBX[,-c(hc)] #Box-Cox  
dfPredBRX = dfPredBCSX[,-c(hc)]  
  
dfModSRX = dfModImpSsX[,-c(hc)] #Only Spatial Sign  
dfPredSRX = dfPredImpSsX[,-c(hc)]

Finalizing data

set.seed(2017)  
n75 <- floor(0.75 \* nrow(dfBevMod)) #75$ of sample size  
n <- sample(seq\_len(nrow(dfBevMod)), size = n75)  
  
#Box-Cox, Center, Scale  
dfTrainBCSX <- dfModBCSRX[n,]  
dfTestBCSX <- dfModBCSRX[-n,]  
  
#Box-Cox  
dfTrainBX <- dfModBX[n,]  
dfTestBX <- dfModBX[-n,]  
  
#Only Spatial Sign  
dfTrainX <- dfModSRX[n,]  
dfTestX <- dfModSRX[-n,]  
  
#Response variable  
dfTrainY <- dfModImpY[n]  
dfTestY <- dfModImpY[-n]

At this point data is ready and we can proceed to the modeling step.

# Model Development

## Nonlinear Models

Using the several data sets created from our previous transformations we attempted to fit several non-linear models. Specifically, a Neural Network and MARS model. While data transformations are not always necessary for the MARS method, we will nonetheless benefit from removing data features that would be adding unncessary noise to our final models. The Neural Network can be greatly impacted by highly correlated variables.

### Neural Network

Neural Networks can be thought of as models that work in similar ways to our brain. Inputs are provided and transformed at nodes by assigned weights that then feed-forward to any additional layers containing additional nodes [^1]. A drawback to this method is that without limitations on our linear combinations from one layer to another, the coefficients will have little context [^3].

In the below code snippet, we set our seed for reproducibility, then we set trainControl for 3 repeats of the cross validated method and keep our resamples by setting returnResamp = "all". We then manually tune our grid with the expand.grid function and set the Weight Decay via .decay, the Hidden Units via .size, and then prevent Bagging since we have sufficiently preprocessed our data .bag = FALSE. Also, since we are preforming a regression and not a classfication we set linout to TRUE.

[1] Bishop, Christopher M. Neural Networks for Pattern Recognition. Oxford: New York: Clarendon Press; Oxford University Press, 1995.

[3] Kuhn, Max, and Kjell Johnson. Applied Predictive Modeling. New York: Springer, 2013.

set.seed(1234)  
  
nnet <- function(df, y){  
   
 fitControl <- trainControl(method = "cv",   
 number = 3,   
 returnResamp = "all")  
   
 nnetGrid <- expand.grid(.decay = c(0, 0.01, .1, .5),  
 .size = c(5:15),  
 .bag = FALSE)  
   
 return(train(df, y,   
 method = "avNNet",   
 tuneGrid = nnetGrid,  
 trControl = fitControl,  
 trace = FALSE,  
 linout = TRUE))  
}  
  
nnet.fit.bcsx <- nnet(dfTrainBCSX, dfTrainY)  
nnet.fit.bx <- nnet(dfTrainBX, dfTrainY)  
nnet.fit.x <- nnet(dfTrainX, dfTrainY)

Now that we have trained our models on the available data sets, we will measure the root mean squared error of all three and select the lowest.

list(RMSE\_NNET.BCSX = RMSE(predict(nnet.fit.bcsx, dfTestBCSX), dfTestY),  
 RMSE\_NNET.BCS = RMSE(predict(nnet.fit.bx, dfTestBX), dfTestY),  
 RMSE\_NNET.X = RMSE(predict(nnet.fit.x, dfTestX), dfTestY))

## $RMSE\_NNET.BCSX  
## [1] 0.1182677  
##   
## $RMSE\_NNET.BCS  
## [1] 0.1550596  
##   
## $RMSE\_NNET.X  
## [1] 0.1407773

Based on our RMSE results the final model chosen for the neural network is nnet.fit.bcsx

nnet.fit.bcsx$finalModel

## Model Averaged Neural Network with 5 Repeats   
##   
## a 20-11-1 network with 243 weights  
## options were - linear output units

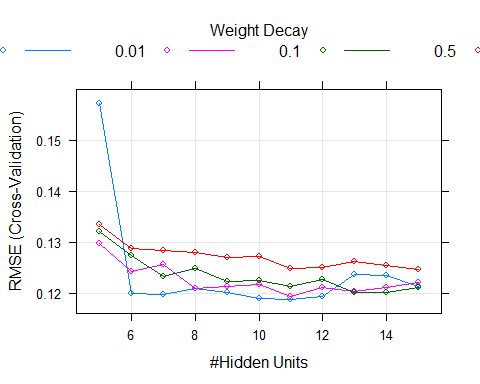
Further, we see that X and Mnf.Flow are the variables with the greatest importance in the model.

varImp(nnet.fit.bcsx)

## loess r-squared variable importance  
##   
## Overall  
## X 100.000  
## Mnf.Flow 86.463  
## Filler.Speed 49.488  
## Filler.Level 42.865  
## Usage.cont 33.177  
## Hyd.Pressure1 24.689  
## Carb.Flow 24.557  
## Hyd.Pressure2 23.417  
## C 22.814  
## Oxygen.Filler 21.224  
## Hyd.Pressure4 16.019  
## Density 15.534  
## B 10.433  
## PC.Volume 5.387  
## PSC 4.496  
## A 1.658  
## PSC.CO2 1.274  
## PSC.Fill 0.976  
## MFR 0.000  
## D 0.000

The grid parameters we set earlier are plotted below to visualize how tuning impacts the model performance.

plot(nnet.fit.bcsx)



### MARS Model

The Multivariate Adaptive Regression Splines or “MARS” model is a nonparametric method, i.e. we are not required to make any assumptions about any underlying distributions such as the neural network. It can achieve this by pivoting on naturally occuring breaks in the data set and essentially building a model out of many linear models developed for specific segemets of the data set [^2] [^3].

[2] J.H. Friedman, “Multivariate adaptive regression splines”, The Annals of Statistics, 19 (1991), pp. 1-141

[3] Kuhn, Max, and Kjell Johnson. Applied Predictive Modeling. New York: Springer, 2013.

In the below code snippet, we set our seed for reproducibility, then we set trainControl for 3 repeats of the cross validated method and keep our resamples by setting returnResamp = "all". We then set our tune grid for 2,3, and 4 product degrees degree= 2:4 and the number of terms possible from 20 to 60 nprune = seq(20,60,20). We would not need to set these values if we intended to use the training set without any resampling or parameter tuning.

library(caret)  
  
set.seed(1234)  
  
mars <- function(df, y){  
   
 fitControl <- trainControl(method = "cv",   
 number = 3,   
 returnResamp = "all")  
  
 MARSGrid <- expand.grid(degree= 3:5,   
 nprune = seq(20,60,20))  
   
 return(train(df, y,   
 method = "earth",   
 tuneGrid = MARSGrid,  
 trControl = fitControl))  
 }  
  
mars.fit.bcsx <- mars(dfTrainBCSX, dfTrainY)  
mars.fit.bx <- mars(dfTrainBX, dfTrainY)  
mars.fit.x <- mars(dfTrainX, dfTrainY)

Now that we have trained our models on the available data sets, we will measure the root mean squared error of all three and select the lowest.

list(RMSE\_MARS.BCSX = RMSE(predict(mars.fit.bcsx, dfTestBCSX), dfTestY),  
 RMSE\_MARS.BCS = RMSE(predict(mars.fit.bx, dfTestBX), dfTestY),  
 RMSE\_MARS.X = RMSE(predict(mars.fit.x, dfTestX), dfTestY))

## $RMSE\_MARS.BCSX  
## [1] 0.1218774  
##   
## $RMSE\_MARS.BCS  
## [1] 0.1131589  
##   
## $RMSE\_MARS.X  
## [1] 0.1260135

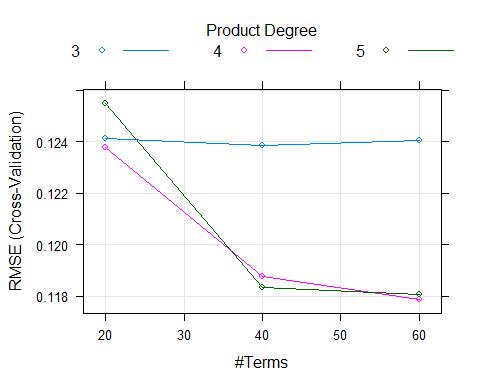
The model fitted to the mars.fit.bx preformed the best and is further selected to be evaluated. The model results are provided below.

mars.fit.bx$finalModel

## Selected 39 of 48 terms, and 15 of 36 predictors  
## Termination condition: Reached maximum RSq 0.9990 at 48 terms  
## Importance: Mnf.Flow, C, X, Temperature, Air.Pressurer, Filler.Speed, ...  
## Number of terms at each degree of interaction: 1 9 16 11 2  
## GCV 0.01211891 RSS 21.09636 GRSq 0.5952478 RSq 0.6341722

The below figure provides insight into the tuning parameters. We can see that our 5 degree model begins to outperform our 4 degree model at the max of 40 terms but the 4 degree model outperforms the 5 degree model at the 60 maximum terms.

plot(mars.fit.bx)



In our final MARS model, the variable of greatest importance is Mnf.Flow.

varImp(mars.fit.bx)

## earth variable importance  
##   
## only 20 most important variables shown (out of 36)  
##   
## Overall  
## Mnf.Flow 100.00  
## C 81.67  
## X 74.73  
## Temperature 63.89  
## Air.Pressurer 63.89  
## Oxygen.Filler 54.50  
## Filler.Speed 52.43  
## Density 52.43  
## D 49.52  
## Carb.Pressure1 45.23  
## Carb.Rel 45.23  
## Alch.Rel 30.39  
## Balling 29.13  
## Pressure.Vacuum 21.28  
## Carb.Volume 11.80  
## Balling.Lvl 0.00  
## Hyd.Pressure2 0.00  
## Filler.Level 0.00  
## PSC 0.00  
## Fill.Pressure 0.00

### Model Choice

Between the two non linear models the lowest RMSE measure is MARS, so we will move forward with that model. It appears that our Neural Net model may suffer from overfitting since the Neural Net has a much better RMSE on the training data set than the MARS model.

list(RMSE\_MARS = RMSE(predict(mars.fit.bx, dfTestBX), dfTestY),  
 RMSE\_NNET = RMSE(predict(nnet.fit.bcsx, dfTestBCSX), dfTestY))

## $RMSE\_MARS  
## [1] 0.1131589  
##   
## $RMSE\_NNET  
## [1] 0.1182677

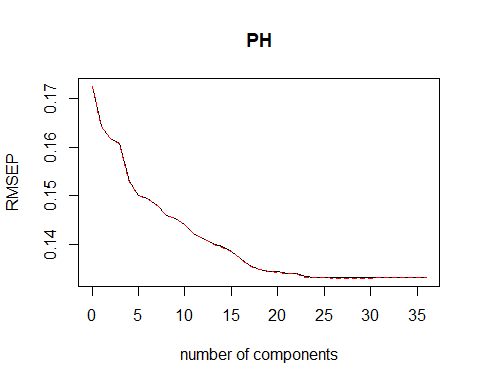
dfModImp <- read.csv("https://raw.githubusercontent.com/ChristopheHunt/CUNY-DATA624/master/data/TrainImputeData.csv")  
dfPredImp <- read.csv("https://raw.githubusercontent.com/ChristopheHunt/CUNY-DATA624/master/data/PredictImputeData.csv")

Partial Least Squares Regression (PLSR) is a multivatiate method related to Principal Components Regression (PCR) that differs because it finds a linear regression that projects predicted and observed values to a new space. These methods are helpful in situations where there are many potentially correlated predictor variables and relatively small samples. In theory, PLSR should be a better method than PCA, because if too few components are selected there could potentially be bad predictions. However, in practice, there doesn’t appear to be much difference in most situations as there are very similar prediction accuracies.

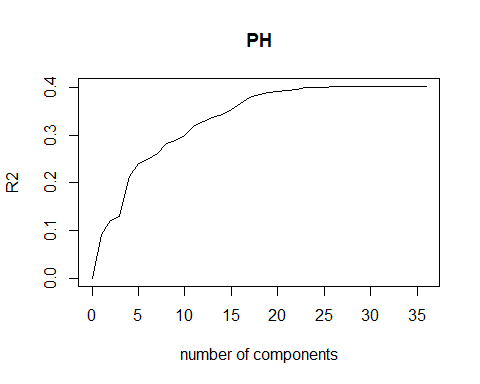
set.seed(1234)  
plsFit = plsr(PH ~ ., data=dfModImp, validation="CV")  
pls.pred = predict(plsFit, dfPredImp[1:5, ], ncomp=1:2)  
  
pls.pred

## , , 1 comps  
##   
## PH  
## 1 8.614191  
## 2 8.613145  
## 3 8.616916  
## 4 8.539746  
## 5 8.621102  
##   
## , , 2 comps  
##   
## PH  
## 1 8.635192  
## 2 8.634208  
## 3 8.635659  
## 4 8.650415  
## 5 8.636982

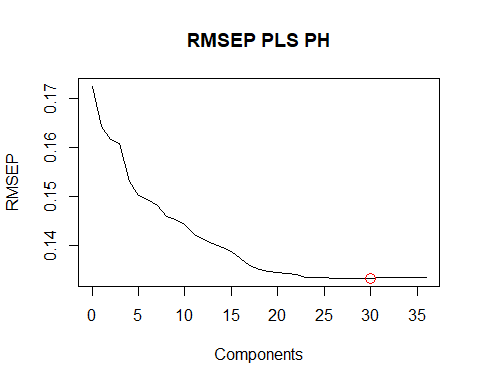
validationplot(plsFit, val.type="RMSEP")



validationplot(plsFit, val.type="R2")



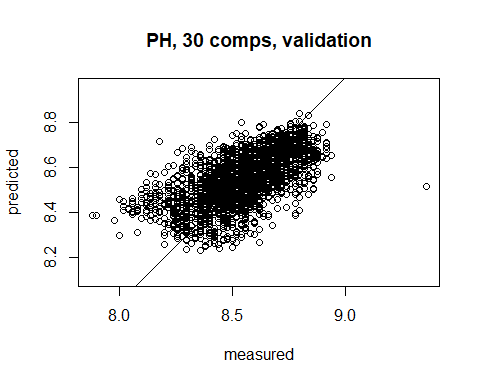
pls.RMSEP = RMSEP(plsFit, estimate="CV")  
plot(pls.RMSEP, main="RMSEP PLS PH", xlab="Components")  
min\_comp = which.min(pls.RMSEP$val)  
points(min\_comp, min(pls.RMSEP$val), pch=1, col="red", cex=1.5)



min\_comp

## [1] 30

plot(plsFit, ncomp=30, asp=1, line=TRUE)



pls.pred2 = predict(plsFit, dfPredImp, ncomp=30)  
pls.pred2

## , , 30 comps  
##   
## PH  
## 1 8.583340  
## 2 8.601578  
## 3 8.605833  
## 4 8.548635  
## 5 8.528368  
## 6 8.628903  
## 7 8.579779  
## 8 8.572863  
## 9 8.665425  
## 10 8.603080  
## 11 8.637534  
## 12 8.606228  
## 13 8.589768  
## 14 8.619004  
## 15 8.408674  
## 16 8.542402  
## 17 8.610035  
## 18 8.591883  
## 19 8.620827  
## 20 8.626382  
## 21 8.583062  
## 22 8.721609  
## 23 8.481919  
## 24 8.674872  
## 25 8.637988  
## 26 8.439427  
## 27 8.528859  
## 28 8.652329  
## 29 8.665838  
## 30 8.697615  
## 31 8.625927  
## 32 8.580866  
## 33 8.652165  
## 34 8.589373  
## 35 8.713613  
## 36 8.562809  
## 37 8.587600  
## 38 8.544160  
## 39 8.647712  
## 40 8.686181  
## 41 8.750200  
## 42 8.642188  
## 43 8.556191  
## 44 8.515569  
## 45 8.604593  
## 46 8.612154  
## 47 8.634431  
## 48 8.622042  
## 49 8.611582  
## 50 8.644532  
## 51 8.600851  
## 52 8.625026  
## 53 8.676077  
## 54 8.622463  
## 55 8.692805  
## 56 8.647025  
## 57 8.421324  
## 58 8.482953  
## 59 8.623701  
## 60 8.656599  
## 61 8.747833  
## 62 8.633775  
## 63 8.711970  
## 64 8.676809  
## 65 8.671551  
## 66 8.571380  
## 67 8.557620  
## 68 8.565365  
## 69 8.615030  
## 70 8.585019  
## 71 8.446092  
## 72 8.470805  
## 73 8.604864  
## 74 8.545763  
## 75 8.564722  
## 76 8.517739  
## 77 8.744208  
## 78 8.687437  
## 79 8.719003  
## 80 8.688091  
## 81 8.778676  
## 82 8.492765  
## 83 8.529838  
## 84 8.522084  
## 85 8.577033  
## 86 8.573122  
## 87 8.708556  
## 88 8.649894  
## 89 8.515728  
## 90 8.684509  
## 91 8.599790  
## 92 8.165542  
## 93 8.511175  
## 94 8.352300  
## 95 8.448409  
## 96 8.628027  
## 97 8.598708  
## 98 8.620877  
## 99 8.536881  
## 100 8.539324  
## 101 8.546716  
## 102 8.686072  
## 103 8.649214  
## 104 8.639911  
## 105 8.681627  
## 106 8.683792  
## 107 8.511794  
## 108 8.506181  
## 109 8.521203  
## 110 8.499428  
## 111 8.636831  
## 112 8.645815  
## 113 8.640391  
## 114 8.726315  
## 115 8.590566  
## 116 8.687818  
## 117 8.652248  
## 118 8.717283  
## 119 8.710723  
## 120 8.676863  
## 121 8.651755  
## 122 8.660012  
## 123 8.731341  
## 124 8.505011  
## 125 8.480895  
## 126 8.470299  
## 127 8.415256  
## 128 8.265968  
## 129 8.457516  
## 130 8.387919  
## 131 8.461432  
## 132 8.460244  
## 133 8.471375  
## 134 8.377787  
## 135 8.393968  
## 136 8.463764  
## 137 8.515683  
## 138 8.481518  
## 139 8.515785  
## 140 8.550155  
## 141 8.415264  
## 142 8.478054  
## 143 8.410519  
## 144 8.352375  
## 145 8.338040  
## 146 8.407509  
## 147 8.363635  
## 148 8.447091  
## 149 8.419357  
## 150 8.422146  
## 151 8.468902  
## 152 8.484013  
## 153 8.417408  
## 154 8.533998  
## 155 8.297211  
## 156 8.340601  
## 157 8.343720  
## 158 8.406906  
## 159 8.460847  
## 160 8.478005  
## 161 8.539701  
## 162 8.504673  
## 163 8.485437  
## 164 8.486665  
## 165 8.436546  
## 166 8.465926  
## 167 8.394476  
## 168 8.541670  
## 169 8.614516  
## 170 8.488418  
## 171 8.425781  
## 172 8.514705  
## 173 8.414915  
## 174 8.458232  
## 175 8.486961  
## 176 8.526935  
## 177 8.432330  
## 178 8.414950  
## 179 8.302110  
## 180 8.383137  
## 181 8.352659  
## 182 8.444637  
## 183 8.375415  
## 184 8.418838  
## 185 8.423220  
## 186 8.302828  
## 187 8.326489  
## 188 8.620683  
## 189 8.421743  
## 190 8.367473  
## 191 8.380718  
## 192 8.477821  
## 193 8.449976  
## 194 8.537251  
## 195 8.449129  
## 196 8.318196  
## 197 8.337999  
## 198 8.361088  
## 199 8.365810  
## 200 8.427305  
## 201 8.461596  
## 202 8.444313  
## 203 8.579866  
## 204 8.278126  
## 205 8.348888  
## 206 8.421156  
## 207 8.411937  
## 208 8.455462  
## 209 8.368689  
## 210 8.361183  
## 211 8.274483  
## 212 8.240345  
## 213 8.238177  
## 214 8.387309  
## 215 8.314191  
## 216 8.315406  
## 217 8.383751  
## 218 8.368191  
## 219 8.439755  
## 220 8.475282  
## 221 8.438573  
## 222 8.457265  
## 223 8.428929  
## 224 8.207657  
## 225 8.449068  
## 226 8.393044  
## 227 8.413349  
## 228 8.425461  
## 229 8.459476  
## 230 8.437051  
## 231 8.470639  
## 232 8.438299  
## 233 8.424943  
## 234 8.453663  
## 235 8.489971  
## 236 8.415962  
## 237 8.473326  
## 238 8.519842  
## 239 8.393520  
## 240 8.383809  
## 241 8.361971  
## 242 8.394161  
## 243 8.350275  
## 244 8.304780  
## 245 8.399470  
## 246 8.431180  
## 247 8.415712  
## 248 8.477259  
## 249 8.504913  
## 250 8.471101  
## 251 8.451834  
## 252 8.442229  
## 253 8.457188  
## 254 8.430043  
## 255 8.520361  
## 256 8.260783  
## 257 8.458854  
## 258 8.499821  
## 259 8.445846  
## 260 8.431023  
## 261 8.469259  
## 262 8.522249  
## 263 8.503038  
## 264 8.484833  
## 265 8.324782  
## 266 8.312529  
## 267 8.331692

With the vast amounts of algorithms available, several should be explored to help make accurate predictions on the dataset. Linear regression is often the simple first step as these models are fast to train albeit with a high bias. The final models are typically easier to analyze and if they are accurate enough it may save moving on to more complex non-linear models. In this example we will start with a simple Generalized Linear Model (GLM) to perform a logistic regression, mix in more complex models then compare the results. A 10-fold cross validation is used for comparison and although not utilized below, a repeated cross validation can be set although it should be noted that repeating a cross valdation with exactly the same splitting will yield exactly the same result for every repetition. Non-linear algorithms make fewer assumptions about the function being modeled so this will result in higher variance but often result in higher accuracy. Because of its flexibility these models tend to be slower to train and may require increased memory resources. We will explore a Neural Network and MARS model in further detail but will take a quick look at a k-Nearest Neigbor (KNN) and a Support Vector Machine (SVM) algorithm below.

Classification and Regression Trees (CART) and a Bagged CART are also compared below. CART split attributes based on values that minimize a loss function such as RMSE in the below example. Bagging CART is an ensemble method, which we will explore further later, that creates multiple models of the same type from different subsets of the same data. The predictions are then combined together for better results. This approach is particularly useful for high variance methods such as decision trees.

trainControl <- trainControl(method = "cv", number = 10)  
  
#GLM  
set.seed(1234)  
fit.glm <- train(PH~., data=dfModImp, method="glm", metric="RMSE", trControl=trainControl,  
 tuneLength = 5, preProc = c("center", "scale"))  
fit.glm

## Generalized Linear Model   
##   
## 2571 samples  
## 36 predictor  
##   
## Pre-processing: centered (36), scaled (36)   
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 2314, 2314, 2314, 2312, 2314, 2314, ...   
## Resampling results:  
##   
## RMSE Rsquared MAE   
## 0.1336941 0.4014538 0.1035013

#SVM  
set.seed(1234)  
fit.svm <- train(PH~., data=dfModImp, method="svmLinear3", metric="RMSE", trControl=trainControl, tuneLength = 5, svr\_eps = .1, preProc = c("center", "scale"))  
fit.svm

## L2 Regularized Support Vector Machine (dual) with Linear Kernel   
##   
## 2571 samples  
## 36 predictor  
##   
## Pre-processing: centered (36), scaled (36)   
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 2314, 2314, 2314, 2312, 2314, 2314, ...   
## Resampling results across tuning parameters:  
##   
## cost Loss RMSE Rsquared MAE   
## 0.25 L1 0.1794758 0.3230042 0.1480714  
## 0.25 L2 0.1347935 0.3912482 0.1043152  
## 0.50 L1 0.1773276 0.3229858 0.1460276  
## 0.50 L2 0.1353488 0.3864330 0.1044418  
## 1.00 L1 0.1762712 0.3229765 0.1450213  
## 1.00 L2 0.1351602 0.3882844 0.1040097  
## 2.00 L1 0.1757476 0.3229719 0.1445198  
## 2.00 L2 0.1367263 0.3791064 0.1055107  
## 4.00 L1 0.1754869 0.3229696 0.1442695  
## 4.00 L2 0.1415372 0.3428813 0.1098640  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final values used for the model were cost = 0.25 and Loss = L2.

#KNN  
set.seed(1234)  
fit.knn <- train(PH~., data=dfModImp, method="knn", metric="RMSE", trControl=trainControl,  
 tuneLength = 5, preProc = c("center", "scale"))  
fit.knn

## k-Nearest Neighbors   
##   
## 2571 samples  
## 36 predictor  
##   
## Pre-processing: centered (36), scaled (36)   
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 2314, 2314, 2314, 2312, 2314, 2314, ...   
## Resampling results across tuning parameters:  
##   
## k RMSE Rsquared MAE   
## 5 0.1186557 0.5329320 0.08750895  
## 7 0.1177431 0.5391565 0.08733818  
## 9 0.1183880 0.5346838 0.08860023  
## 11 0.1191883 0.5297174 0.08971221  
## 13 0.1199656 0.5239618 0.09067160  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final value used for the model was k = 7.

#CART  
set.seed(1234)  
fit.cart <- train(PH~., data=dfModImp, method="rpart", metric="RMSE", trControl=trainControl,  
 tuneLength = 5, preProc = c("center", "scale"))  
fit.cart

## CART   
##   
## 2571 samples  
## 36 predictor  
##   
## Pre-processing: centered (36), scaled (36)   
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 2314, 2314, 2314, 2312, 2314, 2314, ...   
## Resampling results across tuning parameters:  
##   
## cp RMSE Rsquared MAE   
## 0.02449866 0.1320985 0.4139347 0.1021212  
## 0.04289798 0.1357536 0.3805193 0.1047916  
## 0.06257969 0.1428339 0.3151390 0.1088900  
## 0.07576762 0.1491084 0.2560344 0.1151092  
## 0.22944632 0.1613498 0.2031147 0.1272420  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final value used for the model was cp = 0.02449866.

#Bagged CART  
set.seed(1234)  
fit.bagcart <- train(PH~., data=dfModImp, method="treebag", metric="RMSE", trControl=trainControl,  
 tuneLength = 5, preProc = c("center", "scale"))  
fit.bagcart

## Bagged CART   
##   
## 2571 samples  
## 36 predictor  
##   
## Pre-processing: centered (36), scaled (36)   
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 2314, 2314, 2314, 2312, 2314, 2314, ...   
## Resampling results:  
##   
## RMSE Rsquared MAE   
## 0.106051 0.6279657 0.0807397

#Compare results of the algorithms we ran  
results <- resamples(list(GLM=fit.glm, SVM=fit.svm, KNN=fit.knn, CART=fit.cart, BaggedCart=fit.bagcart))  
  
summary(results)

##   
## Call:  
## summary.resamples(object = results)  
##   
## Models: GLM, SVM, KNN, CART, BaggedCart   
## Number of resamples: 10   
##   
## MAE   
## Min. 1st Qu. Median Mean 3rd Qu.  
## GLM 0.09584651 0.10003234 0.10240396 0.10350131 0.10766877  
## SVM 0.09735266 0.10113564 0.10191450 0.10431520 0.10906841  
## KNN 0.08086076 0.08450493 0.08733073 0.08733818 0.09068830  
## CART 0.09253838 0.10015558 0.10212189 0.10212123 0.10514431  
## BaggedCart 0.07234370 0.07802265 0.08148214 0.08073970 0.08403983  
## Max. NA's  
## GLM 0.11002310 0  
## SVM 0.11115424 0  
## KNN 0.09399666 0  
## CART 0.10964481 0  
## BaggedCart 0.08613952 0  
##   
## RMSE   
## Min. 1st Qu. Median Mean 3rd Qu. Max.  
## GLM 0.12464203 0.1283189 0.1315466 0.1336941 0.1397657 0.1436487  
## SVM 0.12641331 0.1292742 0.1323995 0.1347935 0.1422470 0.1438852  
## KNN 0.10633303 0.1141141 0.1151281 0.1177431 0.1222481 0.1305251  
## CART 0.11574383 0.1280689 0.1318011 0.1320985 0.1377113 0.1448673  
## BaggedCart 0.09435403 0.1014102 0.1053985 0.1060510 0.1124663 0.1185575  
## NA's  
## GLM 0  
## SVM 0  
## KNN 0  
## CART 0  
## BaggedCart 0  
##   
## Rsquared   
## Min. 1st Qu. Median Mean 3rd Qu. Max.  
## GLM 0.3404238 0.3899162 0.4014200 0.4014538 0.4206822 0.4609980  
## SVM 0.3223913 0.3764739 0.3979777 0.3912482 0.4152274 0.4518719  
## KNN 0.4803567 0.5015028 0.5415167 0.5391565 0.5649686 0.6199366  
## CART 0.3302931 0.3880648 0.4124382 0.4139347 0.4499189 0.4700435  
## BaggedCart 0.5629121 0.6152075 0.6317394 0.6279657 0.6497779 0.7010340  
## NA's  
## GLM 0  
## SVM 0  
## KNN 0  
## CART 0  
## BaggedCart 0

The Bagged CART performed the best from the above models with a mean RMSE of 0.1060510 and a mean R-Squared of 0.6279657. We will explore further to see if we can find better results.

Ensemble Regression Ensemble methods generally refer to models combining predictions, either in classification or regression, of several base estimators to improve robustness over a single estimator. The goal of ensemble regression is to combine many models in order to increase the prediction accuracy in learning problems with a numerical target. The focus will be on regression not classification with Random Forest and Gradient Boosting (GBM).

Regression trees tend to be unstable, a seemingly insignificant change in the data can have a large impact on the model. The Random Forest can help solve this problem through bagging. Bagging originates from bootstrap aggregating which is a machine learning techique proposed by Breiman to stabalize potentially unstable estimators. Essentially, each variable is given several opportunities to be in the model across multiple bootstrap samples and the final forecast will be the average forecast across all samples.

Gradient Boosting (GBM) is another ensemble method explored that is similarly applied to regression and classification problems. Boosting originated from the notion that weak learners can become better. The first successful boosting algorithm was Adaptive Boosting or AdaBoost. Later, based on this framework, GBM attempted to solve a numerical optimization problem by minimizing the loss of the model by adding weak learners using a gradient descent. These class of algorithms were described as stage-wise additive because a new weak learner is added incrementally, simultaneaously an existing weak learner is left unchanged.

Random Forest

library(randomForest)  
  
set.seed(1234)  
  
rf <- function(df,y){  
 fitControl <- trainControl(method = "cv",  
 number = 10, #5folds)  
   
rfgrid <- expand.grid(interaction.depth = 2,  
 n.trees = 500,  
 shrinkage = 0.1,  
 n.minobsinnode = 10))  
   
return(train(df, y,   
 method = "randomForest",   
 tuneGrid = rfgrid,   
 trControl = fitControl))  
}  
  
rf.fit.bcsx <- randomForest(dfTrainBCSX, dfTrainY)  
rf.fit.bx <- randomForest(dfTrainBX, dfTrainY)  
rf.fit.x <- randomForest(dfTrainX, dfTrainY)

list(RMSE\_RF.BCSX = RMSE(predict(rf.fit.bcsx, dfTestBCSX), dfTestY),  
 RMSE\_RF.BCS = RMSE(predict(rf.fit.bx, dfTestBX), dfTestY),  
 RMSE\_RF.X = RMSE(predict(rf.fit.x, dfTestX), dfTestY))

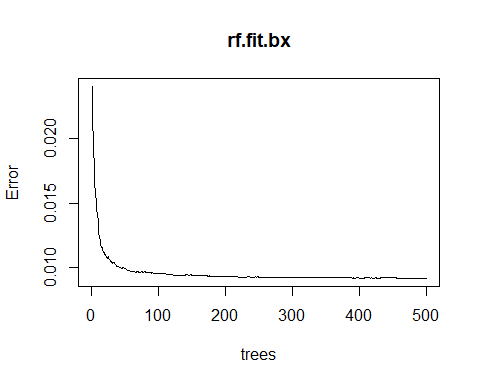
## $RMSE\_RF.BCSX  
## [1] 0.09756769  
##   
## $RMSE\_RF.BCS  
## [1] 0.09255377  
##   
## $RMSE\_RF.X  
## [1] 0.09775936

summary(rf.fit.bx, digit=3)

## Length Class Mode   
## call 3 -none- call   
## type 1 -none- character  
## predicted 1928 -none- numeric   
## mse 500 -none- numeric   
## rsq 500 -none- numeric   
## oob.times 1928 -none- numeric   
## importance 36 -none- numeric   
## importanceSD 0 -none- NULL   
## localImportance 0 -none- NULL   
## proximity 0 -none- NULL   
## ntree 1 -none- numeric   
## mtry 1 -none- numeric   
## forest 11 -none- list   
## coefs 0 -none- NULL   
## y 1928 -none- numeric   
## test 0 -none- NULL   
## inbag 0 -none- NULL

#varImp(rf.fit.bx)  
#Error in varImp[, "%IncMSE"] : subscript out of bounds

plot(rf.fit.bx)



GBM

library(caret)  
  
set.seed(1234)  
  
gbm <- function(df,y){  
 fitControl <- trainControl(method = "cv",  
 number = 10)  
   
gbmgrid <- expand.grid(interaction.depth = 2,  
 n.trees = 500,  
 shrinkage = 0.1,  
 n.minobsinnode = 10)  
   
return(train(df, y,   
 method = "gbm",   
 tuneGrid = gbmgrid,   
 trControl = fitControl))  
}  
  
gbm.fit.bcsx <- gbm(dfTrainBCSX, dfTrainY)

## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0278 nan 0.1000 0.0016  
## 2 0.0264 nan 0.1000 0.0014  
## 3 0.0252 nan 0.1000 0.0011  
## 4 0.0243 nan 0.1000 0.0010  
## 5 0.0235 nan 0.1000 0.0008  
## 6 0.0228 nan 0.1000 0.0007  
## 7 0.0220 nan 0.1000 0.0007  
## 8 0.0214 nan 0.1000 0.0005  
## 9 0.0208 nan 0.1000 0.0006  
## 10 0.0204 nan 0.1000 0.0004  
## 20 0.0177 nan 0.1000 0.0001  
## 40 0.0152 nan 0.1000 0.0000  
## 60 0.0139 nan 0.1000 0.0000  
## 80 0.0129 nan 0.1000 0.0000  
## 100 0.0122 nan 0.1000 -0.0000  
## 120 0.0115 nan 0.1000 0.0000  
## 140 0.0110 nan 0.1000 -0.0000  
## 160 0.0106 nan 0.1000 0.0000  
## 180 0.0102 nan 0.1000 -0.0000  
## 200 0.0098 nan 0.1000 -0.0000  
## 220 0.0095 nan 0.1000 -0.0000  
## 240 0.0093 nan 0.1000 -0.0000  
## 260 0.0089 nan 0.1000 -0.0000  
## 280 0.0087 nan 0.1000 -0.0000  
## 300 0.0085 nan 0.1000 -0.0000  
## 320 0.0083 nan 0.1000 -0.0000  
## 340 0.0081 nan 0.1000 -0.0000  
## 360 0.0079 nan 0.1000 -0.0000  
## 380 0.0078 nan 0.1000 0.0000  
## 400 0.0076 nan 0.1000 -0.0000  
## 420 0.0074 nan 0.1000 -0.0000  
## 440 0.0073 nan 0.1000 -0.0000  
## 460 0.0071 nan 0.1000 -0.0000  
## 480 0.0070 nan 0.1000 -0.0000  
## 500 0.0068 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0017  
## 2 0.0264 nan 0.1000 0.0014  
## 3 0.0252 nan 0.1000 0.0011  
## 4 0.0242 nan 0.1000 0.0009  
## 5 0.0234 nan 0.1000 0.0008  
## 6 0.0227 nan 0.1000 0.0007  
## 7 0.0219 nan 0.1000 0.0006  
## 8 0.0213 nan 0.1000 0.0005  
## 9 0.0208 nan 0.1000 0.0005  
## 10 0.0203 nan 0.1000 0.0004  
## 20 0.0178 nan 0.1000 0.0001  
## 40 0.0155 nan 0.1000 -0.0001  
## 60 0.0143 nan 0.1000 0.0000  
## 80 0.0133 nan 0.1000 0.0000  
## 100 0.0126 nan 0.1000 -0.0000  
## 120 0.0119 nan 0.1000 -0.0000  
## 140 0.0114 nan 0.1000 -0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0103 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 -0.0000  
## 260 0.0093 nan 0.1000 -0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 -0.0000  
## 320 0.0086 nan 0.1000 -0.0000  
## 340 0.0084 nan 0.1000 0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0080 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0077 nan 0.1000 0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0285 nan 0.1000 0.0016  
## 2 0.0271 nan 0.1000 0.0014  
## 3 0.0259 nan 0.1000 0.0011  
## 4 0.0248 nan 0.1000 0.0010  
## 5 0.0240 nan 0.1000 0.0007  
## 6 0.0233 nan 0.1000 0.0006  
## 7 0.0227 nan 0.1000 0.0006  
## 8 0.0221 nan 0.1000 0.0005  
## 9 0.0216 nan 0.1000 0.0005  
## 10 0.0212 nan 0.1000 0.0004  
## 20 0.0184 nan 0.1000 0.0002  
## 40 0.0161 nan 0.1000 0.0000  
## 60 0.0147 nan 0.1000 0.0000  
## 80 0.0137 nan 0.1000 0.0000  
## 100 0.0130 nan 0.1000 -0.0000  
## 120 0.0124 nan 0.1000 -0.0000  
## 140 0.0118 nan 0.1000 0.0000  
## 160 0.0113 nan 0.1000 -0.0000  
## 180 0.0108 nan 0.1000 -0.0000  
## 200 0.0105 nan 0.1000 -0.0000  
## 220 0.0101 nan 0.1000 -0.0000  
## 240 0.0098 nan 0.1000 -0.0000  
## 260 0.0095 nan 0.1000 -0.0000  
## 280 0.0092 nan 0.1000 -0.0000  
## 300 0.0090 nan 0.1000 -0.0000  
## 320 0.0088 nan 0.1000 -0.0000  
## 340 0.0086 nan 0.1000 -0.0000  
## 360 0.0084 nan 0.1000 -0.0000  
## 380 0.0082 nan 0.1000 -0.0000  
## 400 0.0080 nan 0.1000 -0.0000  
## 420 0.0078 nan 0.1000 -0.0000  
## 440 0.0077 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0072 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0285 nan 0.1000 0.0016  
## 2 0.0271 nan 0.1000 0.0013  
## 3 0.0259 nan 0.1000 0.0012  
## 4 0.0249 nan 0.1000 0.0010  
## 5 0.0241 nan 0.1000 0.0008  
## 6 0.0232 nan 0.1000 0.0008  
## 7 0.0226 nan 0.1000 0.0006  
## 8 0.0221 nan 0.1000 0.0005  
## 9 0.0216 nan 0.1000 0.0005  
## 10 0.0211 nan 0.1000 0.0004  
## 20 0.0183 nan 0.1000 0.0001  
## 40 0.0160 nan 0.1000 0.0001  
## 60 0.0147 nan 0.1000 0.0000  
## 80 0.0135 nan 0.1000 -0.0000  
## 100 0.0127 nan 0.1000 -0.0000  
## 120 0.0121 nan 0.1000 -0.0000  
## 140 0.0116 nan 0.1000 0.0000  
## 160 0.0111 nan 0.1000 -0.0000  
## 180 0.0107 nan 0.1000 -0.0000  
## 200 0.0104 nan 0.1000 -0.0000  
## 220 0.0101 nan 0.1000 -0.0000  
## 240 0.0098 nan 0.1000 -0.0000  
## 260 0.0095 nan 0.1000 -0.0000  
## 280 0.0093 nan 0.1000 -0.0000  
## 300 0.0091 nan 0.1000 -0.0000  
## 320 0.0088 nan 0.1000 -0.0000  
## 340 0.0086 nan 0.1000 -0.0000  
## 360 0.0085 nan 0.1000 -0.0000  
## 380 0.0083 nan 0.1000 -0.0000  
## 400 0.0081 nan 0.1000 -0.0000  
## 420 0.0080 nan 0.1000 -0.0000  
## 440 0.0078 nan 0.1000 0.0000  
## 460 0.0076 nan 0.1000 -0.0000  
## 480 0.0075 nan 0.1000 -0.0000  
## 500 0.0074 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0284 nan 0.1000 0.0017  
## 2 0.0270 nan 0.1000 0.0014  
## 3 0.0258 nan 0.1000 0.0012  
## 4 0.0248 nan 0.1000 0.0010  
## 5 0.0240 nan 0.1000 0.0008  
## 6 0.0231 nan 0.1000 0.0008  
## 7 0.0225 nan 0.1000 0.0006  
## 8 0.0219 nan 0.1000 0.0005  
## 9 0.0214 nan 0.1000 0.0006  
## 10 0.0208 nan 0.1000 0.0005  
## 20 0.0180 nan 0.1000 0.0002  
## 40 0.0157 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 0.0000  
## 80 0.0135 nan 0.1000 -0.0000  
## 100 0.0127 nan 0.1000 -0.0000  
## 120 0.0121 nan 0.1000 0.0000  
## 140 0.0116 nan 0.1000 -0.0000  
## 160 0.0112 nan 0.1000 -0.0000  
## 180 0.0108 nan 0.1000 0.0000  
## 200 0.0105 nan 0.1000 -0.0000  
## 220 0.0101 nan 0.1000 -0.0000  
## 240 0.0099 nan 0.1000 -0.0000  
## 260 0.0096 nan 0.1000 -0.0000  
## 280 0.0094 nan 0.1000 -0.0000  
## 300 0.0091 nan 0.1000 -0.0000  
## 320 0.0089 nan 0.1000 -0.0000  
## 340 0.0087 nan 0.1000 0.0000  
## 360 0.0085 nan 0.1000 -0.0000  
## 380 0.0082 nan 0.1000 0.0000  
## 400 0.0081 nan 0.1000 -0.0000  
## 420 0.0079 nan 0.1000 -0.0000  
## 440 0.0078 nan 0.1000 -0.0000  
## 460 0.0076 nan 0.1000 -0.0000  
## 480 0.0075 nan 0.1000 -0.0000  
## 500 0.0073 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0017  
## 2 0.0265 nan 0.1000 0.0013  
## 3 0.0253 nan 0.1000 0.0011  
## 4 0.0244 nan 0.1000 0.0009  
## 5 0.0235 nan 0.1000 0.0009  
## 6 0.0228 nan 0.1000 0.0007  
## 7 0.0223 nan 0.1000 0.0005  
## 8 0.0217 nan 0.1000 0.0006  
## 9 0.0211 nan 0.1000 0.0005  
## 10 0.0206 nan 0.1000 0.0004  
## 20 0.0179 nan 0.1000 0.0001  
## 40 0.0155 nan 0.1000 0.0000  
## 60 0.0142 nan 0.1000 0.0000  
## 80 0.0133 nan 0.1000 -0.0000  
## 100 0.0126 nan 0.1000 0.0000  
## 120 0.0118 nan 0.1000 -0.0000  
## 140 0.0113 nan 0.1000 0.0000  
## 160 0.0108 nan 0.1000 -0.0000  
## 180 0.0105 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 -0.0000  
## 260 0.0094 nan 0.1000 -0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 -0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0085 nan 0.1000 -0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0080 nan 0.1000 -0.0000  
## 400 0.0078 nan 0.1000 -0.0000  
## 420 0.0077 nan 0.1000 -0.0000  
## 440 0.0075 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0072 nan 0.1000 -0.0000  
## 500 0.0070 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0283 nan 0.1000 0.0017  
## 2 0.0269 nan 0.1000 0.0014  
## 3 0.0257 nan 0.1000 0.0012  
## 4 0.0248 nan 0.1000 0.0008  
## 5 0.0239 nan 0.1000 0.0008  
## 6 0.0231 nan 0.1000 0.0008  
## 7 0.0225 nan 0.1000 0.0005  
## 8 0.0218 nan 0.1000 0.0006  
## 9 0.0213 nan 0.1000 0.0005  
## 10 0.0208 nan 0.1000 0.0004  
## 20 0.0180 nan 0.1000 0.0001  
## 40 0.0158 nan 0.1000 0.0001  
## 60 0.0144 nan 0.1000 0.0000  
## 80 0.0135 nan 0.1000 -0.0001  
## 100 0.0127 nan 0.1000 -0.0000  
## 120 0.0121 nan 0.1000 -0.0001  
## 140 0.0116 nan 0.1000 -0.0000  
## 160 0.0111 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 -0.0000  
## 260 0.0094 nan 0.1000 -0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 -0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0084 nan 0.1000 -0.0000  
## 360 0.0083 nan 0.1000 -0.0000  
## 380 0.0081 nan 0.1000 0.0000  
## 400 0.0079 nan 0.1000 0.0000  
## 420 0.0077 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0075 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0280 nan 0.1000 0.0017  
## 2 0.0266 nan 0.1000 0.0014  
## 3 0.0254 nan 0.1000 0.0011  
## 4 0.0242 nan 0.1000 0.0012  
## 5 0.0234 nan 0.1000 0.0008  
## 6 0.0227 nan 0.1000 0.0006  
## 7 0.0219 nan 0.1000 0.0007  
## 8 0.0214 nan 0.1000 0.0006  
## 9 0.0209 nan 0.1000 0.0005  
## 10 0.0203 nan 0.1000 0.0005  
## 20 0.0177 nan 0.1000 0.0002  
## 40 0.0156 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 0.0000  
## 80 0.0133 nan 0.1000 0.0000  
## 100 0.0125 nan 0.1000 -0.0000  
## 120 0.0120 nan 0.1000 -0.0000  
## 140 0.0115 nan 0.1000 0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0105 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0097 nan 0.1000 -0.0000  
## 260 0.0094 nan 0.1000 0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 -0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0085 nan 0.1000 -0.0000  
## 360 0.0083 nan 0.1000 -0.0000  
## 380 0.0081 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0077 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0075 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0072 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0283 nan 0.1000 0.0015  
## 2 0.0268 nan 0.1000 0.0014  
## 3 0.0254 nan 0.1000 0.0011  
## 4 0.0244 nan 0.1000 0.0009  
## 5 0.0234 nan 0.1000 0.0008  
## 6 0.0227 nan 0.1000 0.0006  
## 7 0.0220 nan 0.1000 0.0006  
## 8 0.0215 nan 0.1000 0.0005  
## 9 0.0209 nan 0.1000 0.0005  
## 10 0.0205 nan 0.1000 0.0004  
## 20 0.0178 nan 0.1000 0.0001  
## 40 0.0156 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 -0.0000  
## 80 0.0134 nan 0.1000 0.0000  
## 100 0.0126 nan 0.1000 0.0000  
## 120 0.0120 nan 0.1000 -0.0000  
## 140 0.0115 nan 0.1000 0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0107 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0097 nan 0.1000 -0.0000  
## 260 0.0094 nan 0.1000 -0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0088 nan 0.1000 -0.0000  
## 320 0.0085 nan 0.1000 0.0000  
## 340 0.0083 nan 0.1000 -0.0000  
## 360 0.0081 nan 0.1000 -0.0000  
## 380 0.0079 nan 0.1000 -0.0000  
## 400 0.0077 nan 0.1000 -0.0000  
## 420 0.0076 nan 0.1000 -0.0000  
## 440 0.0074 nan 0.1000 -0.0000  
## 460 0.0073 nan 0.1000 -0.0000  
## 480 0.0072 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0287 nan 0.1000 0.0017  
## 2 0.0272 nan 0.1000 0.0014  
## 3 0.0260 nan 0.1000 0.0013  
## 4 0.0248 nan 0.1000 0.0010  
## 5 0.0240 nan 0.1000 0.0008  
## 6 0.0232 nan 0.1000 0.0007  
## 7 0.0225 nan 0.1000 0.0007  
## 8 0.0220 nan 0.1000 0.0004  
## 9 0.0214 nan 0.1000 0.0005  
## 10 0.0209 nan 0.1000 0.0005  
## 20 0.0181 nan 0.1000 0.0002  
## 40 0.0158 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 -0.0000  
## 80 0.0134 nan 0.1000 -0.0000  
## 100 0.0126 nan 0.1000 0.0000  
## 120 0.0120 nan 0.1000 0.0000  
## 140 0.0115 nan 0.1000 0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0107 nan 0.1000 -0.0000  
## 200 0.0103 nan 0.1000 -0.0000  
## 220 0.0100 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 0.0000  
## 260 0.0094 nan 0.1000 -0.0000  
## 280 0.0092 nan 0.1000 -0.0000  
## 300 0.0090 nan 0.1000 -0.0000  
## 320 0.0088 nan 0.1000 0.0000  
## 340 0.0085 nan 0.1000 -0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0081 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0077 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0072 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0282 nan 0.1000 0.0017  
## 2 0.0268 nan 0.1000 0.0014  
## 3 0.0256 nan 0.1000 0.0011  
## 4 0.0247 nan 0.1000 0.0009  
## 5 0.0238 nan 0.1000 0.0009  
## 6 0.0230 nan 0.1000 0.0008  
## 7 0.0223 nan 0.1000 0.0006  
## 8 0.0217 nan 0.1000 0.0006  
## 9 0.0212 nan 0.1000 0.0004  
## 10 0.0207 nan 0.1000 0.0005  
## 20 0.0180 nan 0.1000 0.0002  
## 40 0.0157 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 0.0000  
## 80 0.0135 nan 0.1000 0.0000  
## 100 0.0127 nan 0.1000 -0.0000  
## 120 0.0120 nan 0.1000 -0.0000  
## 140 0.0115 nan 0.1000 -0.0000  
## 160 0.0111 nan 0.1000 -0.0000  
## 180 0.0107 nan 0.1000 0.0000  
## 200 0.0103 nan 0.1000 -0.0000  
## 220 0.0100 nan 0.1000 -0.0000  
## 240 0.0097 nan 0.1000 -0.0000  
## 260 0.0095 nan 0.1000 -0.0000  
## 280 0.0092 nan 0.1000 -0.0000  
## 300 0.0090 nan 0.1000 -0.0000  
## 320 0.0088 nan 0.1000 -0.0000  
## 340 0.0086 nan 0.1000 0.0000  
## 360 0.0084 nan 0.1000 -0.0000  
## 380 0.0082 nan 0.1000 -0.0000  
## 400 0.0080 nan 0.1000 -0.0000  
## 420 0.0079 nan 0.1000 -0.0000  
## 440 0.0077 nan 0.1000 -0.0000  
## 460 0.0075 nan 0.1000 -0.0000  
## 480 0.0074 nan 0.1000 -0.0000  
## 500 0.0072 nan 0.1000 -0.0000

gbm.fit.bx <- gbm(dfTrainBX, dfTrainY)

## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0283 nan 0.1000 0.0017  
## 2 0.0270 nan 0.1000 0.0013  
## 3 0.0258 nan 0.1000 0.0011  
## 4 0.0248 nan 0.1000 0.0009  
## 5 0.0240 nan 0.1000 0.0008  
## 6 0.0231 nan 0.1000 0.0007  
## 7 0.0225 nan 0.1000 0.0006  
## 8 0.0219 nan 0.1000 0.0005  
## 9 0.0214 nan 0.1000 0.0005  
## 10 0.0210 nan 0.1000 0.0004  
## 20 0.0181 nan 0.1000 0.0001  
## 40 0.0155 nan 0.1000 0.0001  
## 60 0.0140 nan 0.1000 0.0000  
## 80 0.0130 nan 0.1000 0.0000  
## 100 0.0122 nan 0.1000 0.0000  
## 120 0.0116 nan 0.1000 0.0000  
## 140 0.0110 nan 0.1000 0.0000  
## 160 0.0104 nan 0.1000 -0.0000  
## 180 0.0100 nan 0.1000 -0.0000  
## 200 0.0096 nan 0.1000 -0.0000  
## 220 0.0093 nan 0.1000 -0.0000  
## 240 0.0090 nan 0.1000 -0.0000  
## 260 0.0087 nan 0.1000 -0.0000  
## 280 0.0084 nan 0.1000 -0.0000  
## 300 0.0082 nan 0.1000 -0.0000  
## 320 0.0080 nan 0.1000 -0.0000  
## 340 0.0078 nan 0.1000 -0.0000  
## 360 0.0075 nan 0.1000 0.0000  
## 380 0.0074 nan 0.1000 -0.0000  
## 400 0.0072 nan 0.1000 -0.0000  
## 420 0.0070 nan 0.1000 -0.0000  
## 440 0.0068 nan 0.1000 -0.0000  
## 460 0.0067 nan 0.1000 -0.0000  
## 480 0.0065 nan 0.1000 -0.0000  
## 500 0.0064 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0285 nan 0.1000 0.0018  
## 2 0.0271 nan 0.1000 0.0013  
## 3 0.0259 nan 0.1000 0.0013  
## 4 0.0248 nan 0.1000 0.0010  
## 5 0.0240 nan 0.1000 0.0009  
## 6 0.0232 nan 0.1000 0.0007  
## 7 0.0226 nan 0.1000 0.0006  
## 8 0.0219 nan 0.1000 0.0007  
## 9 0.0213 nan 0.1000 0.0005  
## 10 0.0208 nan 0.1000 0.0005  
## 20 0.0180 nan 0.1000 0.0002  
## 40 0.0154 nan 0.1000 0.0000  
## 60 0.0140 nan 0.1000 0.0000  
## 80 0.0130 nan 0.1000 -0.0000  
## 100 0.0122 nan 0.1000 -0.0000  
## 120 0.0116 nan 0.1000 -0.0000  
## 140 0.0110 nan 0.1000 -0.0000  
## 160 0.0105 nan 0.1000 -0.0000  
## 180 0.0100 nan 0.1000 -0.0000  
## 200 0.0097 nan 0.1000 -0.0000  
## 220 0.0093 nan 0.1000 0.0000  
## 240 0.0090 nan 0.1000 -0.0000  
## 260 0.0088 nan 0.1000 -0.0000  
## 280 0.0085 nan 0.1000 -0.0000  
## 300 0.0082 nan 0.1000 -0.0000  
## 320 0.0080 nan 0.1000 -0.0000  
## 340 0.0077 nan 0.1000 -0.0000  
## 360 0.0075 nan 0.1000 -0.0000  
## 380 0.0073 nan 0.1000 -0.0000  
## 400 0.0072 nan 0.1000 -0.0000  
## 420 0.0070 nan 0.1000 -0.0000  
## 440 0.0068 nan 0.1000 -0.0000  
## 460 0.0067 nan 0.1000 -0.0000  
## 480 0.0065 nan 0.1000 -0.0000  
## 500 0.0064 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0282 nan 0.1000 0.0016  
## 2 0.0268 nan 0.1000 0.0014  
## 3 0.0257 nan 0.1000 0.0011  
## 4 0.0247 nan 0.1000 0.0010  
## 5 0.0238 nan 0.1000 0.0008  
## 6 0.0230 nan 0.1000 0.0008  
## 7 0.0223 nan 0.1000 0.0007  
## 8 0.0217 nan 0.1000 0.0006  
## 9 0.0212 nan 0.1000 0.0004  
## 10 0.0207 nan 0.1000 0.0005  
## 20 0.0178 nan 0.1000 0.0001  
## 40 0.0153 nan 0.1000 -0.0000  
## 60 0.0140 nan 0.1000 -0.0000  
## 80 0.0131 nan 0.1000 0.0000  
## 100 0.0123 nan 0.1000 -0.0000  
## 120 0.0116 nan 0.1000 -0.0000  
## 140 0.0110 nan 0.1000 -0.0000  
## 160 0.0105 nan 0.1000 0.0000  
## 180 0.0100 nan 0.1000 -0.0000  
## 200 0.0097 nan 0.1000 -0.0000  
## 220 0.0094 nan 0.1000 -0.0000  
## 240 0.0090 nan 0.1000 -0.0000  
## 260 0.0088 nan 0.1000 0.0000  
## 280 0.0085 nan 0.1000 -0.0000  
## 300 0.0082 nan 0.1000 -0.0000  
## 320 0.0080 nan 0.1000 -0.0000  
## 340 0.0078 nan 0.1000 -0.0000  
## 360 0.0075 nan 0.1000 -0.0000  
## 380 0.0073 nan 0.1000 -0.0000  
## 400 0.0071 nan 0.1000 -0.0000  
## 420 0.0069 nan 0.1000 -0.0000  
## 440 0.0068 nan 0.1000 -0.0000  
## 460 0.0066 nan 0.1000 -0.0000  
## 480 0.0065 nan 0.1000 -0.0000  
## 500 0.0063 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0285 nan 0.1000 0.0016  
## 2 0.0271 nan 0.1000 0.0013  
## 3 0.0261 nan 0.1000 0.0010  
## 4 0.0250 nan 0.1000 0.0010  
## 5 0.0241 nan 0.1000 0.0009  
## 6 0.0233 nan 0.1000 0.0006  
## 7 0.0227 nan 0.1000 0.0006  
## 8 0.0221 nan 0.1000 0.0006  
## 9 0.0216 nan 0.1000 0.0005  
## 10 0.0211 nan 0.1000 0.0004  
## 20 0.0183 nan 0.1000 0.0002  
## 40 0.0158 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 -0.0000  
## 80 0.0134 nan 0.1000 -0.0000  
## 100 0.0125 nan 0.1000 0.0000  
## 120 0.0119 nan 0.1000 -0.0000  
## 140 0.0113 nan 0.1000 -0.0000  
## 160 0.0109 nan 0.1000 -0.0000  
## 180 0.0104 nan 0.1000 -0.0000  
## 200 0.0099 nan 0.1000 -0.0000  
## 220 0.0096 nan 0.1000 -0.0000  
## 240 0.0093 nan 0.1000 0.0000  
## 260 0.0090 nan 0.1000 -0.0000  
## 280 0.0087 nan 0.1000 -0.0000  
## 300 0.0083 nan 0.1000 -0.0000  
## 320 0.0081 nan 0.1000 -0.0000  
## 340 0.0080 nan 0.1000 -0.0000  
## 360 0.0078 nan 0.1000 -0.0000  
## 380 0.0076 nan 0.1000 -0.0000  
## 400 0.0073 nan 0.1000 -0.0000  
## 420 0.0071 nan 0.1000 -0.0000  
## 440 0.0070 nan 0.1000 -0.0000  
## 460 0.0068 nan 0.1000 -0.0000  
## 480 0.0066 nan 0.1000 -0.0000  
## 500 0.0065 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0283 nan 0.1000 0.0016  
## 2 0.0268 nan 0.1000 0.0015  
## 3 0.0256 nan 0.1000 0.0012  
## 4 0.0246 nan 0.1000 0.0009  
## 5 0.0236 nan 0.1000 0.0008  
## 6 0.0229 nan 0.1000 0.0006  
## 7 0.0223 nan 0.1000 0.0006  
## 8 0.0217 nan 0.1000 0.0006  
## 9 0.0212 nan 0.1000 0.0005  
## 10 0.0207 nan 0.1000 0.0004  
## 20 0.0179 nan 0.1000 0.0002  
## 40 0.0152 nan 0.1000 0.0000  
## 60 0.0140 nan 0.1000 0.0000  
## 80 0.0129 nan 0.1000 0.0000  
## 100 0.0120 nan 0.1000 -0.0000  
## 120 0.0112 nan 0.1000 0.0000  
## 140 0.0107 nan 0.1000 0.0000  
## 160 0.0102 nan 0.1000 -0.0000  
## 180 0.0099 nan 0.1000 -0.0000  
## 200 0.0095 nan 0.1000 0.0000  
## 220 0.0092 nan 0.1000 -0.0000  
## 240 0.0088 nan 0.1000 -0.0000  
## 260 0.0085 nan 0.1000 -0.0000  
## 280 0.0083 nan 0.1000 -0.0000  
## 300 0.0081 nan 0.1000 -0.0000  
## 320 0.0079 nan 0.1000 -0.0000  
## 340 0.0076 nan 0.1000 -0.0000  
## 360 0.0074 nan 0.1000 -0.0000  
## 380 0.0072 nan 0.1000 -0.0000  
## 400 0.0071 nan 0.1000 -0.0000  
## 420 0.0069 nan 0.1000 -0.0000  
## 440 0.0067 nan 0.1000 -0.0000  
## 460 0.0065 nan 0.1000 -0.0000  
## 480 0.0064 nan 0.1000 -0.0000  
## 500 0.0062 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0285 nan 0.1000 0.0016  
## 2 0.0270 nan 0.1000 0.0013  
## 3 0.0258 nan 0.1000 0.0012  
## 4 0.0248 nan 0.1000 0.0009  
## 5 0.0240 nan 0.1000 0.0008  
## 6 0.0232 nan 0.1000 0.0008  
## 7 0.0226 nan 0.1000 0.0006  
## 8 0.0220 nan 0.1000 0.0005  
## 9 0.0214 nan 0.1000 0.0005  
## 10 0.0210 nan 0.1000 0.0003  
## 20 0.0181 nan 0.1000 0.0001  
## 40 0.0155 nan 0.1000 0.0000  
## 60 0.0140 nan 0.1000 -0.0000  
## 80 0.0129 nan 0.1000 0.0000  
## 100 0.0120 nan 0.1000 -0.0000  
## 120 0.0113 nan 0.1000 0.0000  
## 140 0.0107 nan 0.1000 -0.0000  
## 160 0.0102 nan 0.1000 -0.0000  
## 180 0.0098 nan 0.1000 -0.0000  
## 200 0.0094 nan 0.1000 -0.0000  
## 220 0.0091 nan 0.1000 -0.0000  
## 240 0.0088 nan 0.1000 0.0000  
## 260 0.0085 nan 0.1000 -0.0000  
## 280 0.0082 nan 0.1000 -0.0000  
## 300 0.0080 nan 0.1000 -0.0000  
## 320 0.0078 nan 0.1000 -0.0000  
## 340 0.0076 nan 0.1000 -0.0000  
## 360 0.0074 nan 0.1000 -0.0000  
## 380 0.0072 nan 0.1000 -0.0000  
## 400 0.0070 nan 0.1000 -0.0000  
## 420 0.0069 nan 0.1000 -0.0000  
## 440 0.0067 nan 0.1000 -0.0000  
## 460 0.0065 nan 0.1000 -0.0000  
## 480 0.0064 nan 0.1000 -0.0000  
## 500 0.0062 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0281 nan 0.1000 0.0016  
## 2 0.0267 nan 0.1000 0.0014  
## 3 0.0254 nan 0.1000 0.0012  
## 4 0.0244 nan 0.1000 0.0009  
## 5 0.0237 nan 0.1000 0.0007  
## 6 0.0229 nan 0.1000 0.0008  
## 7 0.0223 nan 0.1000 0.0006  
## 8 0.0216 nan 0.1000 0.0006  
## 9 0.0211 nan 0.1000 0.0005  
## 10 0.0207 nan 0.1000 0.0003  
## 20 0.0179 nan 0.1000 0.0002  
## 40 0.0151 nan 0.1000 -0.0000  
## 60 0.0137 nan 0.1000 -0.0000  
## 80 0.0128 nan 0.1000 -0.0000  
## 100 0.0119 nan 0.1000 0.0000  
## 120 0.0113 nan 0.1000 -0.0000  
## 140 0.0108 nan 0.1000 0.0000  
## 160 0.0103 nan 0.1000 -0.0000  
## 180 0.0098 nan 0.1000 -0.0000  
## 200 0.0095 nan 0.1000 -0.0000  
## 220 0.0092 nan 0.1000 0.0000  
## 240 0.0089 nan 0.1000 -0.0000  
## 260 0.0086 nan 0.1000 -0.0000  
## 280 0.0084 nan 0.1000 -0.0000  
## 300 0.0082 nan 0.1000 -0.0000  
## 320 0.0079 nan 0.1000 -0.0000  
## 340 0.0077 nan 0.1000 -0.0000  
## 360 0.0075 nan 0.1000 -0.0000  
## 380 0.0073 nan 0.1000 -0.0000  
## 400 0.0072 nan 0.1000 -0.0000  
## 420 0.0070 nan 0.1000 0.0000  
## 440 0.0068 nan 0.1000 -0.0000  
## 460 0.0066 nan 0.1000 -0.0000  
## 480 0.0065 nan 0.1000 -0.0000  
## 500 0.0063 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0016  
## 2 0.0265 nan 0.1000 0.0013  
## 3 0.0253 nan 0.1000 0.0011  
## 4 0.0244 nan 0.1000 0.0009  
## 5 0.0236 nan 0.1000 0.0008  
## 6 0.0229 nan 0.1000 0.0006  
## 7 0.0224 nan 0.1000 0.0006  
## 8 0.0218 nan 0.1000 0.0005  
## 9 0.0212 nan 0.1000 0.0006  
## 10 0.0208 nan 0.1000 0.0004  
## 20 0.0178 nan 0.1000 0.0001  
## 40 0.0153 nan 0.1000 0.0001  
## 60 0.0139 nan 0.1000 -0.0000  
## 80 0.0130 nan 0.1000 -0.0000  
## 100 0.0121 nan 0.1000 0.0000  
## 120 0.0116 nan 0.1000 0.0000  
## 140 0.0109 nan 0.1000 -0.0000  
## 160 0.0105 nan 0.1000 0.0000  
## 180 0.0100 nan 0.1000 -0.0000  
## 200 0.0096 nan 0.1000 -0.0000  
## 220 0.0093 nan 0.1000 -0.0000  
## 240 0.0090 nan 0.1000 -0.0000  
## 260 0.0087 nan 0.1000 -0.0000  
## 280 0.0085 nan 0.1000 -0.0000  
## 300 0.0082 nan 0.1000 -0.0000  
## 320 0.0080 nan 0.1000 -0.0000  
## 340 0.0077 nan 0.1000 -0.0000  
## 360 0.0075 nan 0.1000 -0.0000  
## 380 0.0073 nan 0.1000 -0.0000  
## 400 0.0071 nan 0.1000 -0.0000  
## 420 0.0070 nan 0.1000 -0.0000  
## 440 0.0068 nan 0.1000 0.0000  
## 460 0.0066 nan 0.1000 -0.0000  
## 480 0.0065 nan 0.1000 -0.0000  
## 500 0.0063 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0283 nan 0.1000 0.0017  
## 2 0.0270 nan 0.1000 0.0014  
## 3 0.0259 nan 0.1000 0.0012  
## 4 0.0249 nan 0.1000 0.0010  
## 5 0.0240 nan 0.1000 0.0008  
## 6 0.0231 nan 0.1000 0.0008  
## 7 0.0224 nan 0.1000 0.0007  
## 8 0.0219 nan 0.1000 0.0005  
## 9 0.0213 nan 0.1000 0.0005  
## 10 0.0209 nan 0.1000 0.0004  
## 20 0.0179 nan 0.1000 0.0002  
## 40 0.0154 nan 0.1000 0.0001  
## 60 0.0139 nan 0.1000 0.0000  
## 80 0.0129 nan 0.1000 0.0000  
## 100 0.0122 nan 0.1000 -0.0000  
## 120 0.0115 nan 0.1000 -0.0000  
## 140 0.0109 nan 0.1000 0.0000  
## 160 0.0105 nan 0.1000 -0.0000  
## 180 0.0101 nan 0.1000 -0.0000  
## 200 0.0096 nan 0.1000 0.0000  
## 220 0.0093 nan 0.1000 0.0000  
## 240 0.0089 nan 0.1000 -0.0000  
## 260 0.0086 nan 0.1000 -0.0000  
## 280 0.0084 nan 0.1000 -0.0000  
## 300 0.0082 nan 0.1000 -0.0000  
## 320 0.0079 nan 0.1000 -0.0000  
## 340 0.0077 nan 0.1000 -0.0000  
## 360 0.0075 nan 0.1000 -0.0000  
## 380 0.0073 nan 0.1000 -0.0000  
## 400 0.0072 nan 0.1000 -0.0000  
## 420 0.0070 nan 0.1000 -0.0000  
## 440 0.0068 nan 0.1000 -0.0000  
## 460 0.0067 nan 0.1000 -0.0000  
## 480 0.0065 nan 0.1000 0.0000  
## 500 0.0064 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0017  
## 2 0.0263 nan 0.1000 0.0014  
## 3 0.0252 nan 0.1000 0.0011  
## 4 0.0242 nan 0.1000 0.0009  
## 5 0.0232 nan 0.1000 0.0009  
## 6 0.0224 nan 0.1000 0.0007  
## 7 0.0217 nan 0.1000 0.0006  
## 8 0.0212 nan 0.1000 0.0005  
## 9 0.0206 nan 0.1000 0.0005  
## 10 0.0201 nan 0.1000 0.0005  
## 20 0.0174 nan 0.1000 0.0001  
## 40 0.0149 nan 0.1000 0.0000  
## 60 0.0134 nan 0.1000 0.0000  
## 80 0.0124 nan 0.1000 0.0000  
## 100 0.0115 nan 0.1000 0.0000  
## 120 0.0109 nan 0.1000 0.0000  
## 140 0.0104 nan 0.1000 -0.0000  
## 160 0.0099 nan 0.1000 -0.0000  
## 180 0.0095 nan 0.1000 -0.0000  
## 200 0.0091 nan 0.1000 -0.0000  
## 220 0.0088 nan 0.1000 -0.0000  
## 240 0.0085 nan 0.1000 -0.0000  
## 260 0.0082 nan 0.1000 -0.0000  
## 280 0.0079 nan 0.1000 -0.0000  
## 300 0.0077 nan 0.1000 -0.0000  
## 320 0.0074 nan 0.1000 -0.0000  
## 340 0.0072 nan 0.1000 -0.0000  
## 360 0.0070 nan 0.1000 -0.0000  
## 380 0.0068 nan 0.1000 -0.0000  
## 400 0.0067 nan 0.1000 -0.0000  
## 420 0.0065 nan 0.1000 -0.0000  
## 440 0.0063 nan 0.1000 -0.0000  
## 460 0.0062 nan 0.1000 -0.0000  
## 480 0.0060 nan 0.1000 -0.0000  
## 500 0.0059 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0282 nan 0.1000 0.0017  
## 2 0.0267 nan 0.1000 0.0013  
## 3 0.0255 nan 0.1000 0.0011  
## 4 0.0245 nan 0.1000 0.0010  
## 5 0.0236 nan 0.1000 0.0008  
## 6 0.0229 nan 0.1000 0.0006  
## 7 0.0223 nan 0.1000 0.0006  
## 8 0.0217 nan 0.1000 0.0005  
## 9 0.0211 nan 0.1000 0.0004  
## 10 0.0207 nan 0.1000 0.0004  
## 20 0.0179 nan 0.1000 0.0002  
## 40 0.0154 nan 0.1000 0.0001  
## 60 0.0141 nan 0.1000 -0.0000  
## 80 0.0130 nan 0.1000 0.0000  
## 100 0.0122 nan 0.1000 0.0000  
## 120 0.0116 nan 0.1000 0.0000  
## 140 0.0110 nan 0.1000 0.0000  
## 160 0.0106 nan 0.1000 -0.0000  
## 180 0.0101 nan 0.1000 -0.0000  
## 200 0.0097 nan 0.1000 -0.0000  
## 220 0.0094 nan 0.1000 -0.0000  
## 240 0.0091 nan 0.1000 0.0000  
## 260 0.0088 nan 0.1000 -0.0000  
## 280 0.0085 nan 0.1000 -0.0000  
## 300 0.0083 nan 0.1000 -0.0000  
## 320 0.0080 nan 0.1000 -0.0000  
## 340 0.0078 nan 0.1000 -0.0000  
## 360 0.0076 nan 0.1000 -0.0000  
## 380 0.0074 nan 0.1000 -0.0000  
## 400 0.0072 nan 0.1000 0.0000  
## 420 0.0071 nan 0.1000 -0.0000  
## 440 0.0069 nan 0.1000 -0.0000  
## 460 0.0068 nan 0.1000 -0.0000  
## 480 0.0066 nan 0.1000 -0.0000  
## 500 0.0064 nan 0.1000 -0.0000

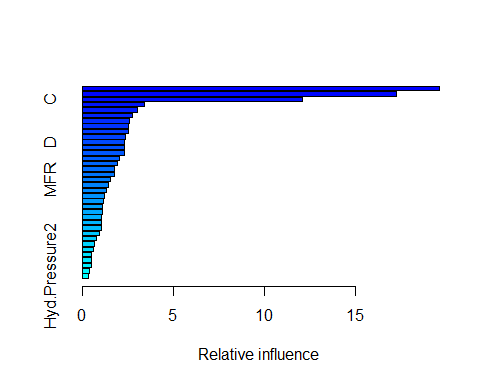
gbm.fit.x <- gbm(dfTrainX, dfTrainY)

## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0281 nan 0.1000 0.0017  
## 2 0.0266 nan 0.1000 0.0014  
## 3 0.0254 nan 0.1000 0.0011  
## 4 0.0244 nan 0.1000 0.0010  
## 5 0.0235 nan 0.1000 0.0008  
## 6 0.0228 nan 0.1000 0.0007  
## 7 0.0221 nan 0.1000 0.0007  
## 8 0.0216 nan 0.1000 0.0005  
## 9 0.0211 nan 0.1000 0.0005  
## 10 0.0206 nan 0.1000 0.0005  
## 20 0.0178 nan 0.1000 0.0001  
## 40 0.0155 nan 0.1000 0.0000  
## 60 0.0142 nan 0.1000 0.0000  
## 80 0.0133 nan 0.1000 -0.0000  
## 100 0.0124 nan 0.1000 -0.0000  
## 120 0.0118 nan 0.1000 -0.0000  
## 140 0.0113 nan 0.1000 -0.0000  
## 160 0.0109 nan 0.1000 -0.0000  
## 180 0.0105 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 0.0000  
## 220 0.0098 nan 0.1000 -0.0000  
## 240 0.0095 nan 0.1000 -0.0000  
## 260 0.0092 nan 0.1000 -0.0000  
## 280 0.0090 nan 0.1000 -0.0000  
## 300 0.0087 nan 0.1000 -0.0000  
## 320 0.0085 nan 0.1000 -0.0000  
## 340 0.0083 nan 0.1000 -0.0000  
## 360 0.0081 nan 0.1000 -0.0000  
## 380 0.0079 nan 0.1000 -0.0000  
## 400 0.0078 nan 0.1000 -0.0000  
## 420 0.0076 nan 0.1000 -0.0000  
## 440 0.0074 nan 0.1000 -0.0000  
## 460 0.0073 nan 0.1000 -0.0000  
## 480 0.0072 nan 0.1000 -0.0000  
## 500 0.0070 nan 0.1000 0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0286 nan 0.1000 0.0016  
## 2 0.0272 nan 0.1000 0.0014  
## 3 0.0260 nan 0.1000 0.0011  
## 4 0.0251 nan 0.1000 0.0009  
## 5 0.0243 nan 0.1000 0.0007  
## 6 0.0236 nan 0.1000 0.0007  
## 7 0.0229 nan 0.1000 0.0007  
## 8 0.0222 nan 0.1000 0.0005  
## 9 0.0217 nan 0.1000 0.0005  
## 10 0.0213 nan 0.1000 0.0004  
## 20 0.0184 nan 0.1000 0.0002  
## 40 0.0161 nan 0.1000 0.0000  
## 60 0.0149 nan 0.1000 0.0000  
## 80 0.0137 nan 0.1000 -0.0000  
## 100 0.0129 nan 0.1000 -0.0000  
## 120 0.0122 nan 0.1000 -0.0000  
## 140 0.0116 nan 0.1000 -0.0000  
## 160 0.0112 nan 0.1000 -0.0000  
## 180 0.0107 nan 0.1000 -0.0000  
## 200 0.0103 nan 0.1000 0.0000  
## 220 0.0100 nan 0.1000 -0.0000  
## 240 0.0097 nan 0.1000 -0.0000  
## 260 0.0094 nan 0.1000 0.0000  
## 280 0.0092 nan 0.1000 -0.0000  
## 300 0.0090 nan 0.1000 -0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0086 nan 0.1000 -0.0000  
## 360 0.0084 nan 0.1000 0.0000  
## 380 0.0082 nan 0.1000 -0.0000  
## 400 0.0080 nan 0.1000 -0.0000  
## 420 0.0078 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 0.0000  
## 460 0.0074 nan 0.1000 0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0284 nan 0.1000 0.0016  
## 2 0.0271 nan 0.1000 0.0013  
## 3 0.0258 nan 0.1000 0.0011  
## 4 0.0248 nan 0.1000 0.0009  
## 5 0.0240 nan 0.1000 0.0007  
## 6 0.0232 nan 0.1000 0.0007  
## 7 0.0225 nan 0.1000 0.0007  
## 8 0.0220 nan 0.1000 0.0006  
## 9 0.0214 nan 0.1000 0.0004  
## 10 0.0209 nan 0.1000 0.0004  
## 20 0.0182 nan 0.1000 0.0002  
## 40 0.0159 nan 0.1000 -0.0000  
## 60 0.0145 nan 0.1000 0.0000  
## 80 0.0135 nan 0.1000 -0.0000  
## 100 0.0128 nan 0.1000 0.0000  
## 120 0.0121 nan 0.1000 0.0000  
## 140 0.0116 nan 0.1000 0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0103 nan 0.1000 -0.0000  
## 220 0.0100 nan 0.1000 -0.0000  
## 240 0.0097 nan 0.1000 0.0000  
## 260 0.0094 nan 0.1000 -0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 -0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0085 nan 0.1000 -0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0081 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0078 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0075 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0072 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0285 nan 0.1000 0.0016  
## 2 0.0270 nan 0.1000 0.0013  
## 3 0.0259 nan 0.1000 0.0011  
## 4 0.0249 nan 0.1000 0.0009  
## 5 0.0239 nan 0.1000 0.0008  
## 6 0.0232 nan 0.1000 0.0006  
## 7 0.0225 nan 0.1000 0.0006  
## 8 0.0219 nan 0.1000 0.0006  
## 9 0.0213 nan 0.1000 0.0005  
## 10 0.0209 nan 0.1000 0.0004  
## 20 0.0181 nan 0.1000 0.0001  
## 40 0.0157 nan 0.1000 0.0001  
## 60 0.0143 nan 0.1000 0.0000  
## 80 0.0134 nan 0.1000 0.0000  
## 100 0.0126 nan 0.1000 -0.0000  
## 120 0.0120 nan 0.1000 -0.0000  
## 140 0.0114 nan 0.1000 -0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 -0.0000  
## 260 0.0093 nan 0.1000 0.0000  
## 280 0.0091 nan 0.1000 0.0000  
## 300 0.0088 nan 0.1000 -0.0000  
## 320 0.0086 nan 0.1000 -0.0000  
## 340 0.0084 nan 0.1000 -0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0080 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 0.0000  
## 420 0.0077 nan 0.1000 0.0000  
## 440 0.0075 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0072 nan 0.1000 -0.0000  
## 500 0.0070 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0282 nan 0.1000 0.0017  
## 2 0.0268 nan 0.1000 0.0014  
## 3 0.0257 nan 0.1000 0.0011  
## 4 0.0245 nan 0.1000 0.0010  
## 5 0.0236 nan 0.1000 0.0009  
## 6 0.0228 nan 0.1000 0.0007  
## 7 0.0222 nan 0.1000 0.0006  
## 8 0.0217 nan 0.1000 0.0005  
## 9 0.0212 nan 0.1000 0.0004  
## 10 0.0207 nan 0.1000 0.0004  
## 20 0.0180 nan 0.1000 0.0001  
## 40 0.0155 nan 0.1000 0.0001  
## 60 0.0142 nan 0.1000 0.0000  
## 80 0.0133 nan 0.1000 0.0000  
## 100 0.0125 nan 0.1000 -0.0000  
## 120 0.0119 nan 0.1000 -0.0000  
## 140 0.0115 nan 0.1000 -0.0000  
## 160 0.0109 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 0.0000  
## 260 0.0094 nan 0.1000 -0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 -0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0084 nan 0.1000 -0.0000  
## 360 0.0083 nan 0.1000 -0.0000  
## 380 0.0081 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0078 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0017  
## 2 0.0264 nan 0.1000 0.0014  
## 3 0.0253 nan 0.1000 0.0011  
## 4 0.0242 nan 0.1000 0.0010  
## 5 0.0232 nan 0.1000 0.0010  
## 6 0.0225 nan 0.1000 0.0007  
## 7 0.0219 nan 0.1000 0.0005  
## 8 0.0212 nan 0.1000 0.0007  
## 9 0.0208 nan 0.1000 0.0004  
## 10 0.0203 nan 0.1000 0.0005  
## 20 0.0177 nan 0.1000 0.0001  
## 40 0.0154 nan 0.1000 -0.0000  
## 60 0.0142 nan 0.1000 -0.0000  
## 80 0.0134 nan 0.1000 -0.0000  
## 100 0.0126 nan 0.1000 -0.0000  
## 120 0.0119 nan 0.1000 -0.0000  
## 140 0.0114 nan 0.1000 -0.0000  
## 160 0.0110 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0101 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0095 nan 0.1000 0.0000  
## 260 0.0093 nan 0.1000 -0.0000  
## 280 0.0090 nan 0.1000 -0.0000  
## 300 0.0088 nan 0.1000 -0.0000  
## 320 0.0086 nan 0.1000 -0.0000  
## 340 0.0084 nan 0.1000 -0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0080 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0077 nan 0.1000 -0.0000  
## 440 0.0075 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0072 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0284 nan 0.1000 0.0017  
## 2 0.0270 nan 0.1000 0.0013  
## 3 0.0258 nan 0.1000 0.0012  
## 4 0.0249 nan 0.1000 0.0009  
## 5 0.0240 nan 0.1000 0.0008  
## 6 0.0233 nan 0.1000 0.0007  
## 7 0.0227 nan 0.1000 0.0006  
## 8 0.0221 nan 0.1000 0.0005  
## 9 0.0216 nan 0.1000 0.0005  
## 10 0.0210 nan 0.1000 0.0005  
## 20 0.0182 nan 0.1000 0.0002  
## 40 0.0158 nan 0.1000 0.0000  
## 60 0.0143 nan 0.1000 0.0000  
## 80 0.0134 nan 0.1000 -0.0000  
## 100 0.0128 nan 0.1000 -0.0001  
## 120 0.0120 nan 0.1000 -0.0000  
## 140 0.0115 nan 0.1000 0.0000  
## 160 0.0110 nan 0.1000 -0.0001  
## 180 0.0107 nan 0.1000 -0.0000  
## 200 0.0103 nan 0.1000 0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 -0.0000  
## 260 0.0093 nan 0.1000 -0.0000  
## 280 0.0090 nan 0.1000 0.0000  
## 300 0.0087 nan 0.1000 -0.0000  
## 320 0.0085 nan 0.1000 -0.0000  
## 340 0.0083 nan 0.1000 -0.0000  
## 360 0.0081 nan 0.1000 0.0000  
## 380 0.0079 nan 0.1000 0.0000  
## 400 0.0078 nan 0.1000 0.0000  
## 420 0.0075 nan 0.1000 -0.0000  
## 440 0.0074 nan 0.1000 -0.0000  
## 460 0.0072 nan 0.1000 -0.0000  
## 480 0.0070 nan 0.1000 -0.0000  
## 500 0.0069 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0016  
## 2 0.0265 nan 0.1000 0.0014  
## 3 0.0254 nan 0.1000 0.0011  
## 4 0.0244 nan 0.1000 0.0009  
## 5 0.0235 nan 0.1000 0.0008  
## 6 0.0228 nan 0.1000 0.0007  
## 7 0.0222 nan 0.1000 0.0006  
## 8 0.0216 nan 0.1000 0.0006  
## 9 0.0211 nan 0.1000 0.0005  
## 10 0.0207 nan 0.1000 0.0004  
## 20 0.0178 nan 0.1000 0.0001  
## 40 0.0156 nan 0.1000 0.0000  
## 60 0.0144 nan 0.1000 0.0000  
## 80 0.0134 nan 0.1000 0.0000  
## 100 0.0126 nan 0.1000 0.0000  
## 120 0.0120 nan 0.1000 -0.0000  
## 140 0.0113 nan 0.1000 -0.0000  
## 160 0.0109 nan 0.1000 -0.0000  
## 180 0.0105 nan 0.1000 -0.0000  
## 200 0.0101 nan 0.1000 -0.0000  
## 220 0.0098 nan 0.1000 -0.0000  
## 240 0.0095 nan 0.1000 -0.0000  
## 260 0.0092 nan 0.1000 -0.0000  
## 280 0.0089 nan 0.1000 -0.0000  
## 300 0.0087 nan 0.1000 -0.0000  
## 320 0.0085 nan 0.1000 -0.0000  
## 340 0.0083 nan 0.1000 -0.0000  
## 360 0.0082 nan 0.1000 -0.0000  
## 380 0.0080 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0076 nan 0.1000 -0.0000  
## 440 0.0075 nan 0.1000 -0.0000  
## 460 0.0074 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0071 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0283 nan 0.1000 0.0017  
## 2 0.0268 nan 0.1000 0.0014  
## 3 0.0257 nan 0.1000 0.0011  
## 4 0.0246 nan 0.1000 0.0010  
## 5 0.0238 nan 0.1000 0.0008  
## 6 0.0230 nan 0.1000 0.0007  
## 7 0.0224 nan 0.1000 0.0006  
## 8 0.0218 nan 0.1000 0.0005  
## 9 0.0213 nan 0.1000 0.0005  
## 10 0.0209 nan 0.1000 0.0004  
## 20 0.0180 nan 0.1000 0.0002  
## 40 0.0156 nan 0.1000 0.0000  
## 60 0.0143 nan 0.1000 0.0000  
## 80 0.0135 nan 0.1000 0.0000  
## 100 0.0127 nan 0.1000 -0.0000  
## 120 0.0121 nan 0.1000 0.0000  
## 140 0.0115 nan 0.1000 0.0000  
## 160 0.0111 nan 0.1000 -0.0000  
## 180 0.0106 nan 0.1000 -0.0000  
## 200 0.0103 nan 0.1000 -0.0000  
## 220 0.0100 nan 0.1000 -0.0000  
## 240 0.0098 nan 0.1000 0.0000  
## 260 0.0095 nan 0.1000 -0.0000  
## 280 0.0093 nan 0.1000 -0.0000  
## 300 0.0090 nan 0.1000 -0.0000  
## 320 0.0088 nan 0.1000 -0.0000  
## 340 0.0086 nan 0.1000 -0.0000  
## 360 0.0084 nan 0.1000 -0.0000  
## 380 0.0082 nan 0.1000 -0.0000  
## 400 0.0080 nan 0.1000 -0.0000  
## 420 0.0079 nan 0.1000 -0.0000  
## 440 0.0077 nan 0.1000 -0.0000  
## 460 0.0076 nan 0.1000 -0.0000  
## 480 0.0074 nan 0.1000 -0.0000  
## 500 0.0073 nan 0.1000 0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0279 nan 0.1000 0.0016  
## 2 0.0265 nan 0.1000 0.0013  
## 3 0.0252 nan 0.1000 0.0012  
## 4 0.0242 nan 0.1000 0.0009  
## 5 0.0232 nan 0.1000 0.0010  
## 6 0.0226 nan 0.1000 0.0006  
## 7 0.0218 nan 0.1000 0.0007  
## 8 0.0211 nan 0.1000 0.0006  
## 9 0.0206 nan 0.1000 0.0005  
## 10 0.0202 nan 0.1000 0.0004  
## 20 0.0173 nan 0.1000 0.0001  
## 40 0.0151 nan 0.1000 0.0000  
## 60 0.0140 nan 0.1000 0.0000  
## 80 0.0131 nan 0.1000 0.0000  
## 100 0.0123 nan 0.1000 -0.0001  
## 120 0.0117 nan 0.1000 0.0000  
## 140 0.0112 nan 0.1000 -0.0000  
## 160 0.0106 nan 0.1000 0.0000  
## 180 0.0102 nan 0.1000 0.0000  
## 200 0.0099 nan 0.1000 -0.0000  
## 220 0.0096 nan 0.1000 -0.0000  
## 240 0.0093 nan 0.1000 -0.0000  
## 260 0.0090 nan 0.1000 -0.0000  
## 280 0.0088 nan 0.1000 -0.0000  
## 300 0.0086 nan 0.1000 -0.0000  
## 320 0.0084 nan 0.1000 -0.0000  
## 340 0.0082 nan 0.1000 -0.0000  
## 360 0.0080 nan 0.1000 0.0000  
## 380 0.0078 nan 0.1000 0.0000  
## 400 0.0076 nan 0.1000 -0.0000  
## 420 0.0075 nan 0.1000 -0.0000  
## 440 0.0073 nan 0.1000 -0.0000  
## 460 0.0072 nan 0.1000 -0.0000  
## 480 0.0070 nan 0.1000 -0.0000  
## 500 0.0069 nan 0.1000 0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.0282 nan 0.1000 0.0017  
## 2 0.0269 nan 0.1000 0.0014  
## 3 0.0258 nan 0.1000 0.0011  
## 4 0.0247 nan 0.1000 0.0010  
## 5 0.0239 nan 0.1000 0.0008  
## 6 0.0232 nan 0.1000 0.0006  
## 7 0.0225 nan 0.1000 0.0007  
## 8 0.0219 nan 0.1000 0.0006  
## 9 0.0213 nan 0.1000 0.0005  
## 10 0.0209 nan 0.1000 0.0004  
## 20 0.0182 nan 0.1000 0.0001  
## 40 0.0157 nan 0.1000 0.0001  
## 60 0.0145 nan 0.1000 -0.0000  
## 80 0.0134 nan 0.1000 0.0000  
## 100 0.0126 nan 0.1000 0.0000  
## 120 0.0120 nan 0.1000 0.0000  
## 140 0.0113 nan 0.1000 -0.0000  
## 160 0.0110 nan 0.1000 0.0000  
## 180 0.0105 nan 0.1000 -0.0000  
## 200 0.0102 nan 0.1000 -0.0000  
## 220 0.0099 nan 0.1000 -0.0000  
## 240 0.0096 nan 0.1000 -0.0000  
## 260 0.0093 nan 0.1000 0.0000  
## 280 0.0091 nan 0.1000 -0.0000  
## 300 0.0089 nan 0.1000 0.0000  
## 320 0.0087 nan 0.1000 -0.0000  
## 340 0.0085 nan 0.1000 -0.0000  
## 360 0.0083 nan 0.1000 -0.0000  
## 380 0.0081 nan 0.1000 -0.0000  
## 400 0.0079 nan 0.1000 -0.0000  
## 420 0.0078 nan 0.1000 -0.0000  
## 440 0.0076 nan 0.1000 -0.0000  
## 460 0.0075 nan 0.1000 -0.0000  
## 480 0.0073 nan 0.1000 -0.0000  
## 500 0.0072 nan 0.1000 -0.0000

list(RMSE\_GBM.BCSX = RMSE(predict(gbm.fit.bcsx, dfTestBCSX), dfTestY),  
 RMSE\_GBM.BCS = RMSE(predict(gbm.fit.bx, dfTestBX), dfTestY),  
 RMSE\_GBM.X = RMSE(predict(gbm.fit.x, dfTestX), dfTestY))

## $RMSE\_GBM.BCSX  
## [1] 0.1068503  
##   
## $RMSE\_GBM.BCS  
## [1] 0.1029799  
##   
## $RMSE\_GBM.X  
## [1] 0.1085995

summary(gbm.fit.bx, digit=3)



## var rel.inf  
## X X 19.6434999  
## Mnf.Flow Mnf.Flow 17.2840810  
## C C 12.0994412  
## Balling Balling 3.4098671  
## Oxygen.Filler Oxygen.Filler 3.0273042  
## Pressure.Vacuum Pressure.Vacuum 2.7766250  
## Filler.Speed Filler.Speed 2.5680898  
## Bowl.Setpoint Bowl.Setpoint 2.5668165  
## Density Density 2.5593469  
## Carb.Flow Carb.Flow 2.3482131  
## D D 2.3298863  
## Temperature Temperature 2.3205853  
## PC.Volume PC.Volume 2.3132528  
## A A 2.0622982  
## Carb.Pressure1 Carb.Pressure1 1.9450957  
## Pressure.Setpoint Pressure.Setpoint 1.7697123  
## Hyd.Pressure1 Hyd.Pressure1 1.7529511  
## MFR MFR 1.5638345  
## Usage.cont Usage.cont 1.4573077  
## Carb.Rel Carb.Rel 1.3037580  
## Alch.Rel Alch.Rel 1.1935697  
## PSC.CO2 PSC.CO2 1.1480211  
## Air.Pressurer Air.Pressurer 1.1086144  
## PSC PSC 1.0937145  
## B B 1.0348596  
## PSC.Fill PSC.Fill 1.0315556  
## Balling.Lvl Balling.Lvl 1.0314630  
## Hyd.Pressure3 Hyd.Pressure3 0.9251599  
## Fill.Pressure Fill.Pressure 0.7939194  
## Fill.Ounces Fill.Ounces 0.6436061  
## Filler.Level Filler.Level 0.6043207  
## Carb.Temp Carb.Temp 0.5265631  
## Carb.Pressure Carb.Pressure 0.5170386  
## Carb.Volume Carb.Volume 0.4938020  
## Hyd.Pressure4 Hyd.Pressure4 0.4132348  
## Hyd.Pressure2 Hyd.Pressure2 0.3385911

#varImp(gbm.fit.bx)

GBM appears to perform better than the group of models, specifically Bagged CART, with a RMSE of 0.1029799, but we see an improvement with Random Forest, 0.09255377 RMSE.